Measurement of the Collins Asymmetry in Mid-Rapidity Jets at STAR

Robert Fersch
University of Kentucky

Presentation for the High-p_T Physics at RHIC RBRC Workshop

Goals of this Presentation:

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- Present a survey of quark transversity (δq) and partonic spin degrees of freedom (Motivation)

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- Demonstrate kinematic coverage of the data and physics in terms of p_T
- Show statistical expectations of measured asymmetries and summarize systematic concerns

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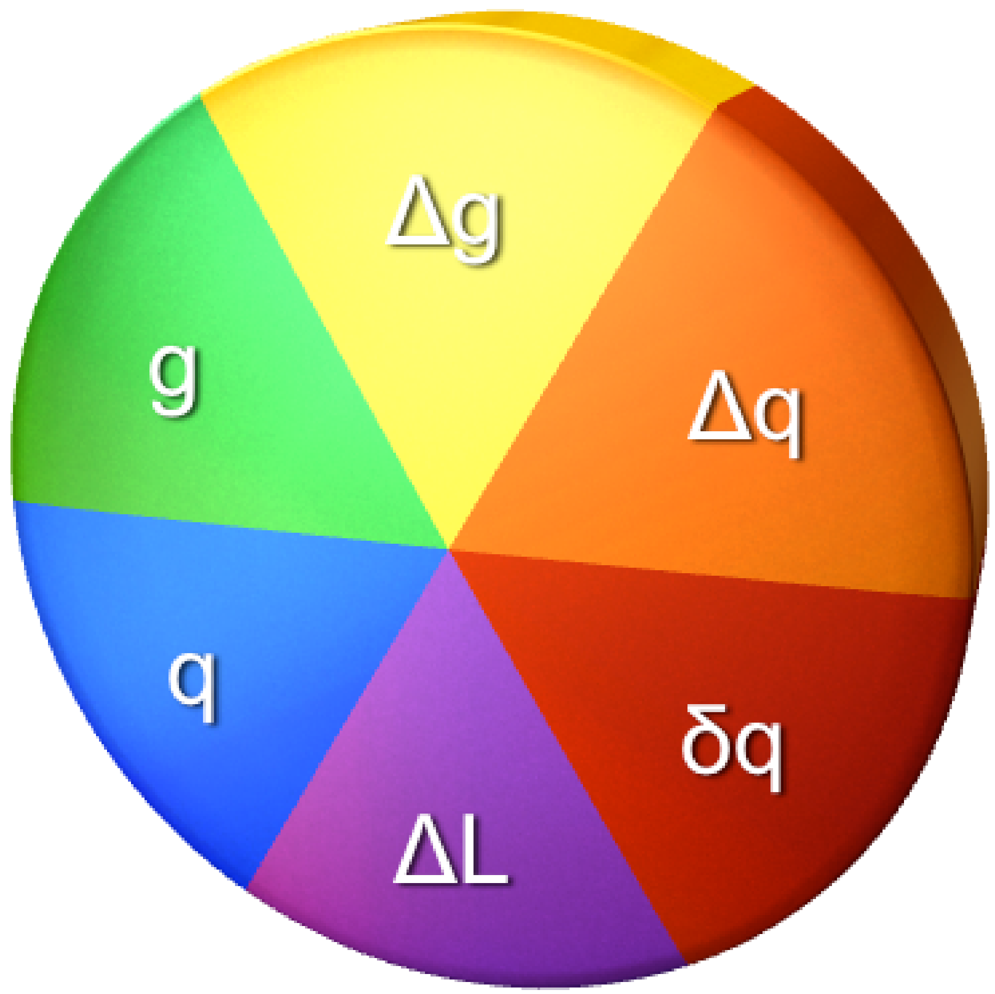
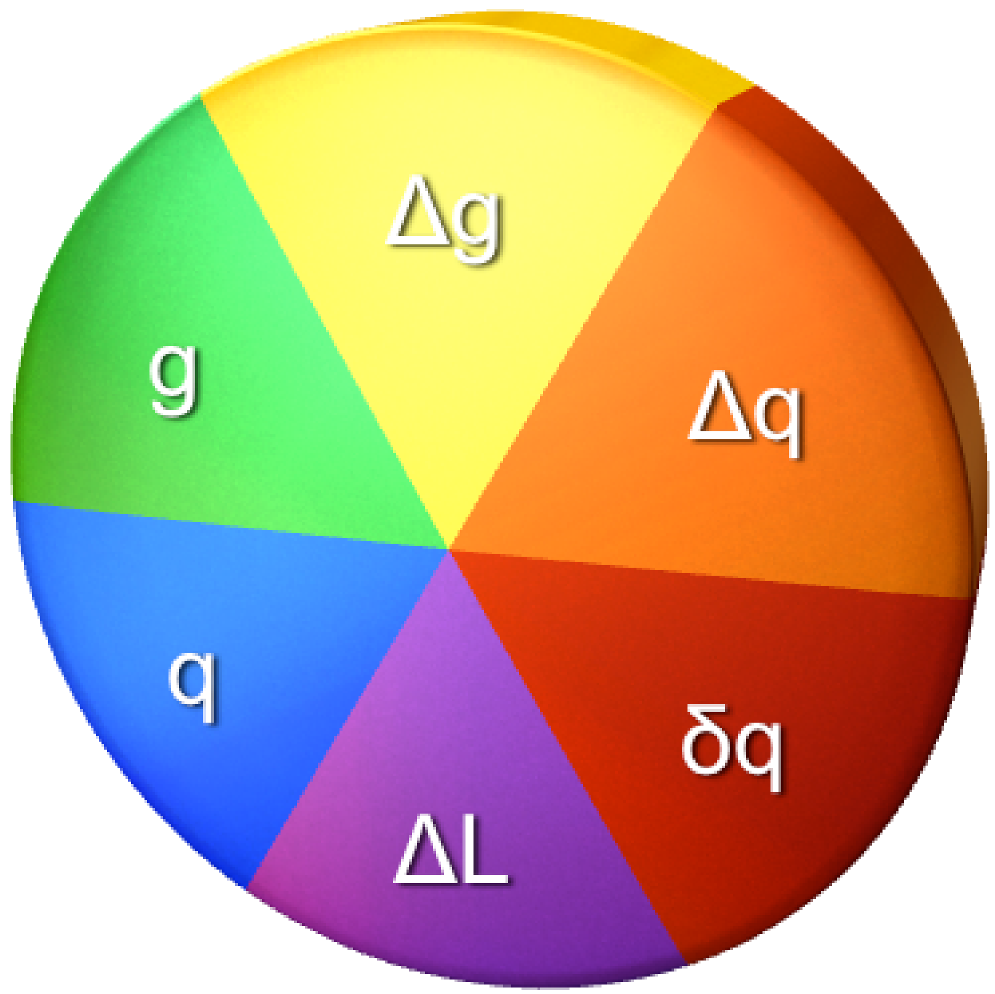
Degrees of Freedom in the Proton



Degrees of Freedom in the Proton

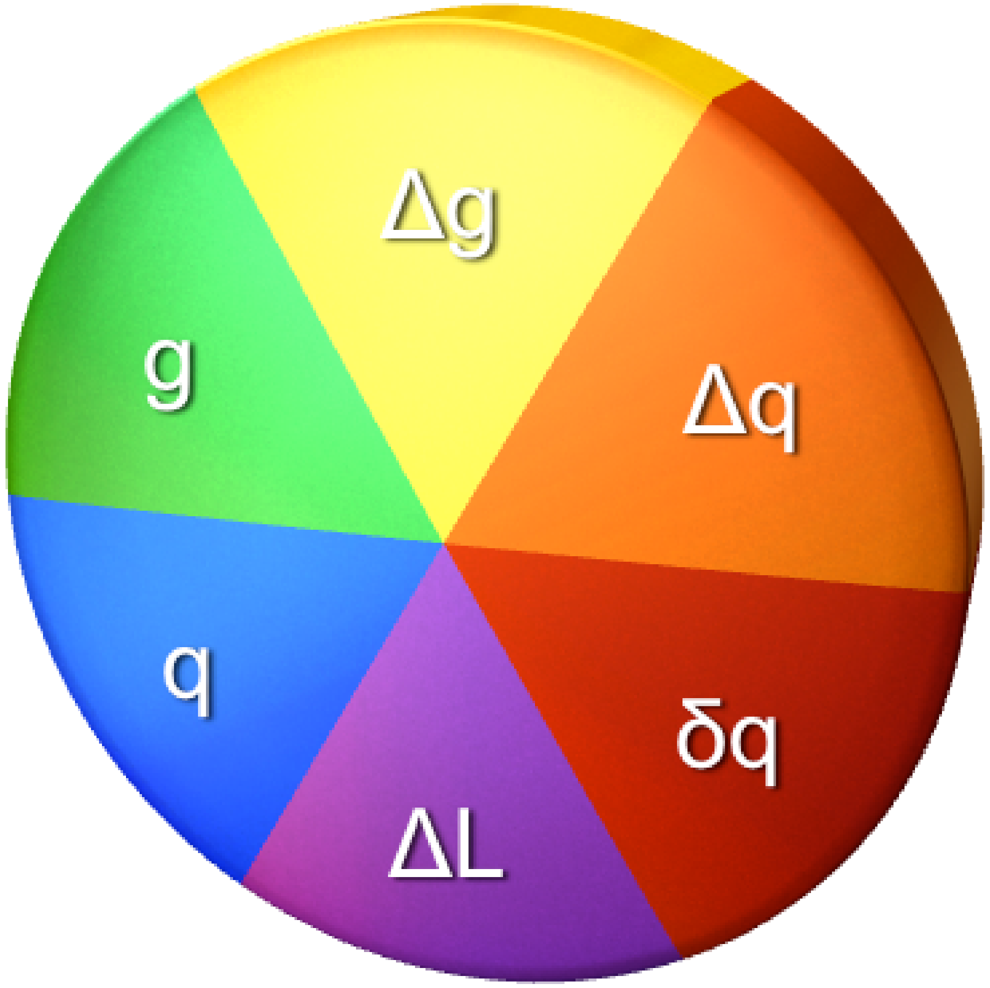
quark density



Degrees of Freedom in the Proton

gluon density

quark density

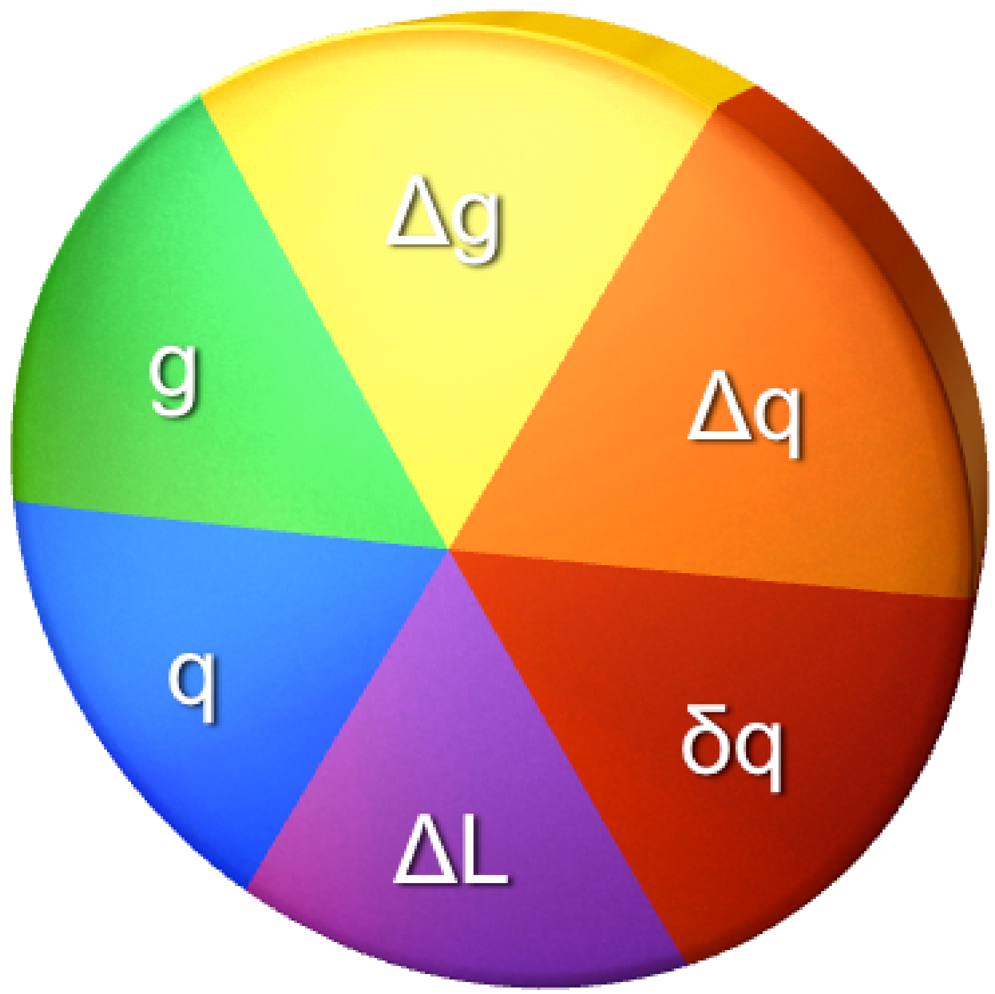


Degrees of Freedom in the Proton

gluon helicity

gluon density

quark density



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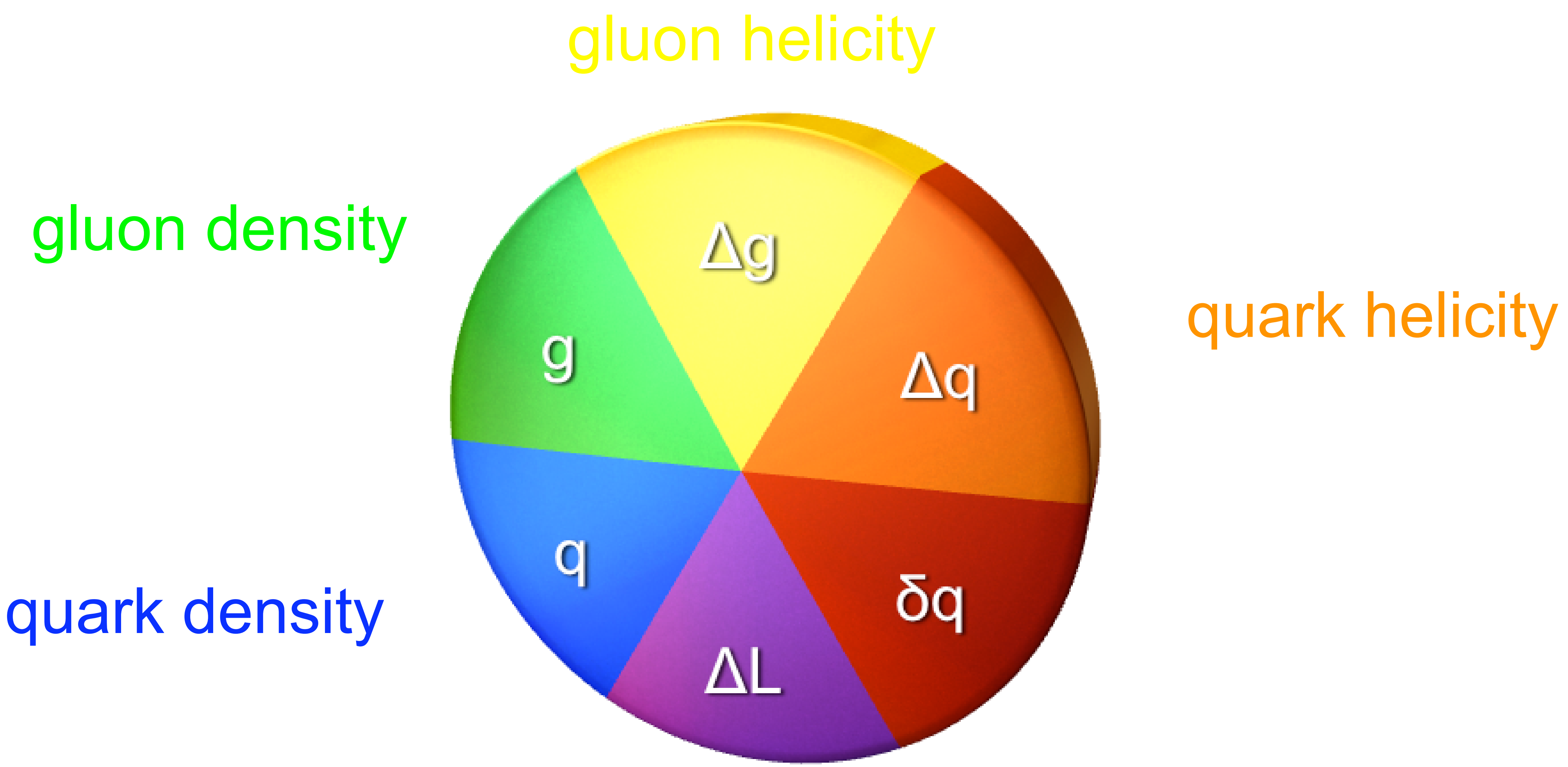

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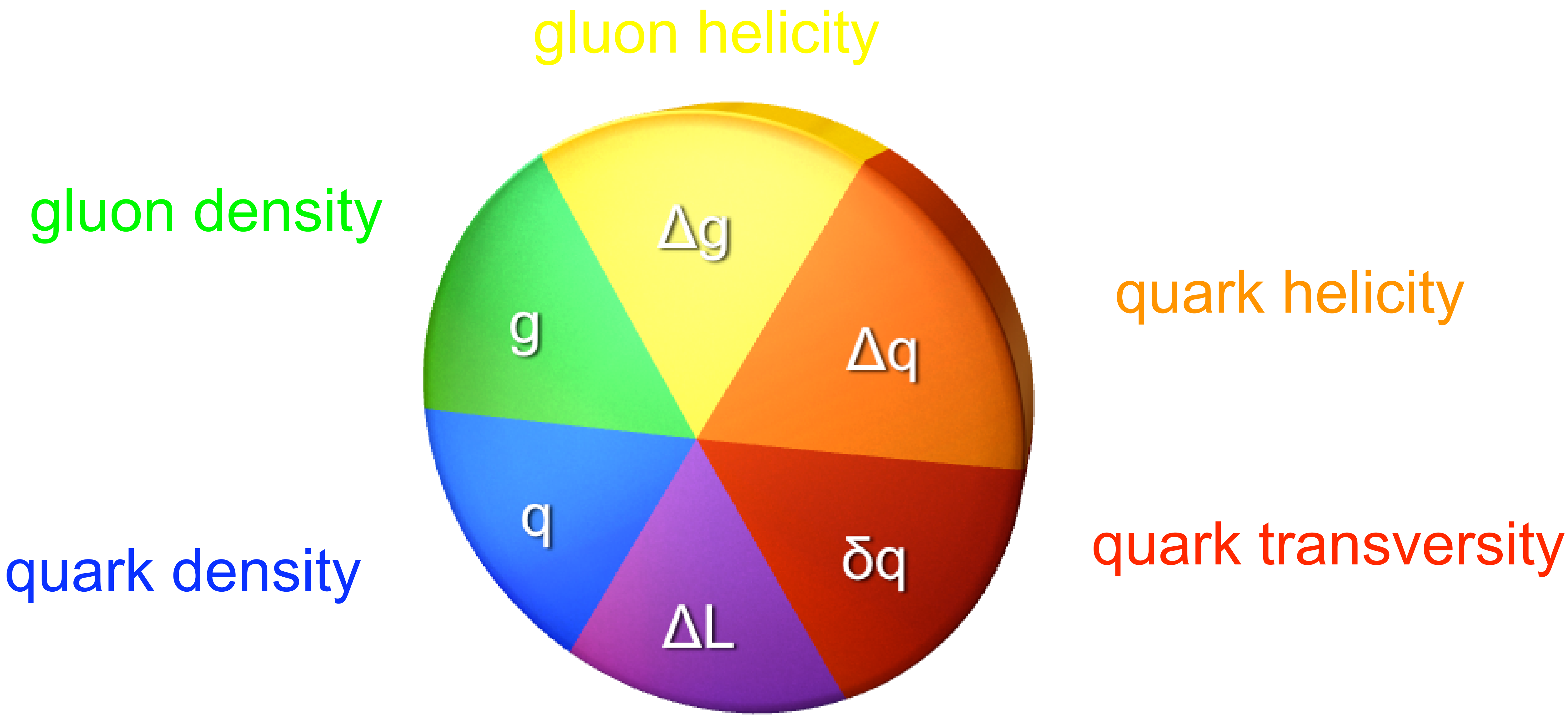

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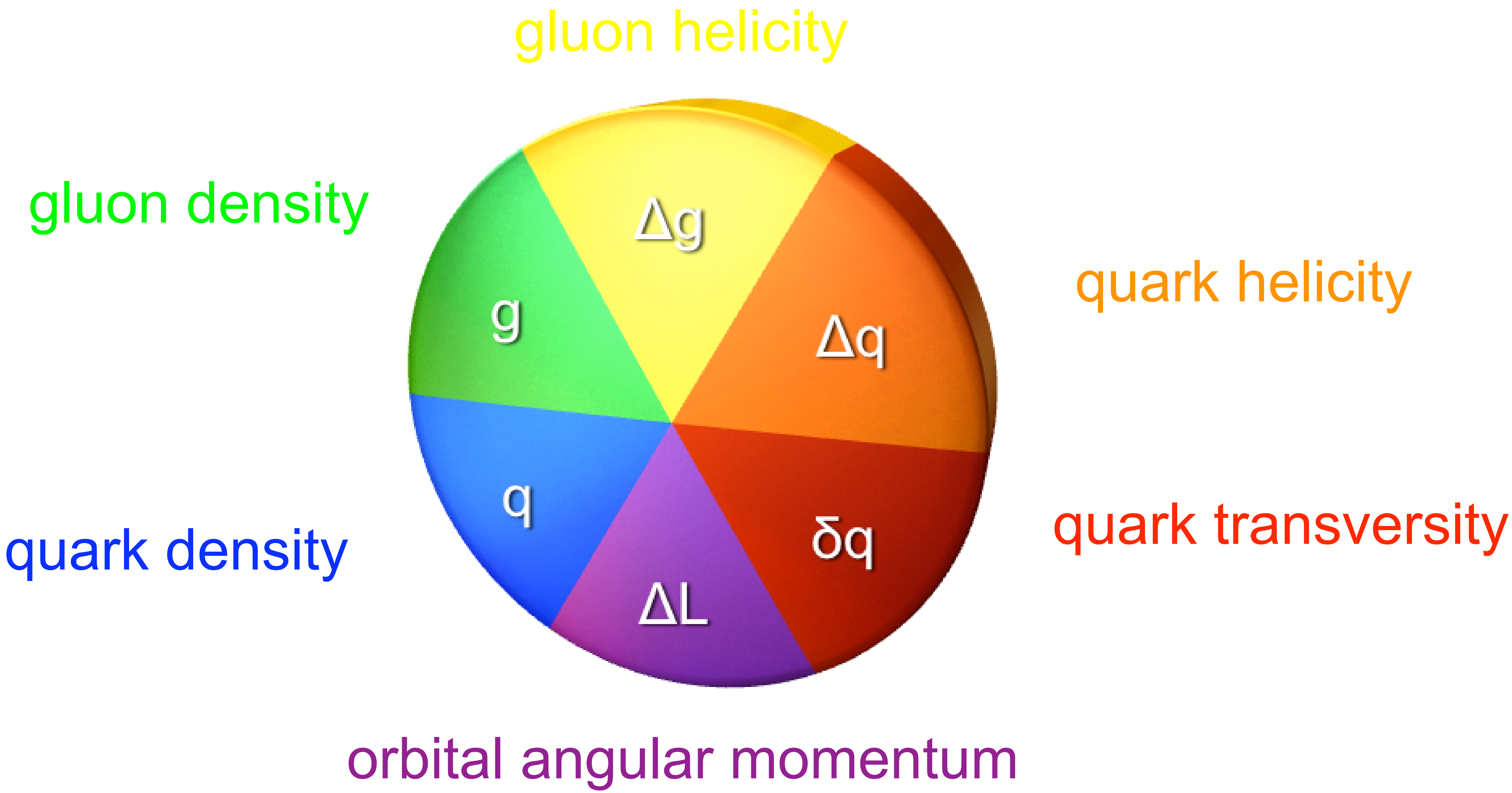
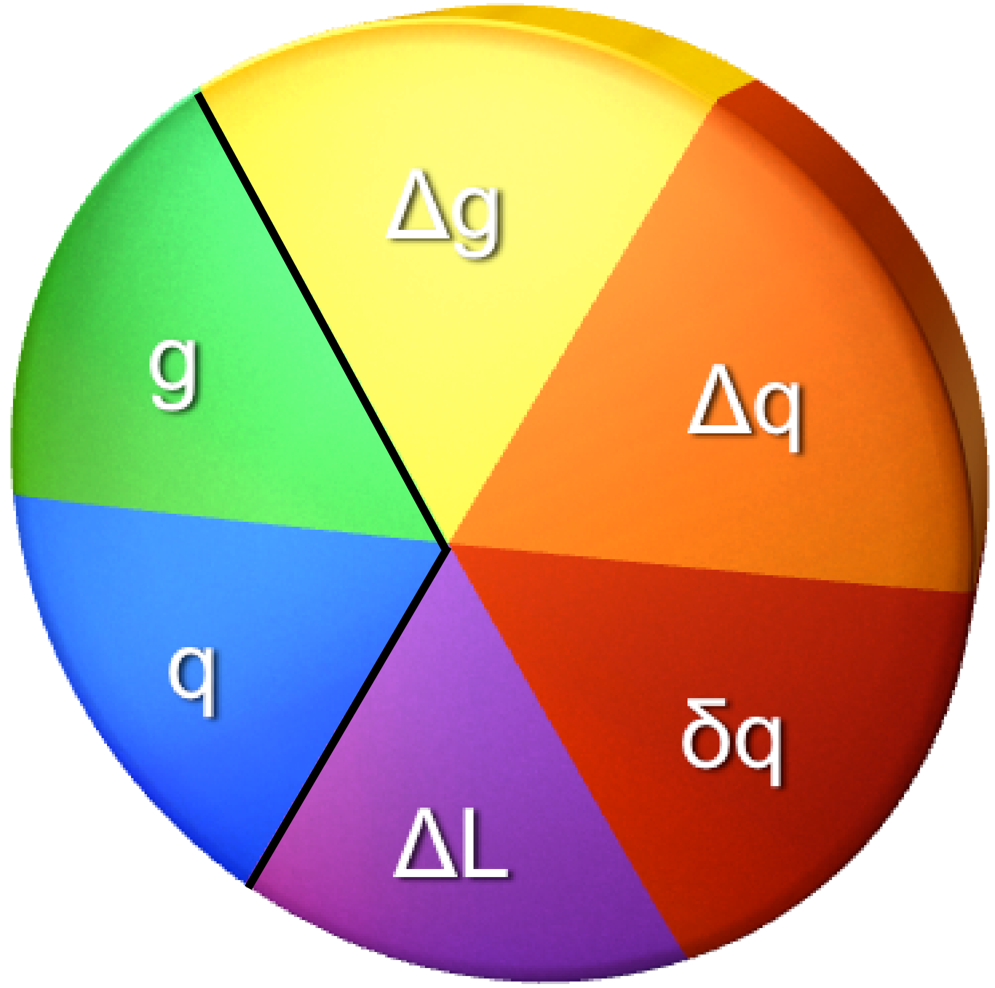


Degrees of Freedom in the Proton

gluon helicity

gluon density

(unpolarized scattering experiments)



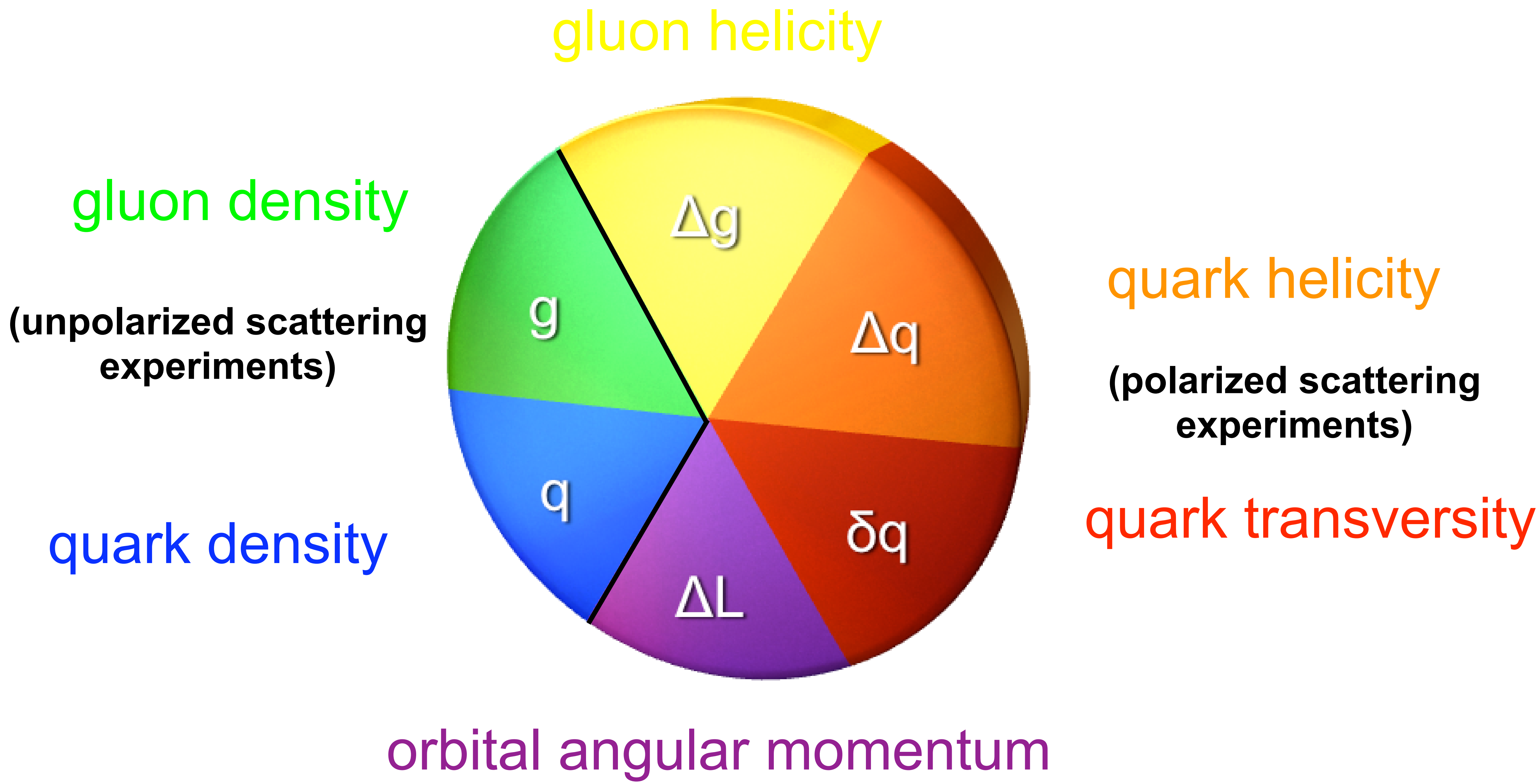
quark helicity

quark density

quark transversity

orbital angular momentum

Degrees of Freedom in the Proton



Quark and Gluon Spin Distributions

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longitudinal and transverse degrees of freedom

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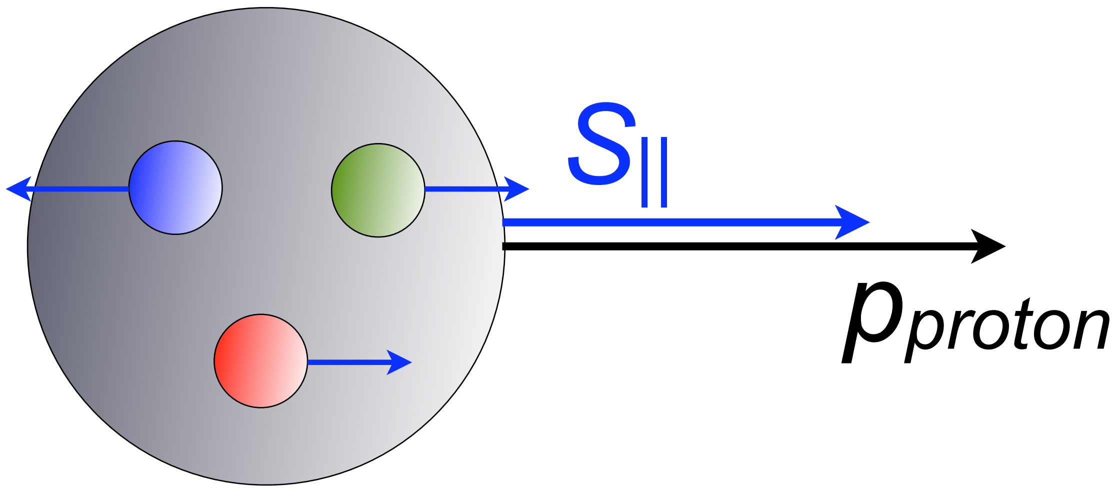
longitudinal and transverse degrees of freedom

"helicity"



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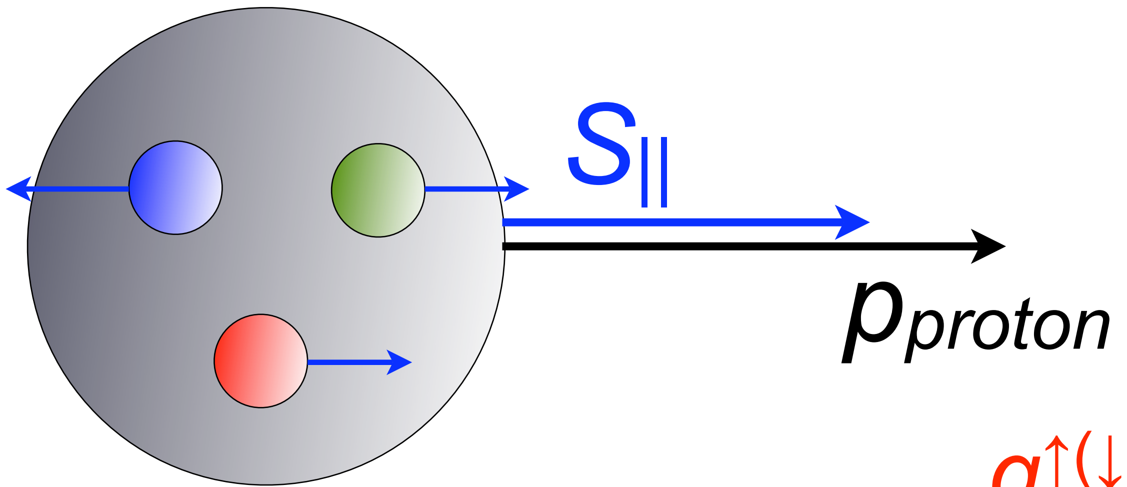

$\Delta q \equiv q^{\uparrow} - q^{\downarrow}$

$q^{\uparrow(\downarrow)}$ is the probability of finding a quark with spin equal (opposite) to $S_{||}$

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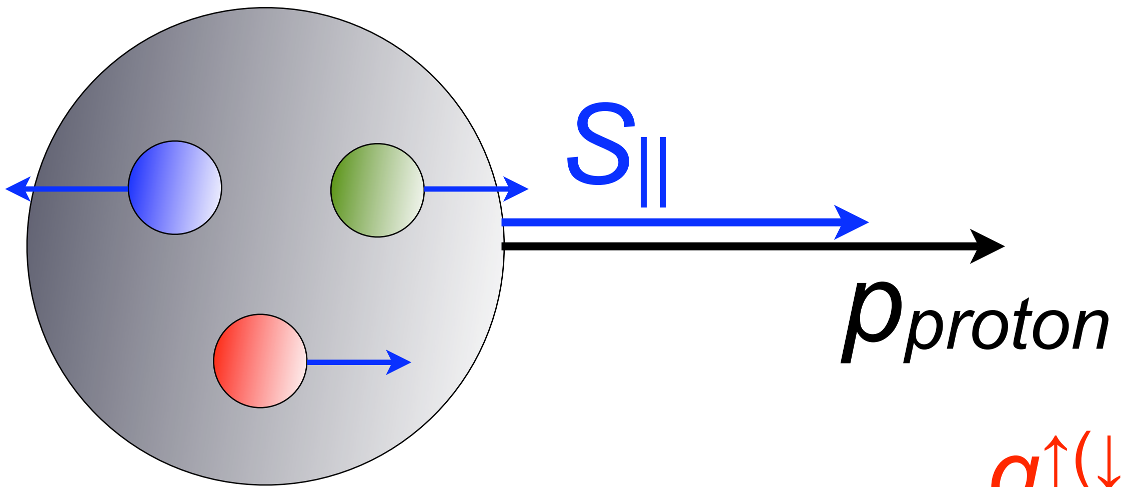

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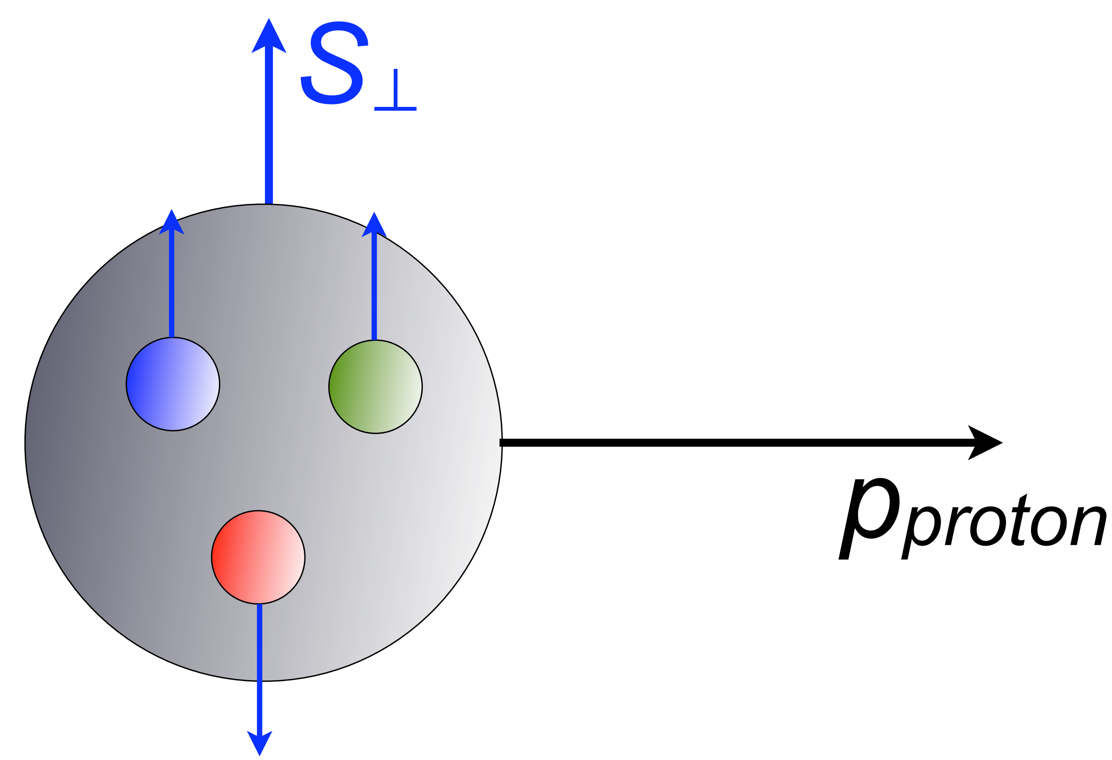

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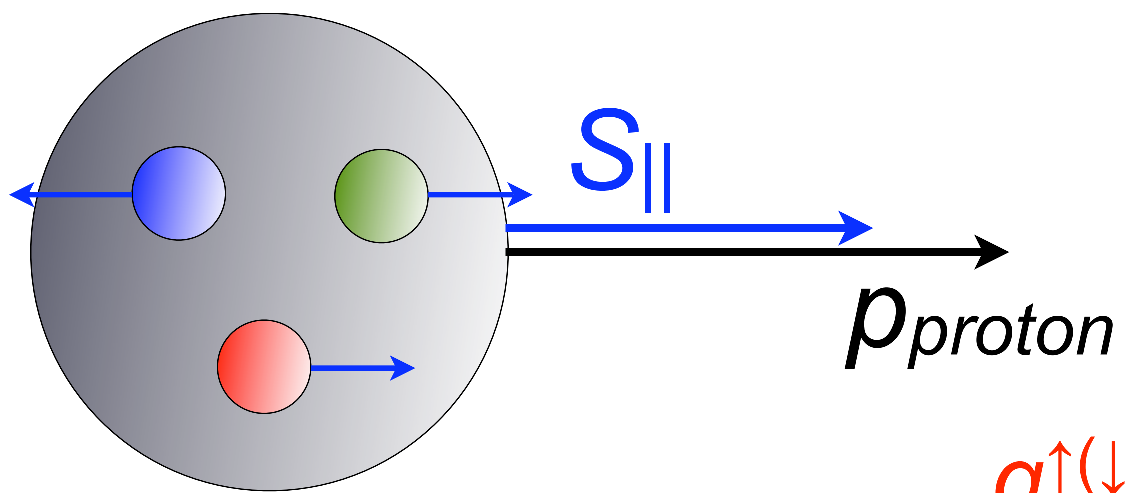

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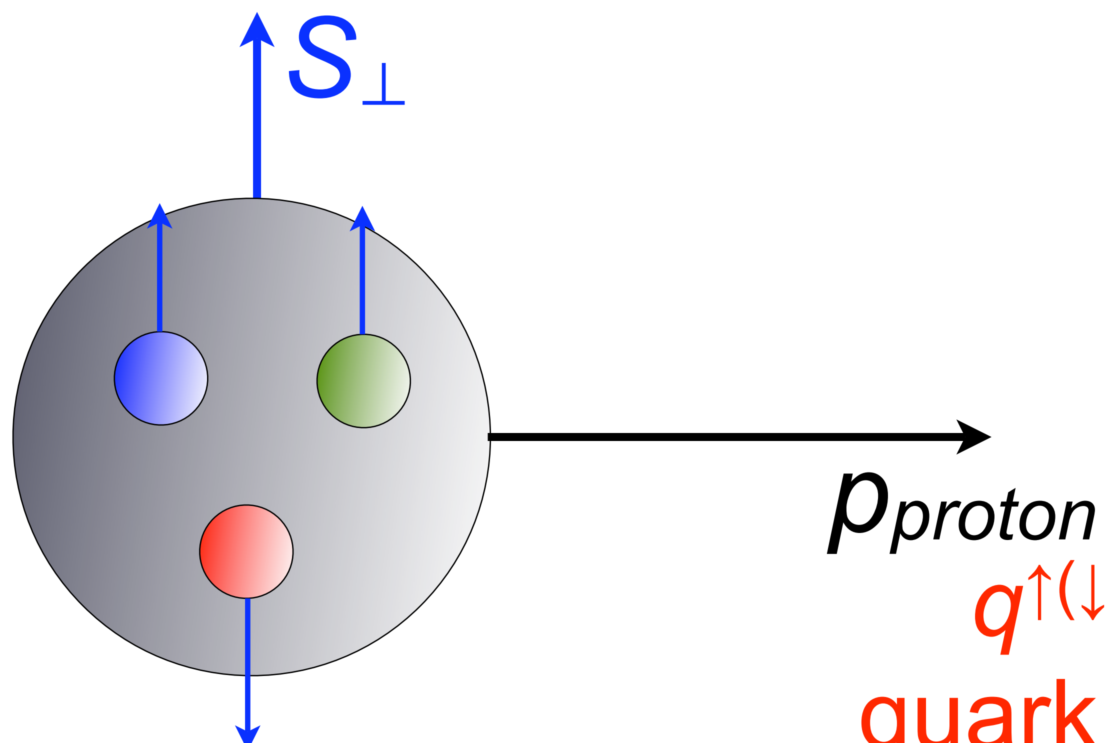

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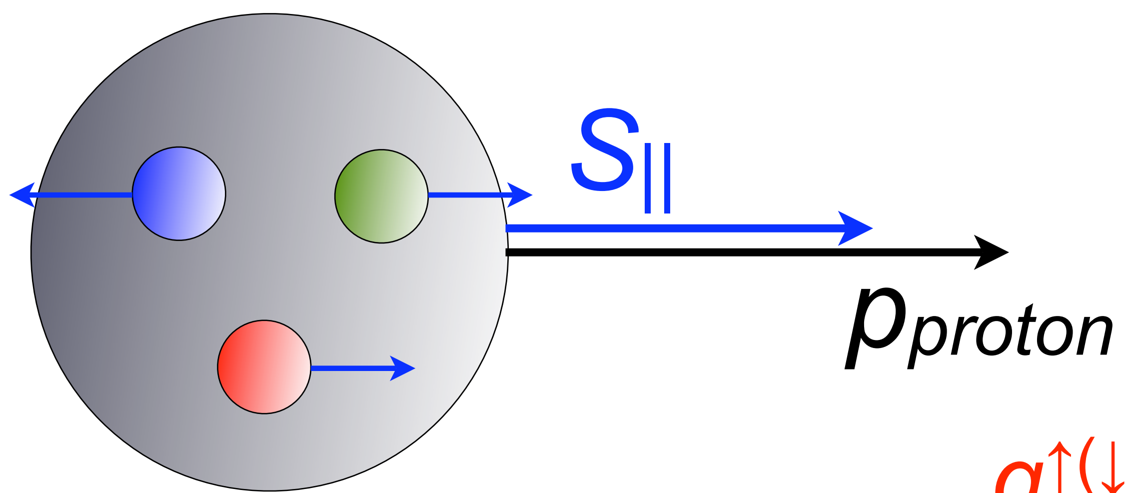

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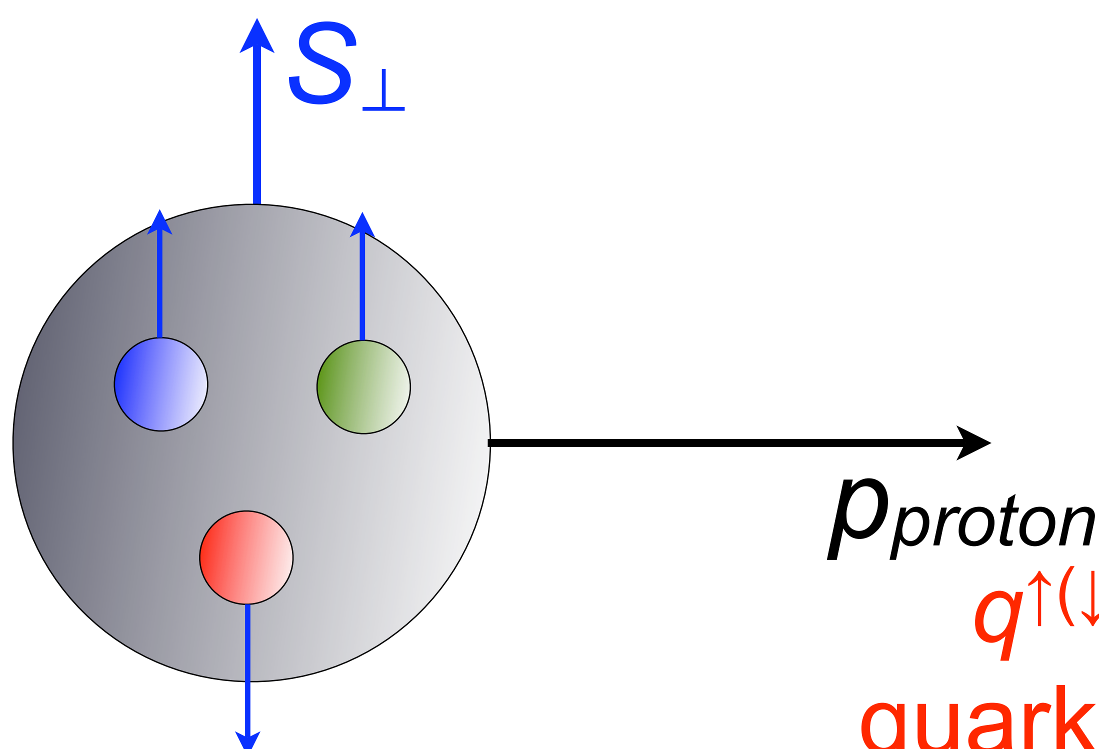

$\delta q \equiv q^{\uparrow} - q^{\downarrow}$

q, Δq, δq **all required for a complete basis in spin-density matrix representation**

$q^{\uparrow(\downarrow)}$ is the probability of finding a quark with spin equal (opposite) to $S_{\perp}$

Existing Measurements of Spin Degrees of Freedom

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Asymmetries ⇒ Global Analysis ⇒ Parton Distribution Functions (PDFs)

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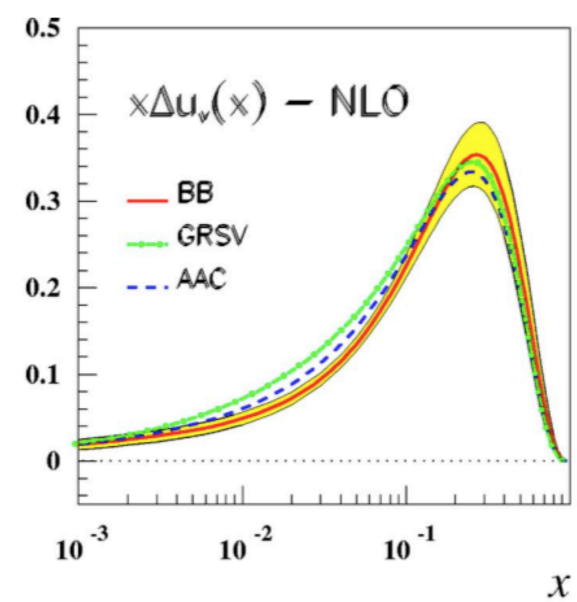
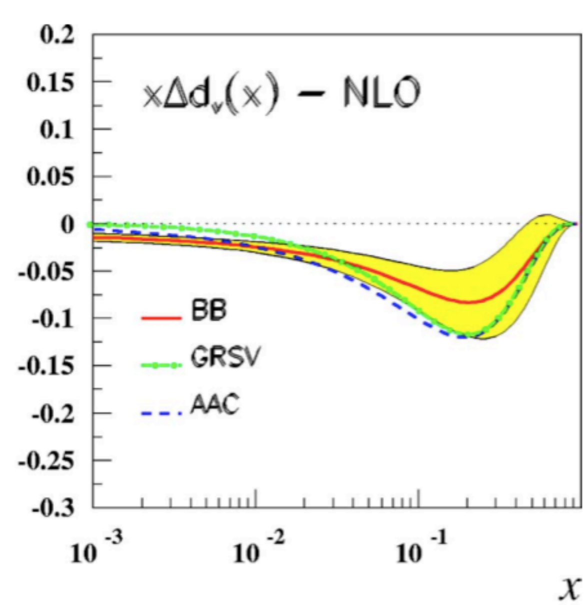
x Δu



x Δd



Rev. Mod. Phys. **77,** 1257(2005) Bass

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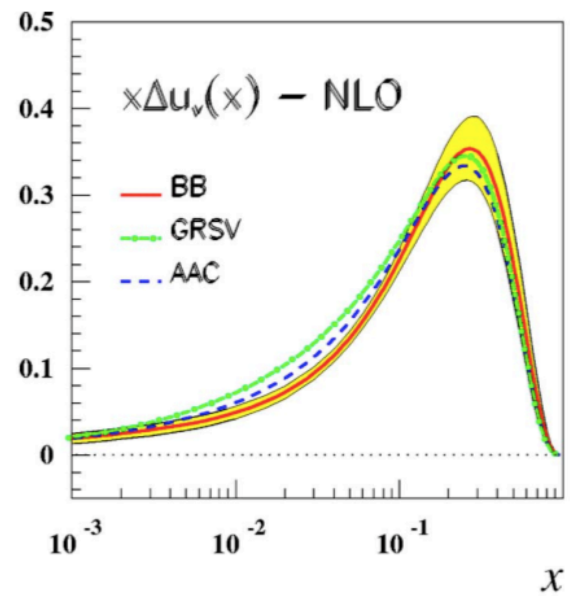
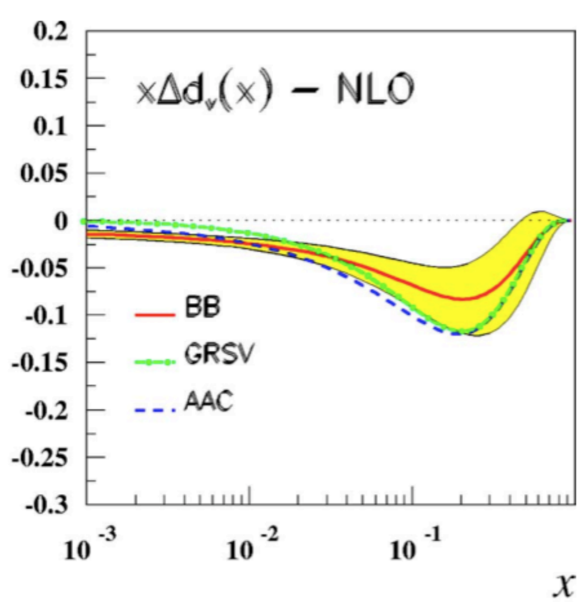
Longitudinal spin (helicity)

x Δu



x Δd



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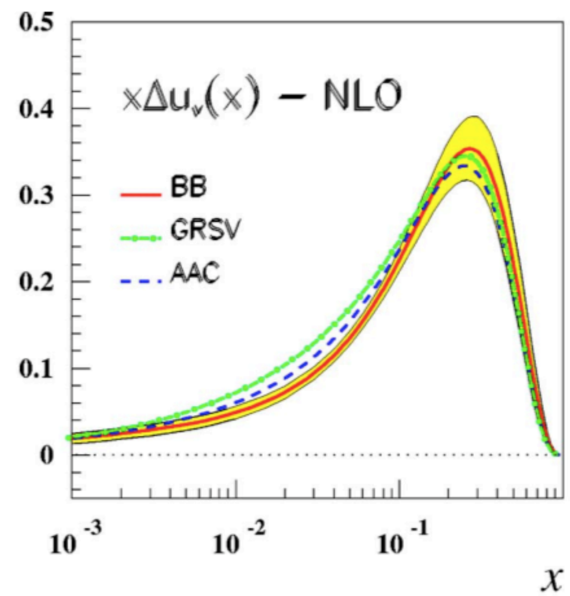
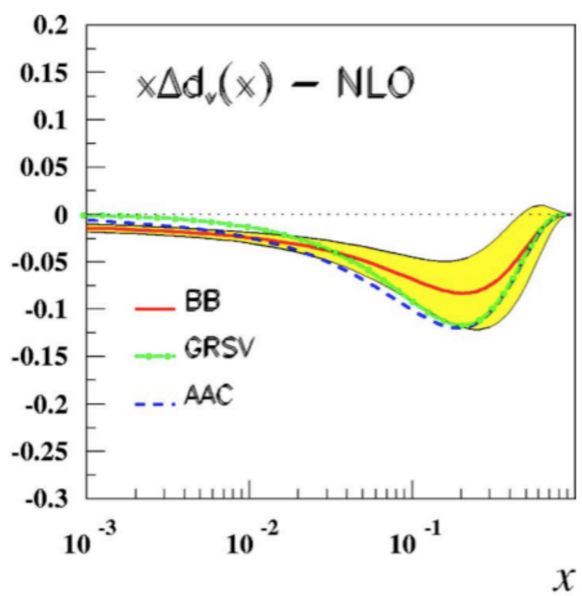


$x \equiv$ Bjorken x ($0<x<1$); 1 = elastic limit

$x\,\Delta d$



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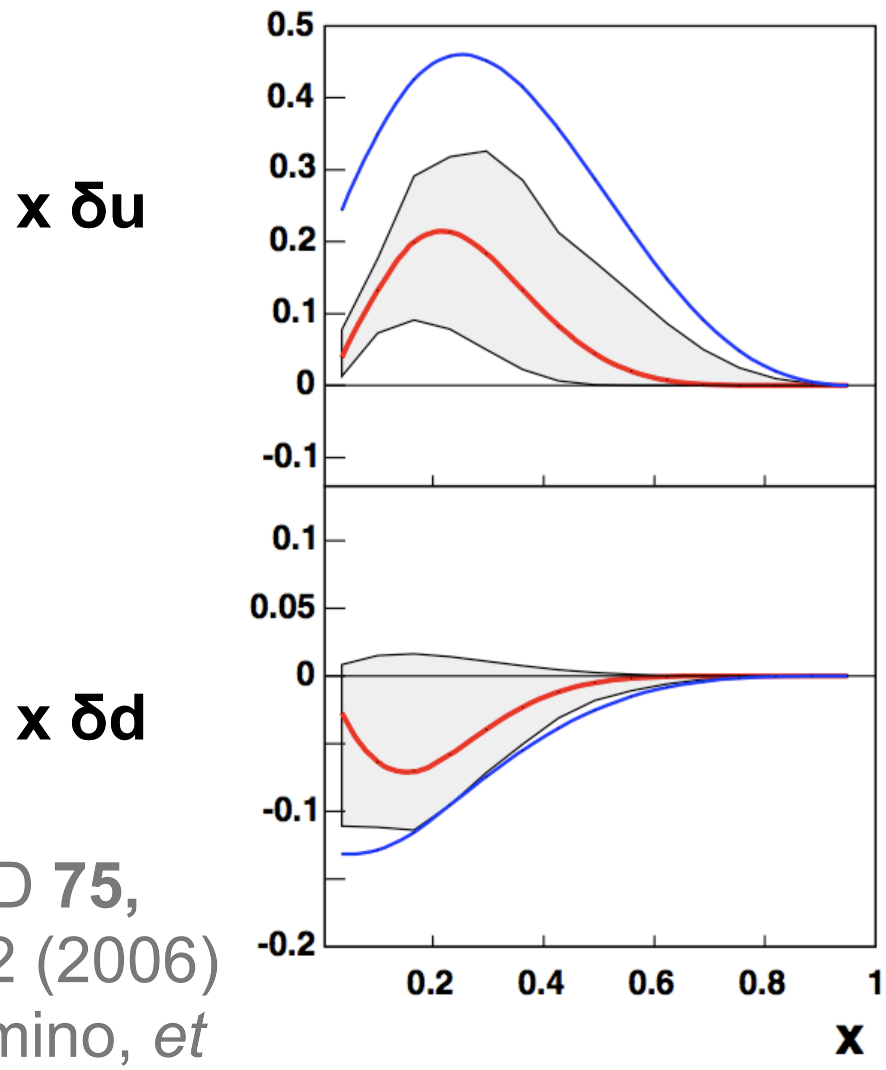
Transverse spin (transversity)



PRD **75,** 054032 (2006) Anselmino, *et al.*

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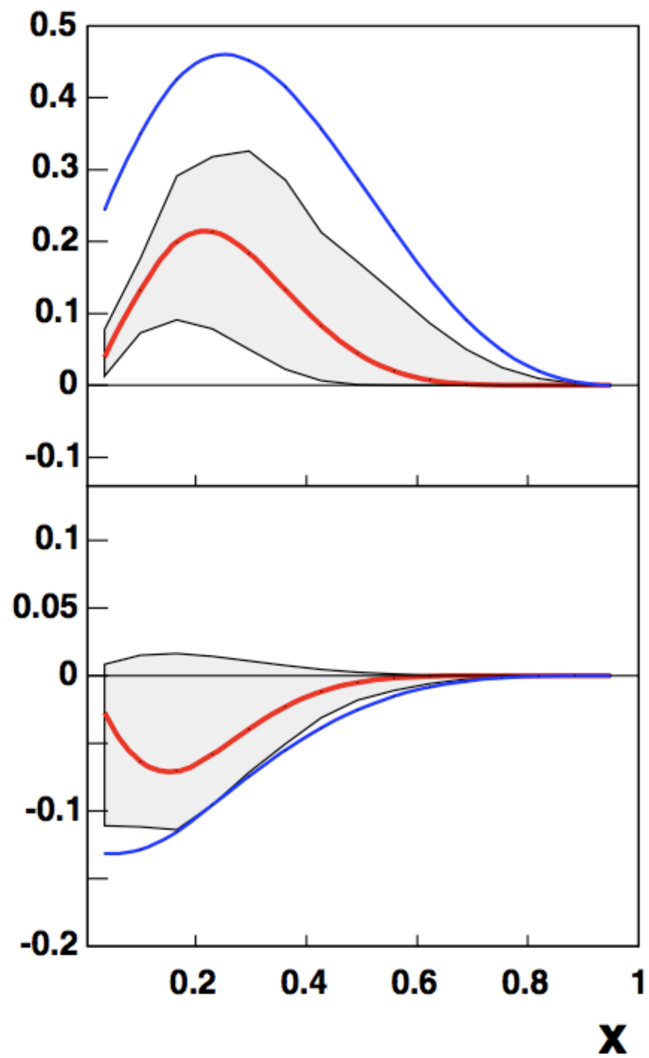
$x\,\delta u$

$x\,\delta d$



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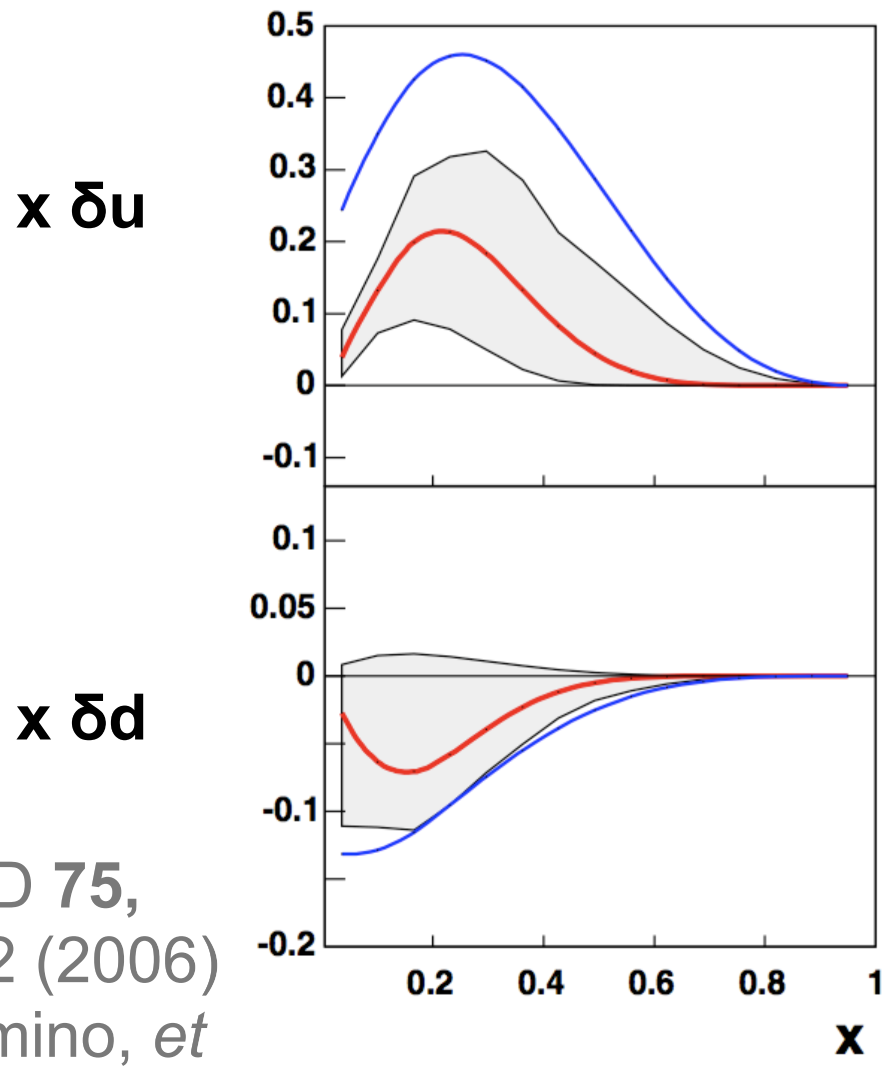

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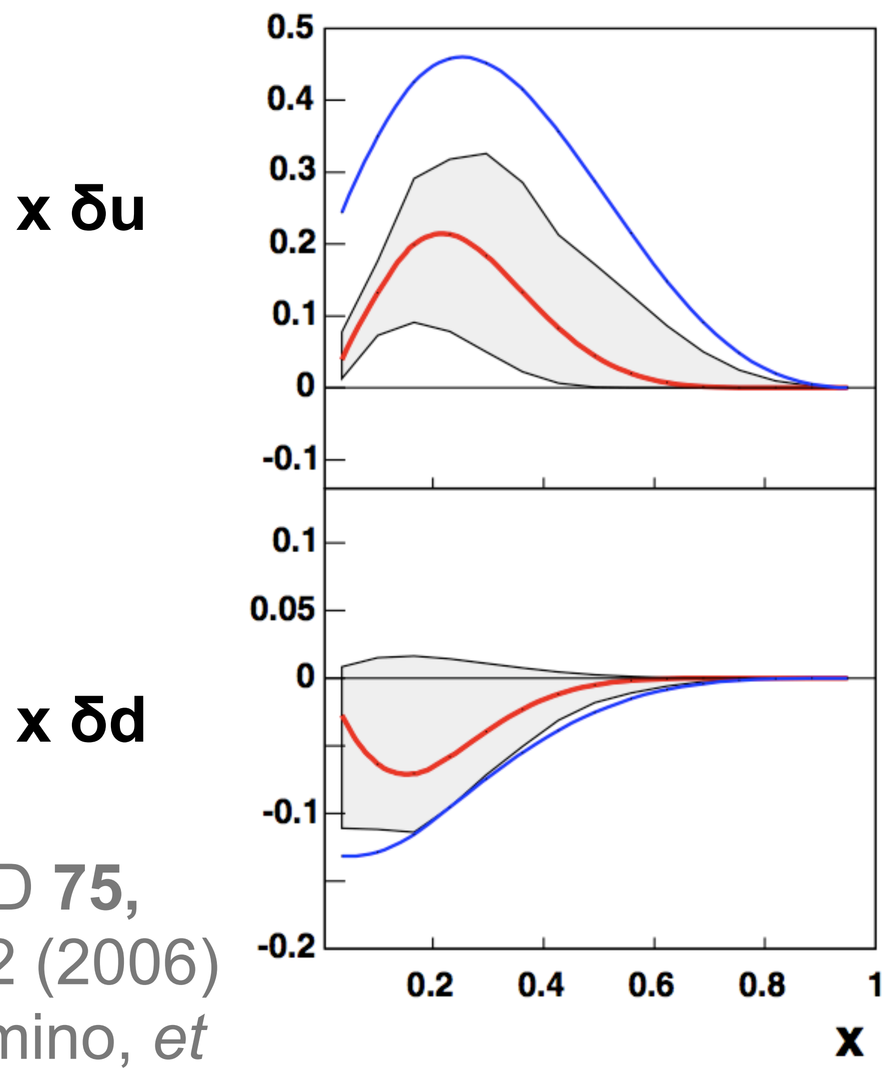

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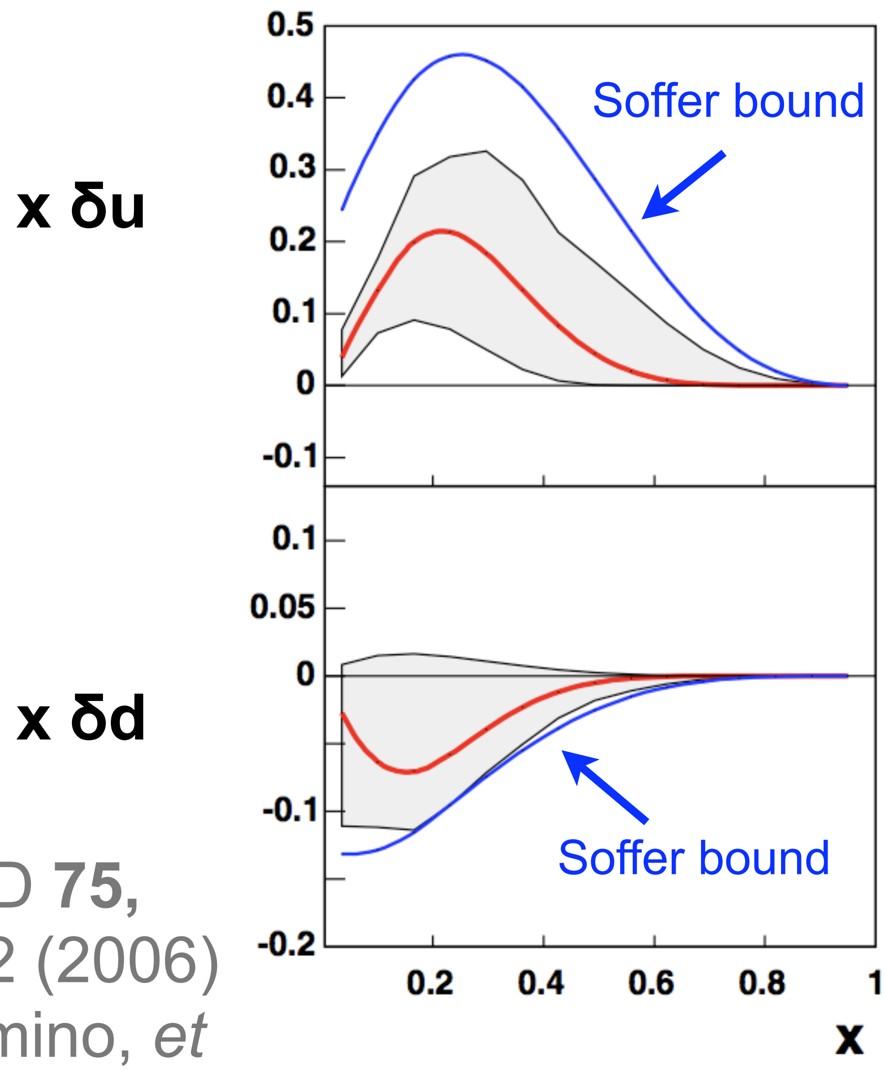

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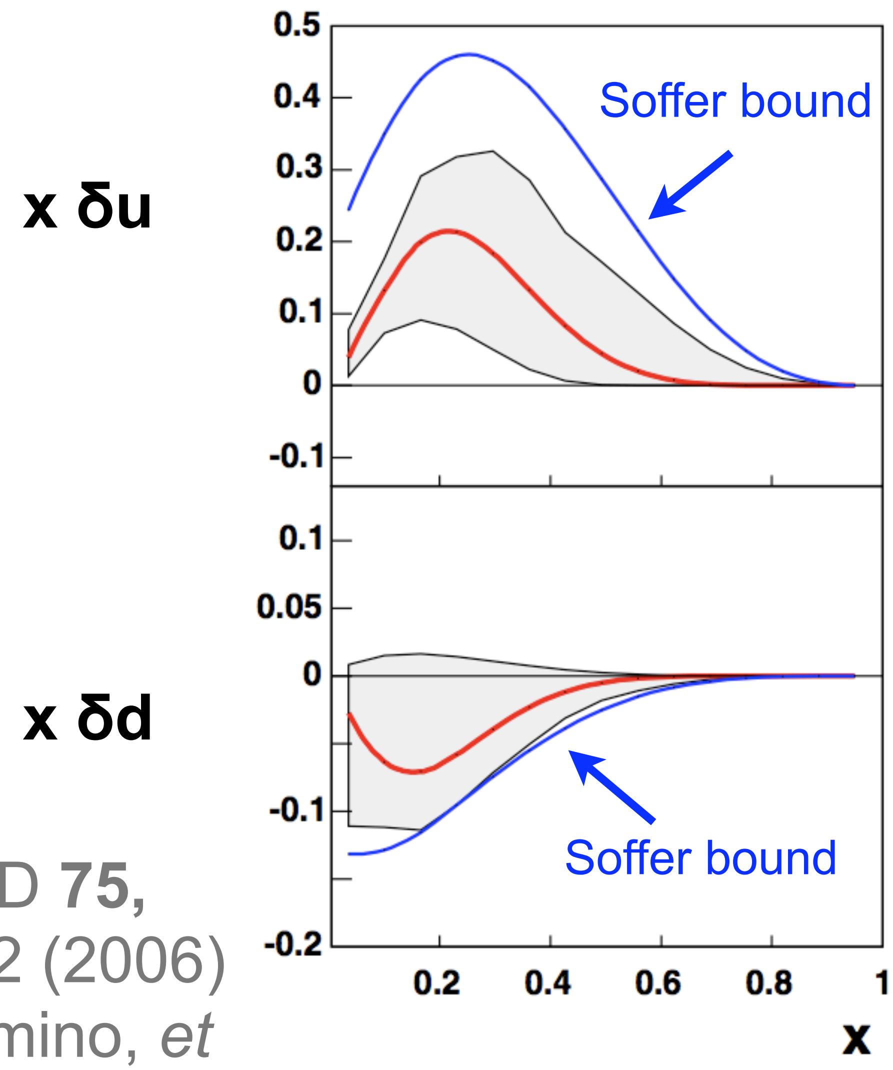

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$$|\delta q(x,Q^2)| \leq \frac{1}{2}[q(x,Q^2) + \Delta q(x,Q^2)]$$

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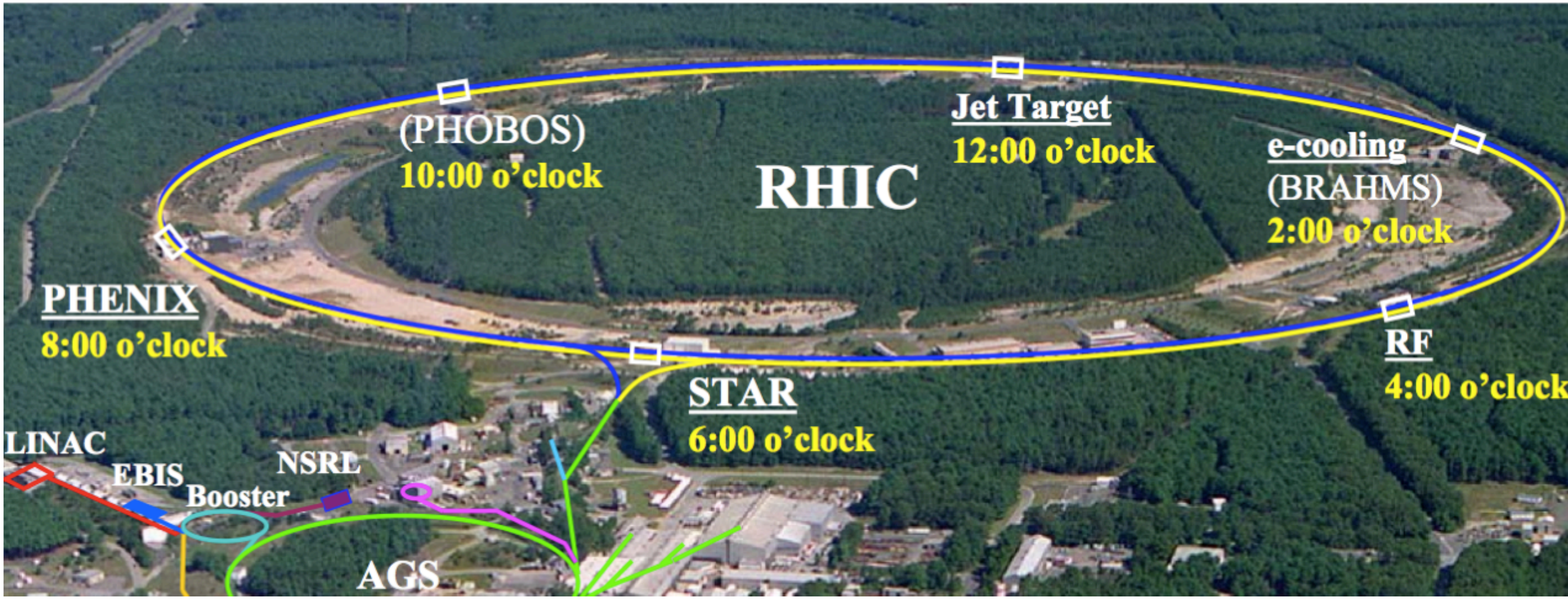
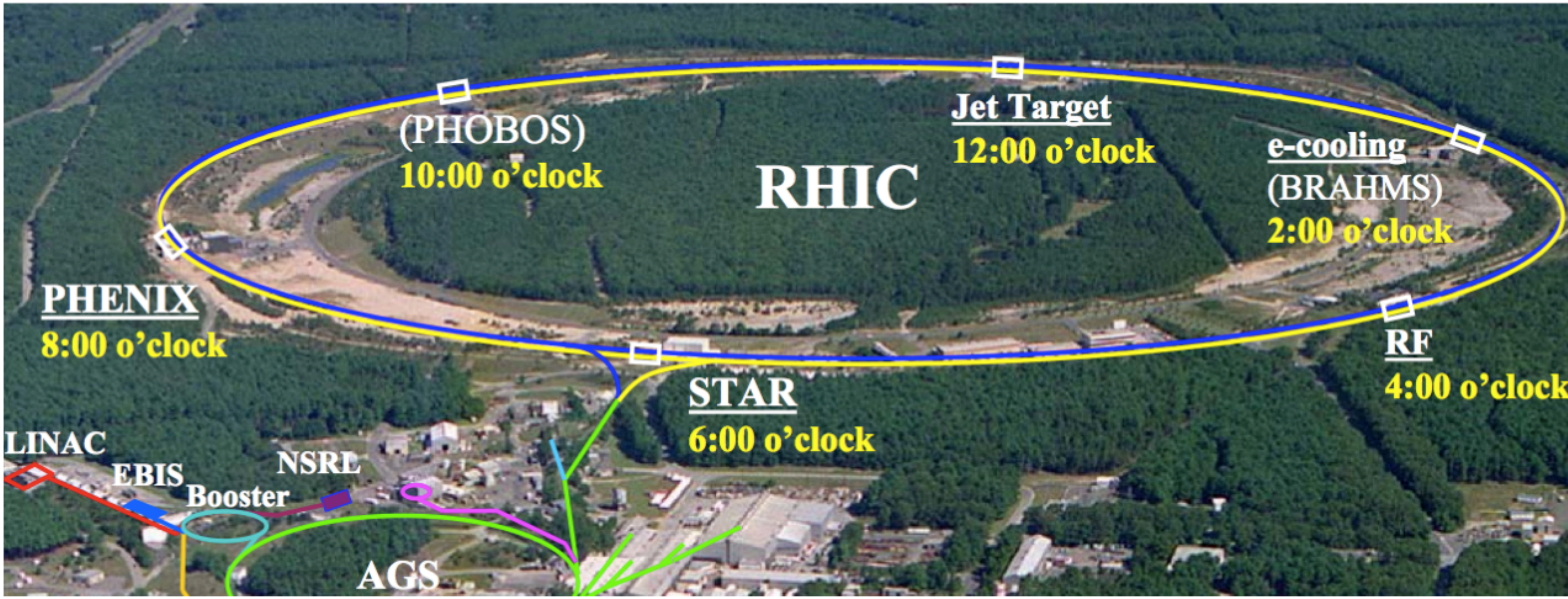
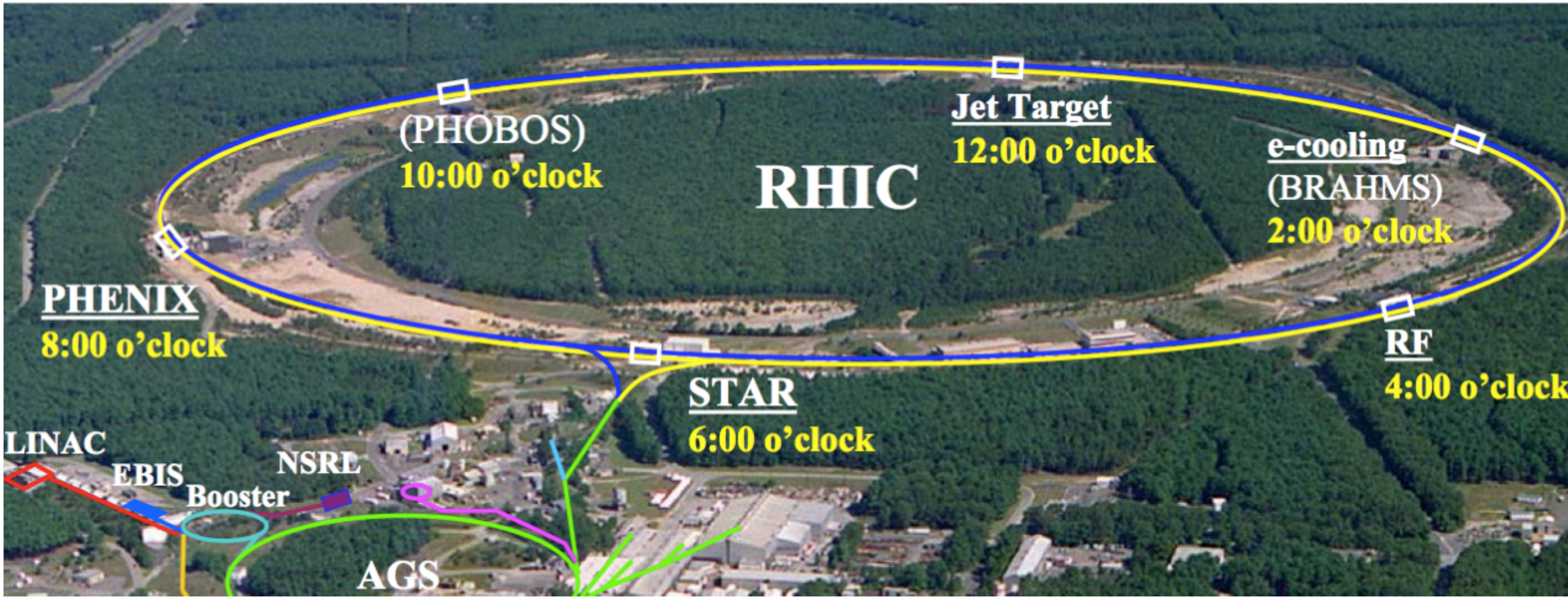
- Conduct a relevant overview of the experimental apparatus (STAR) and Jet Reconstruction



(PHOBOS)
10:00 o'clock
Jet Target
12:00 o'clock
RHIC
e-cooling
(BRAHMS)
2:00 o'clock
PHENIX
8:00 o'clock
RF
4:00 o'clock
STAR
6:00 o'clock
LINAC
EBIS
Booster
NSRL
AGS

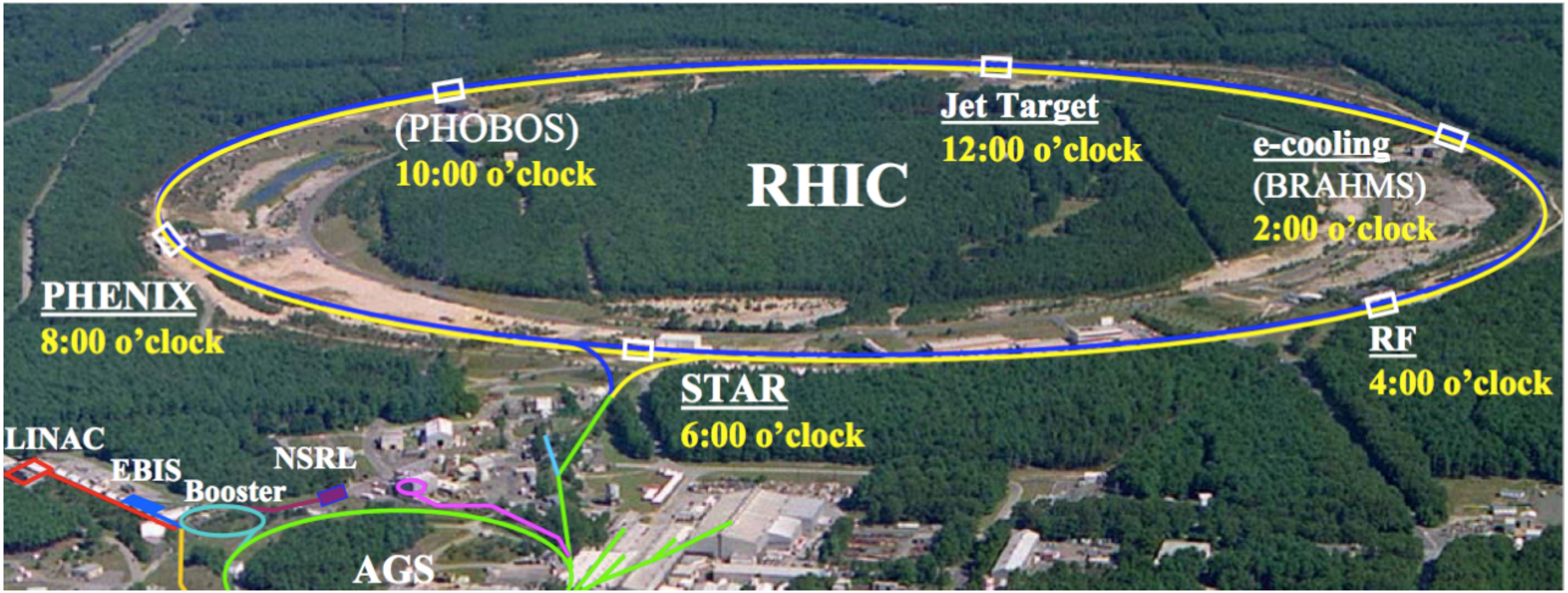


Proton-proton collisions at $\sqrt{s}$ = 200 GeV



Proton-proton collisions at √s = 200 GeV

Beam polarizations as high as ~60%



Proton-proton collisions at $\sqrt{s}$ = 200 GeV

Beam polarizations as high as ~60%

Beam luminosity ~10^{32} $s^{-1}cm^{-2}$ (1 pb^{-1} integrated luminosity)

Experimental Apparatus (S.T.A.R.)

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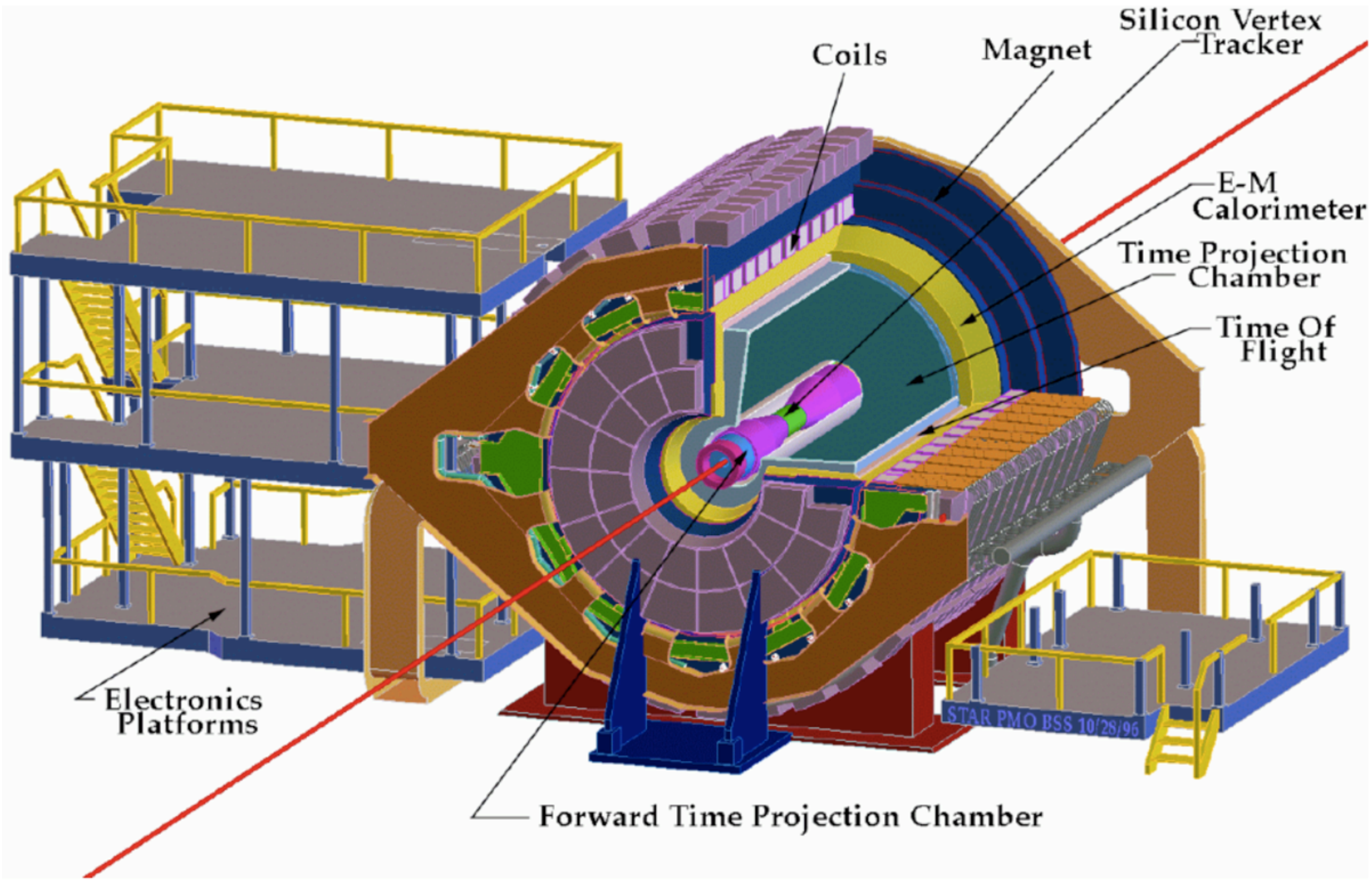

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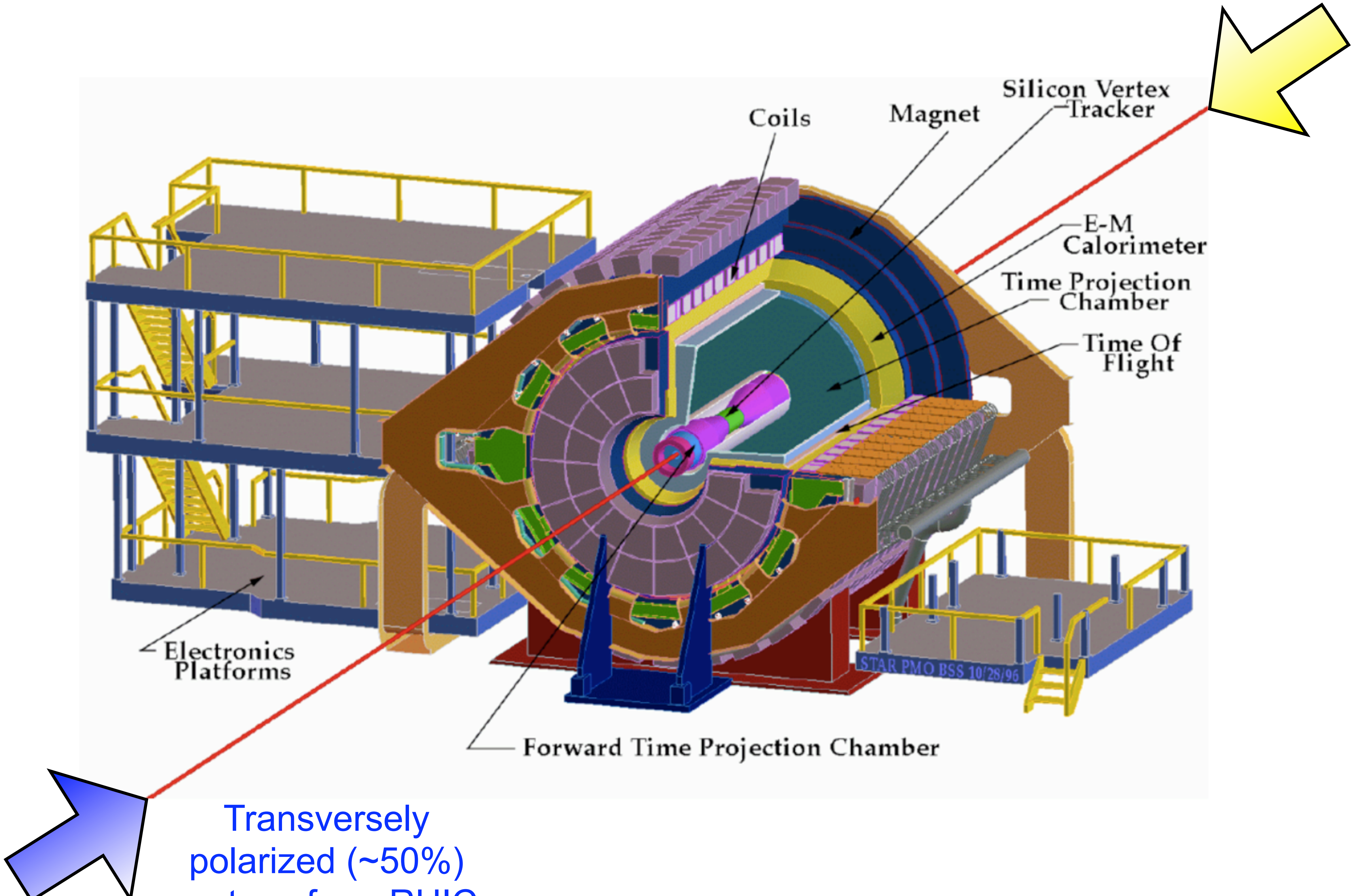

Transversely polarized (~50%) protons from RHIC

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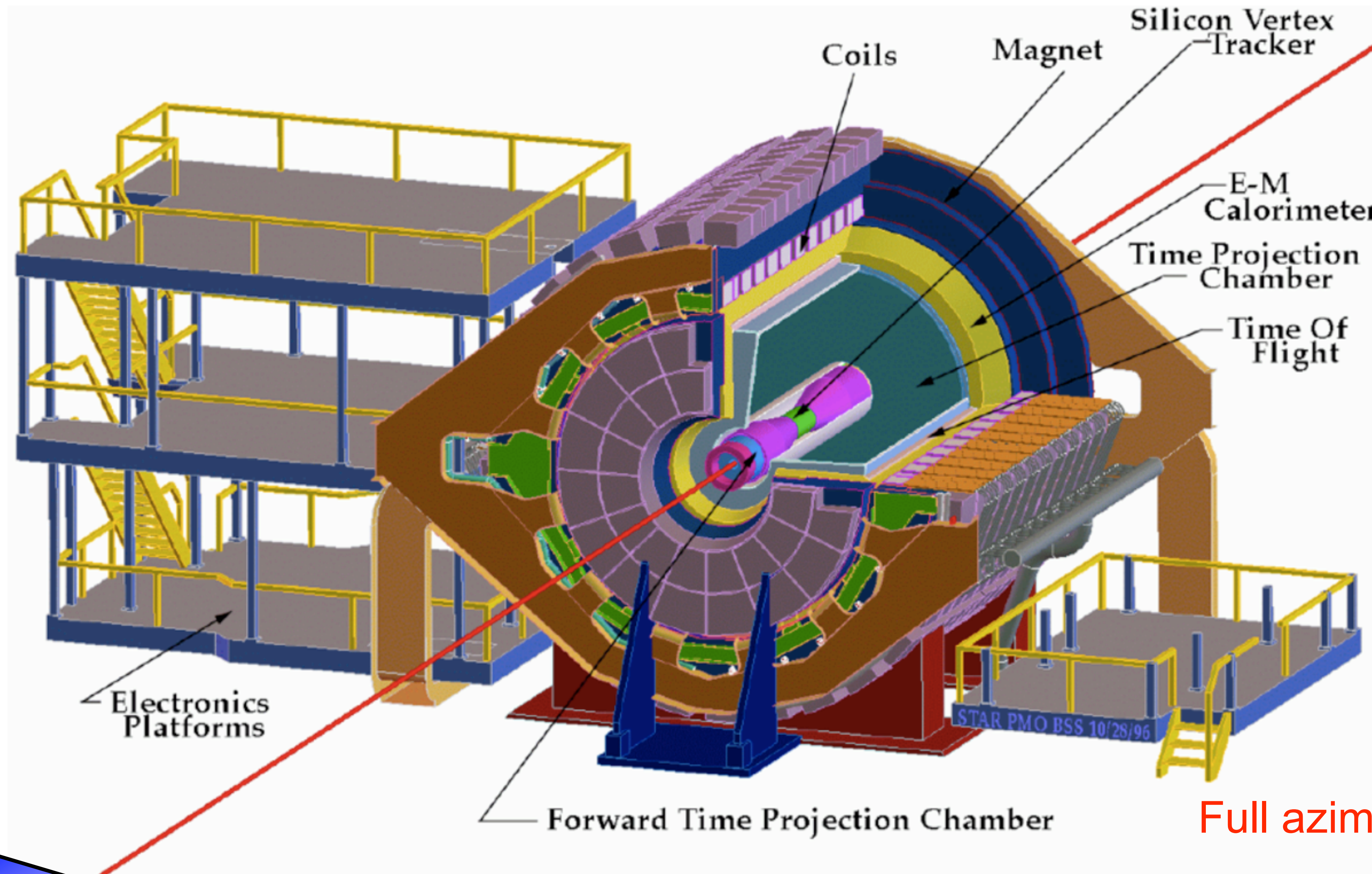

Full azimuthal coverage

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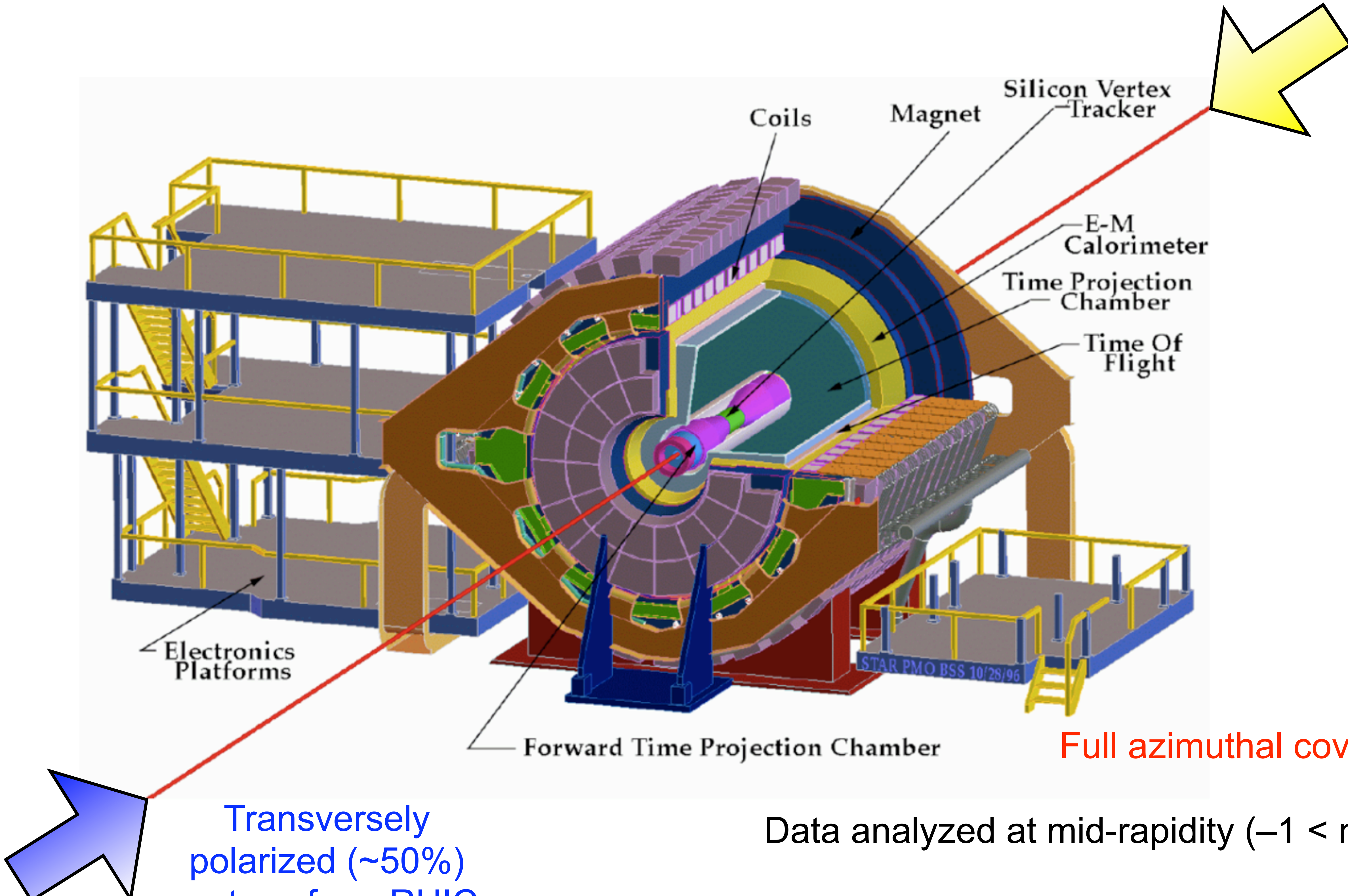

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Data analyzed at mid-rapidity ($-1 < \eta < 1$)

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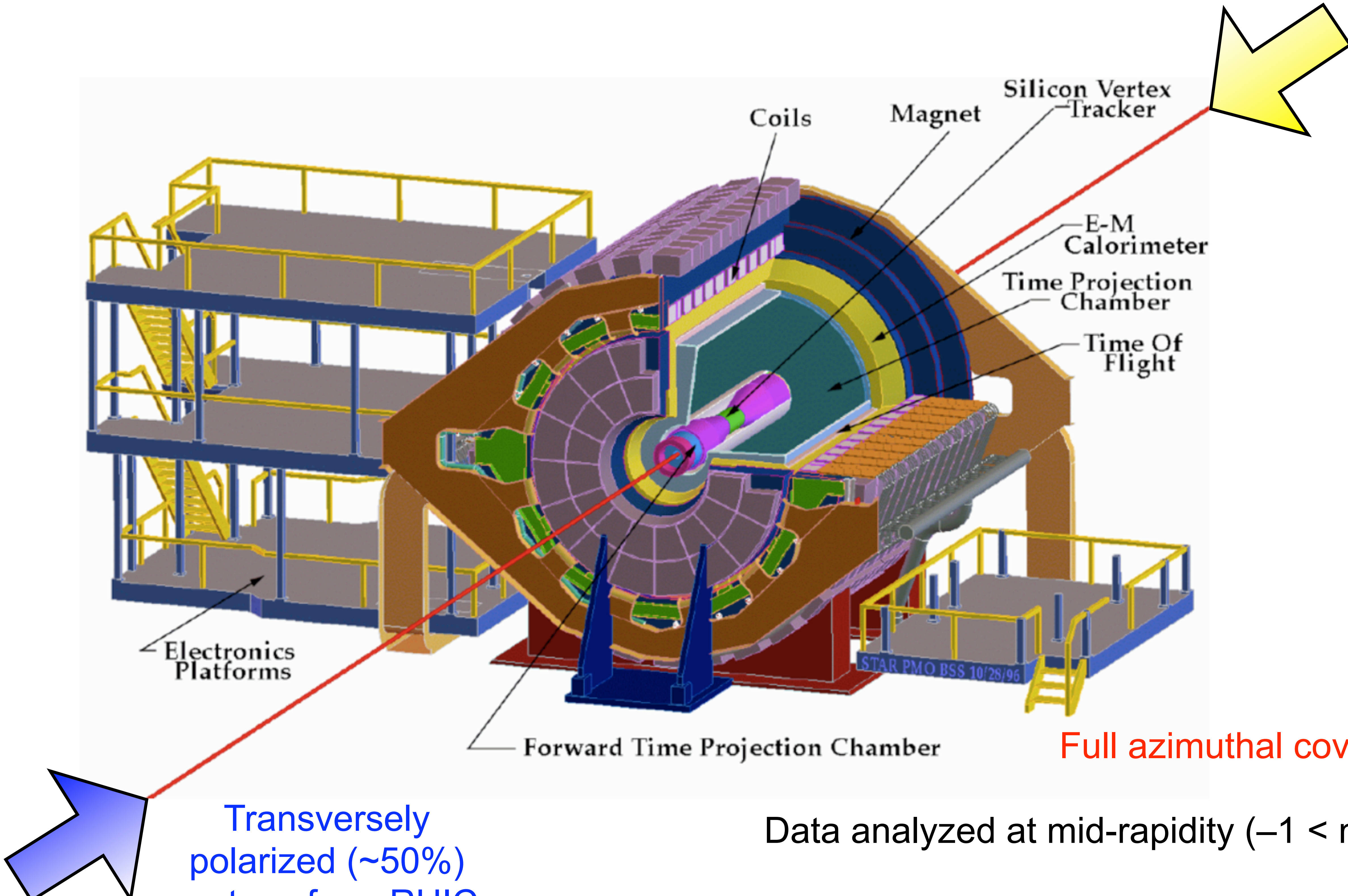

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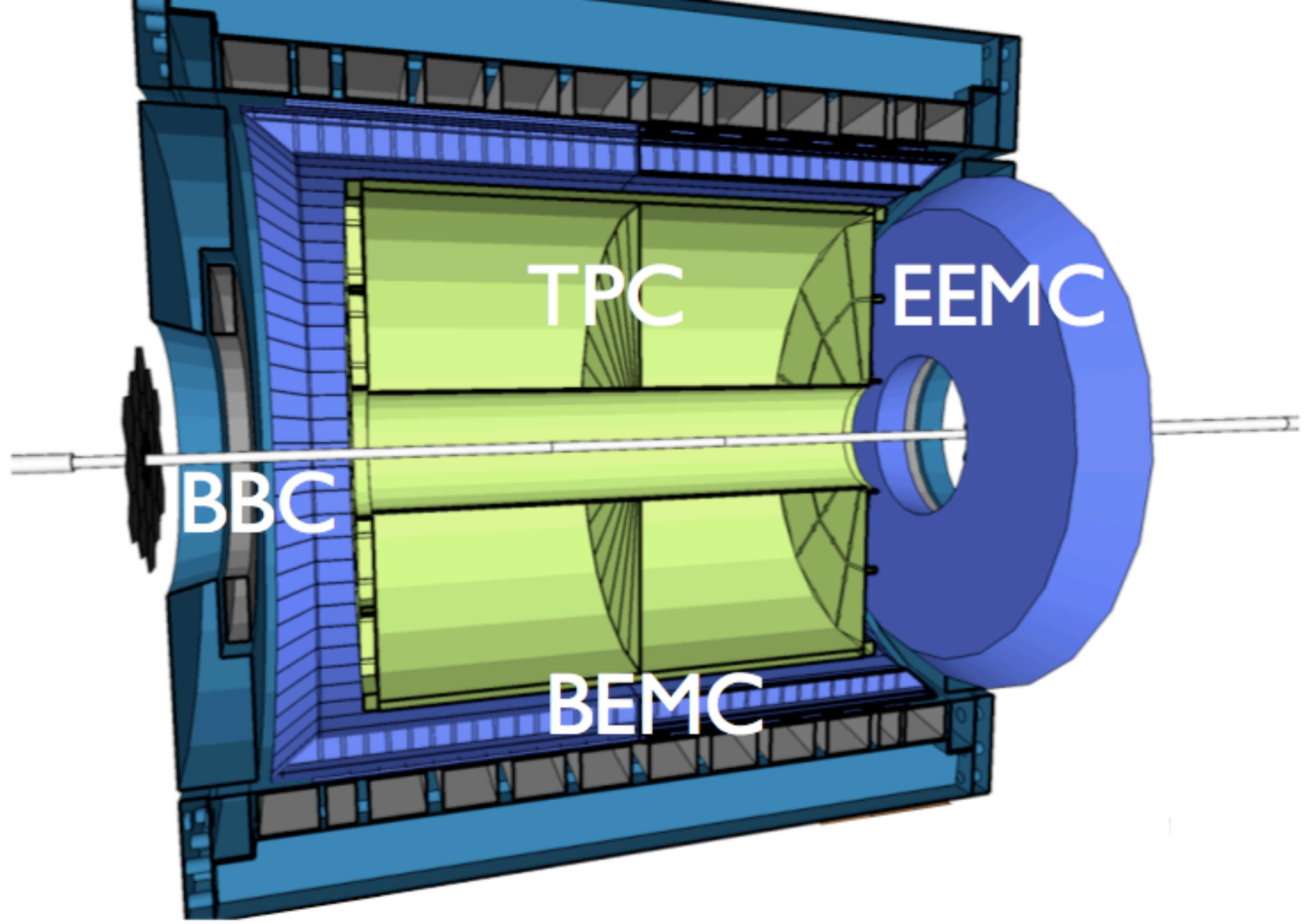
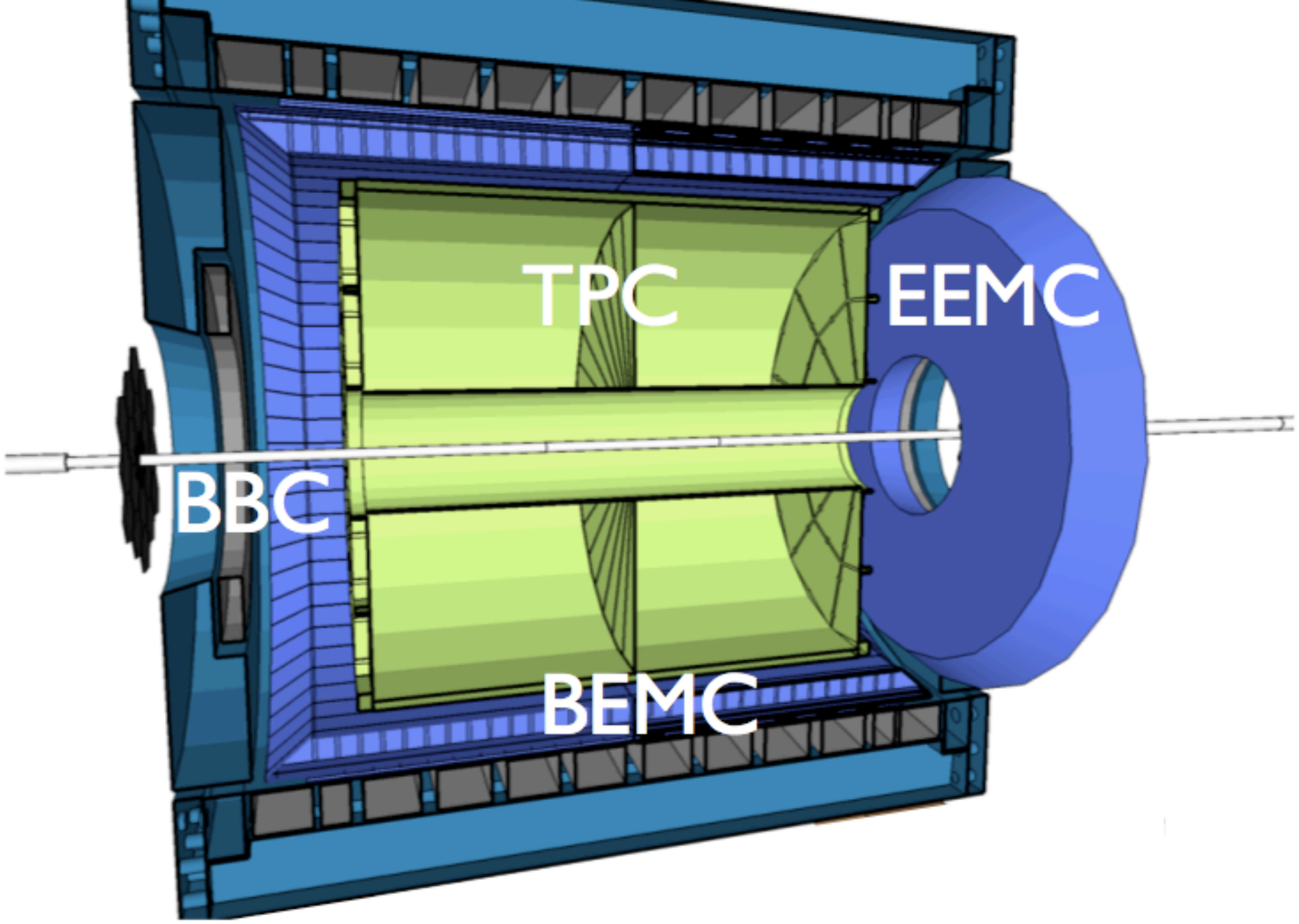
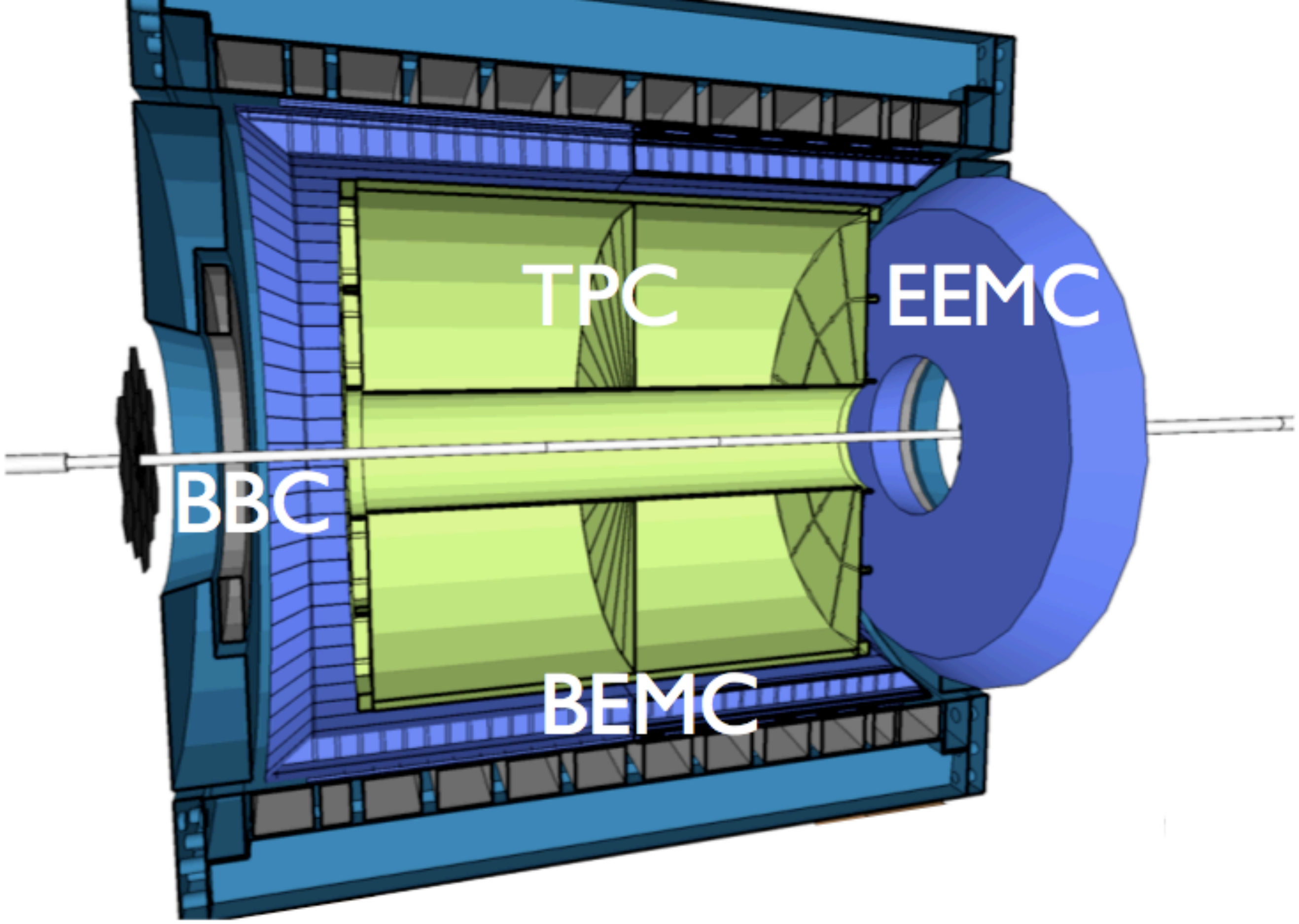
Reconstruction of jets and component charged particle trajectories reconstructed


TPC
EEMC
BBC
BEMC



BBC: relative polarization luminosities; minimum bias trigger



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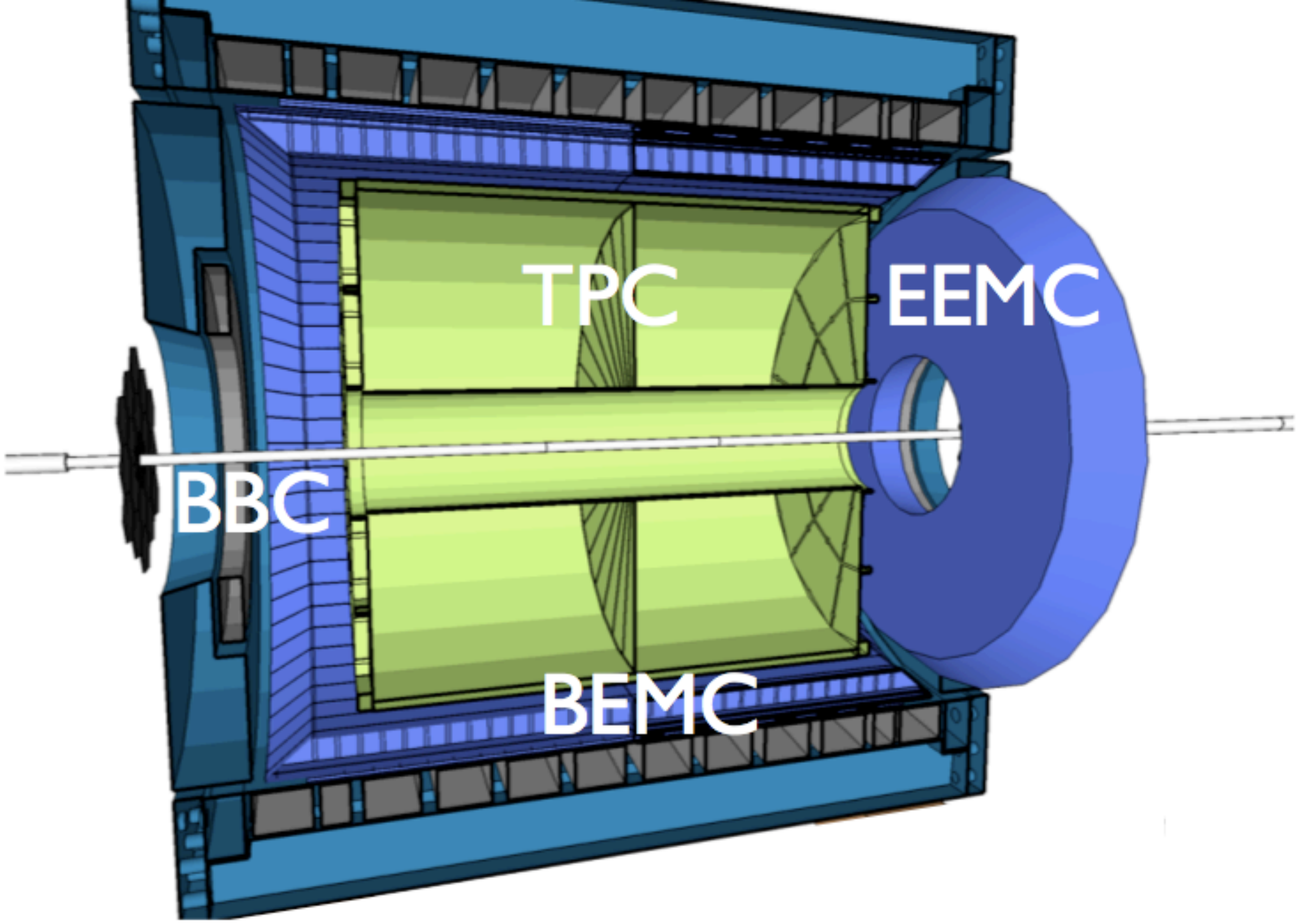
TPC: charged particle tracking; dE/dx PID (p<15 GeV)



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BEMC, EEMC: barrel/endcap calorimeters for triggering, jet reconstruction

Jet Reconstruction

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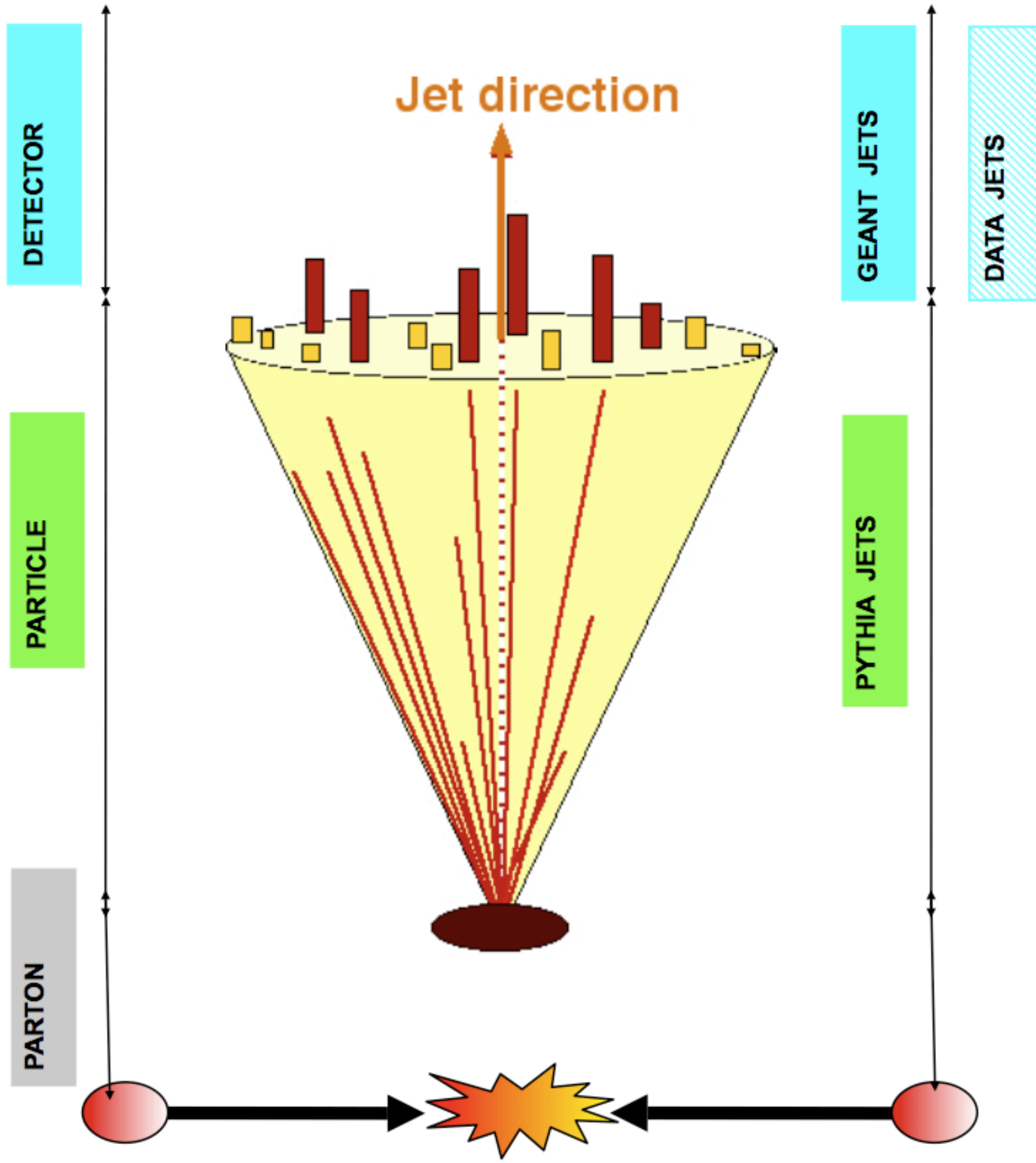

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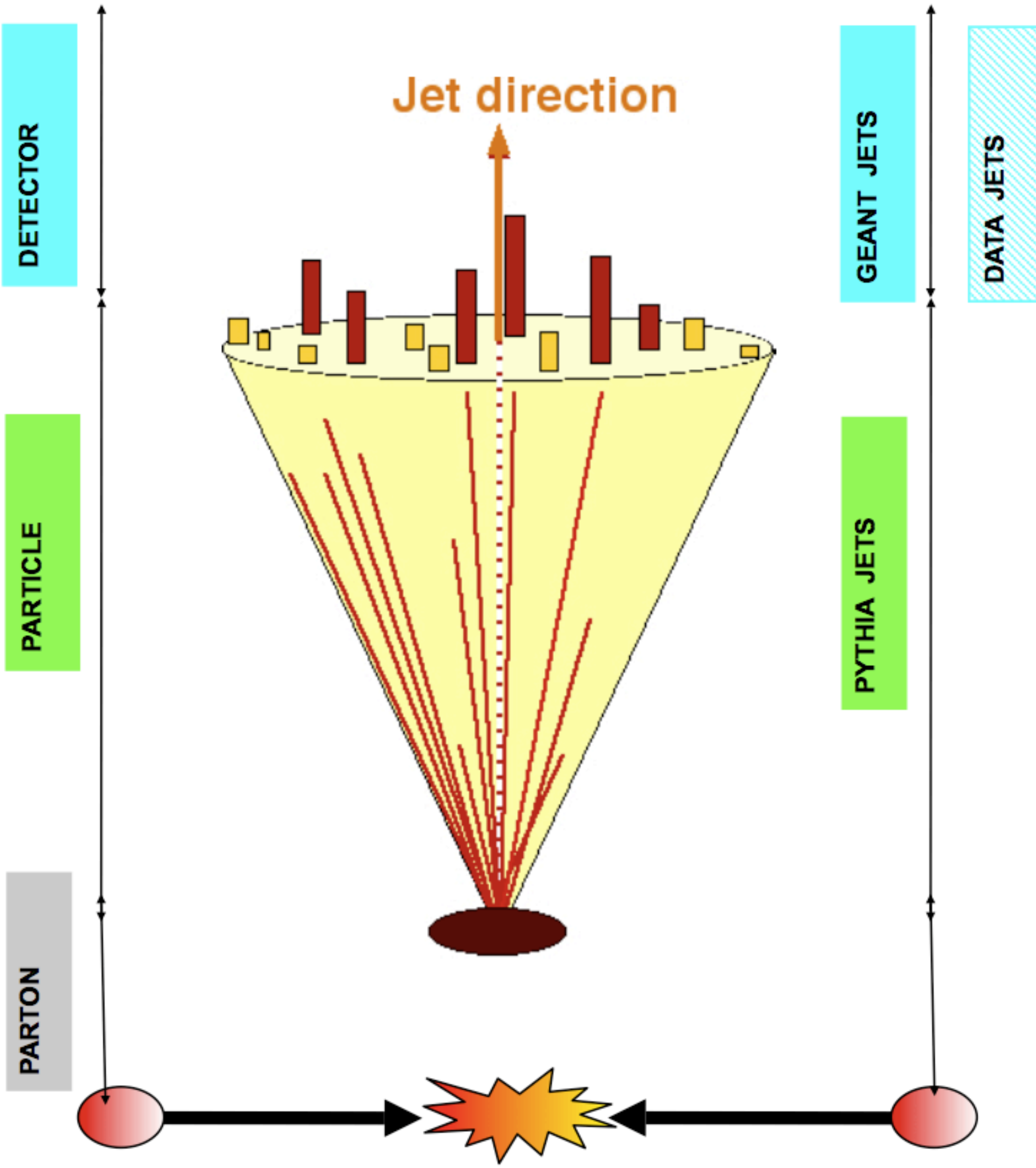
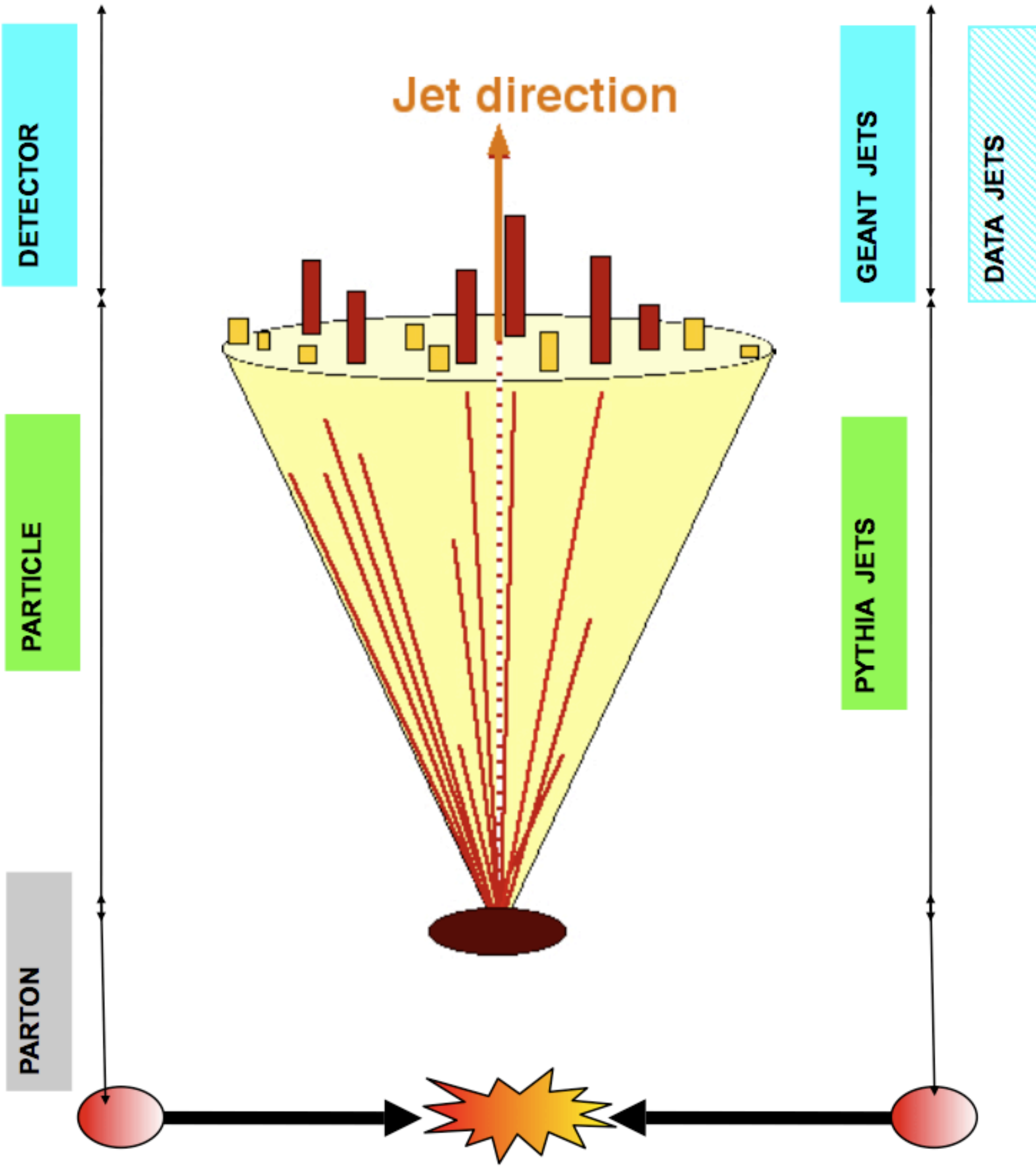


Midpoint Cone Algorithm

(hep-ex/0005012)

Jet Reconstruction

1) TPC track or EMC tower used as “seed”
2) hits inside fixed radius determine cluster energy
3) neighboring clusters calculated & merged if energy overlap > 50%



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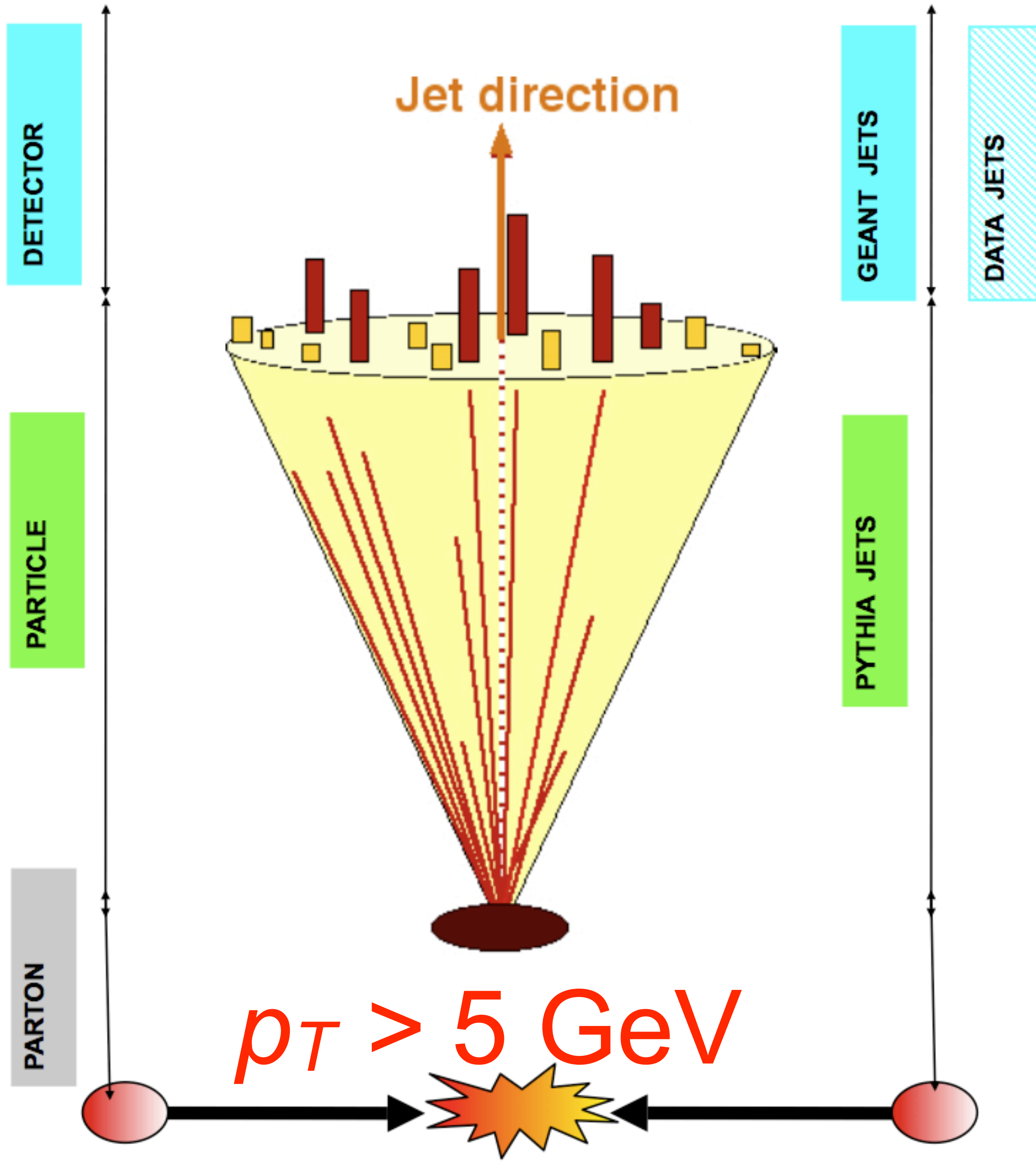

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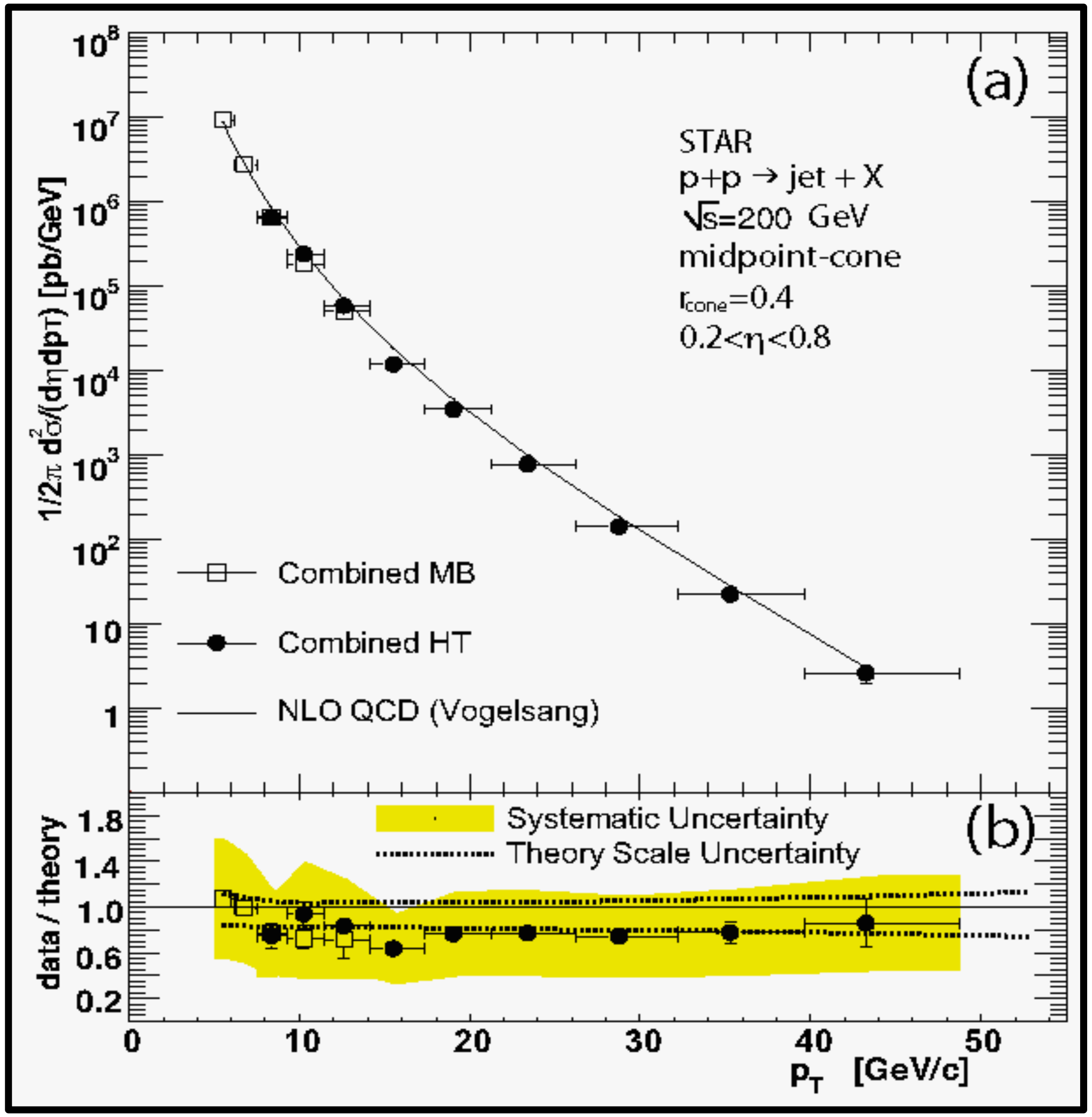

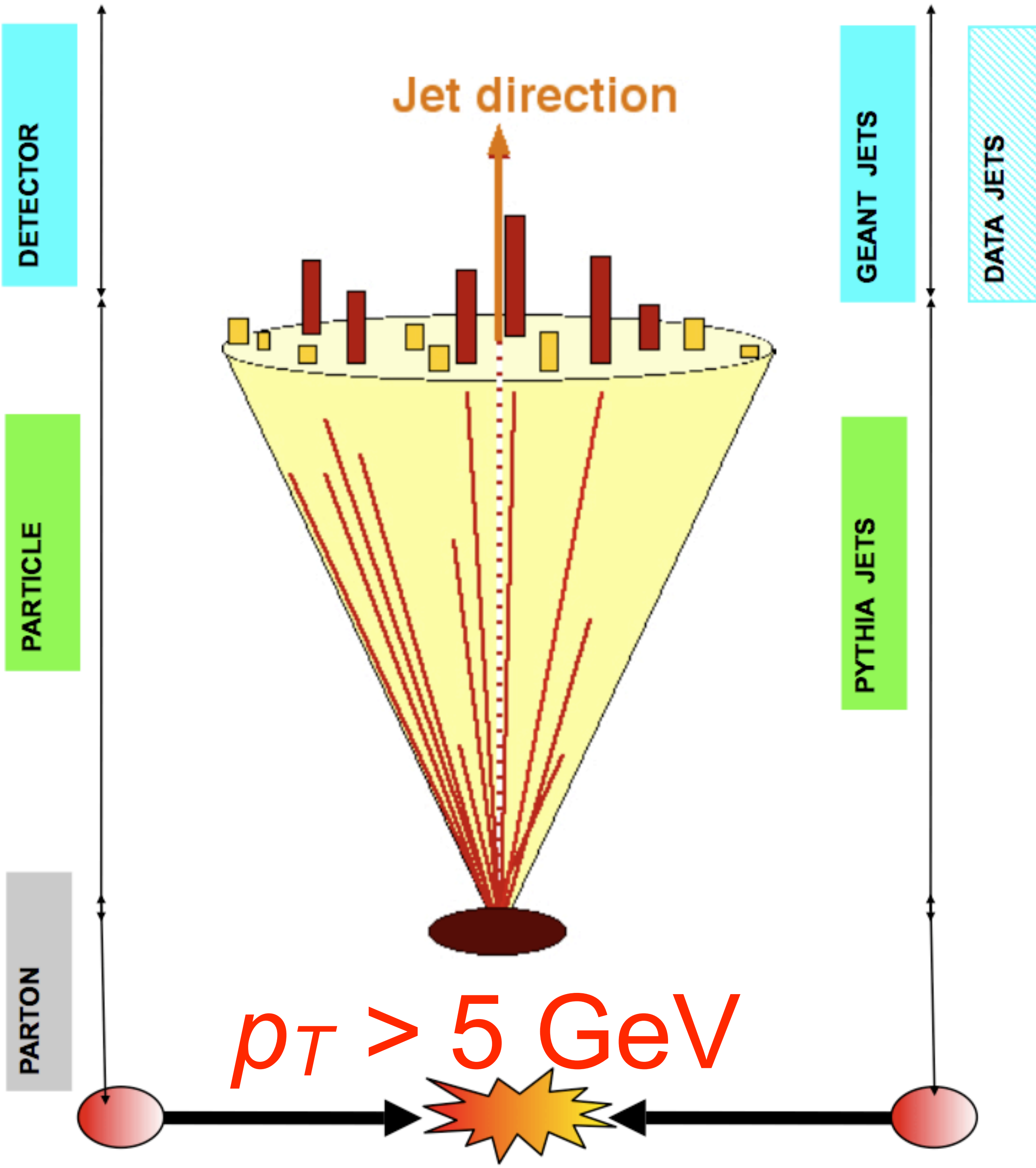

$p_T > 5$ GeV

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Goals of this Presentation:

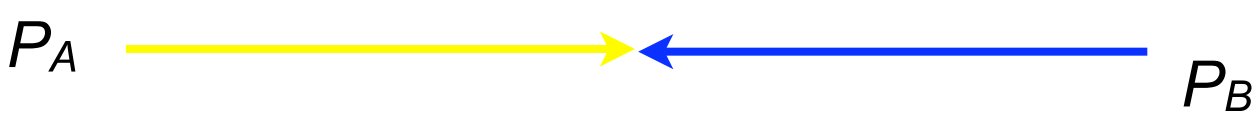
- Relate of δq to the experimentally measurable Collins asymmetry

Experimental access to δq

Experimental access to *δq*

proton-proton scattering:

$$p(P_A, S_\perp) + p(P_B) \to jet(P_J) + X \to \pi^{\pm} + X$$



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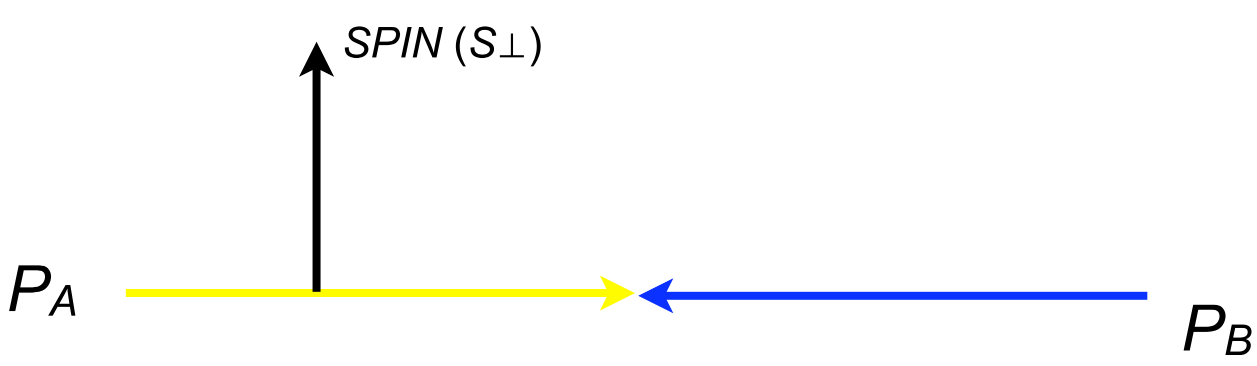

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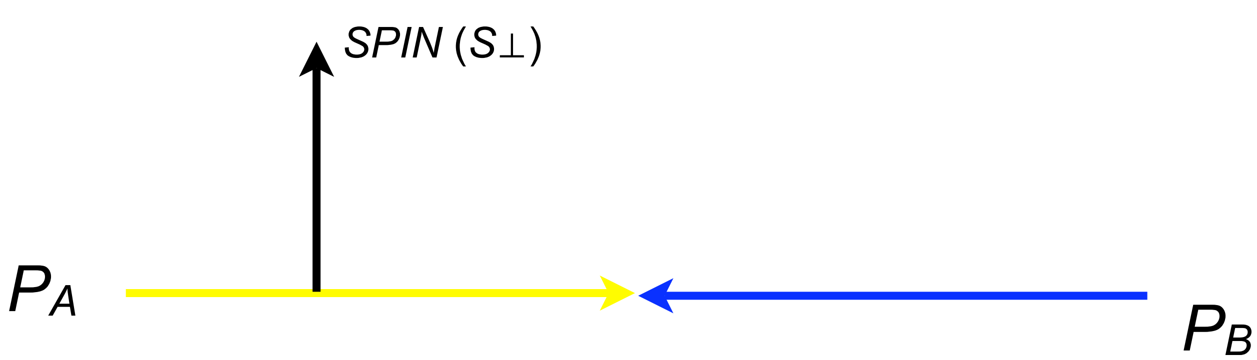

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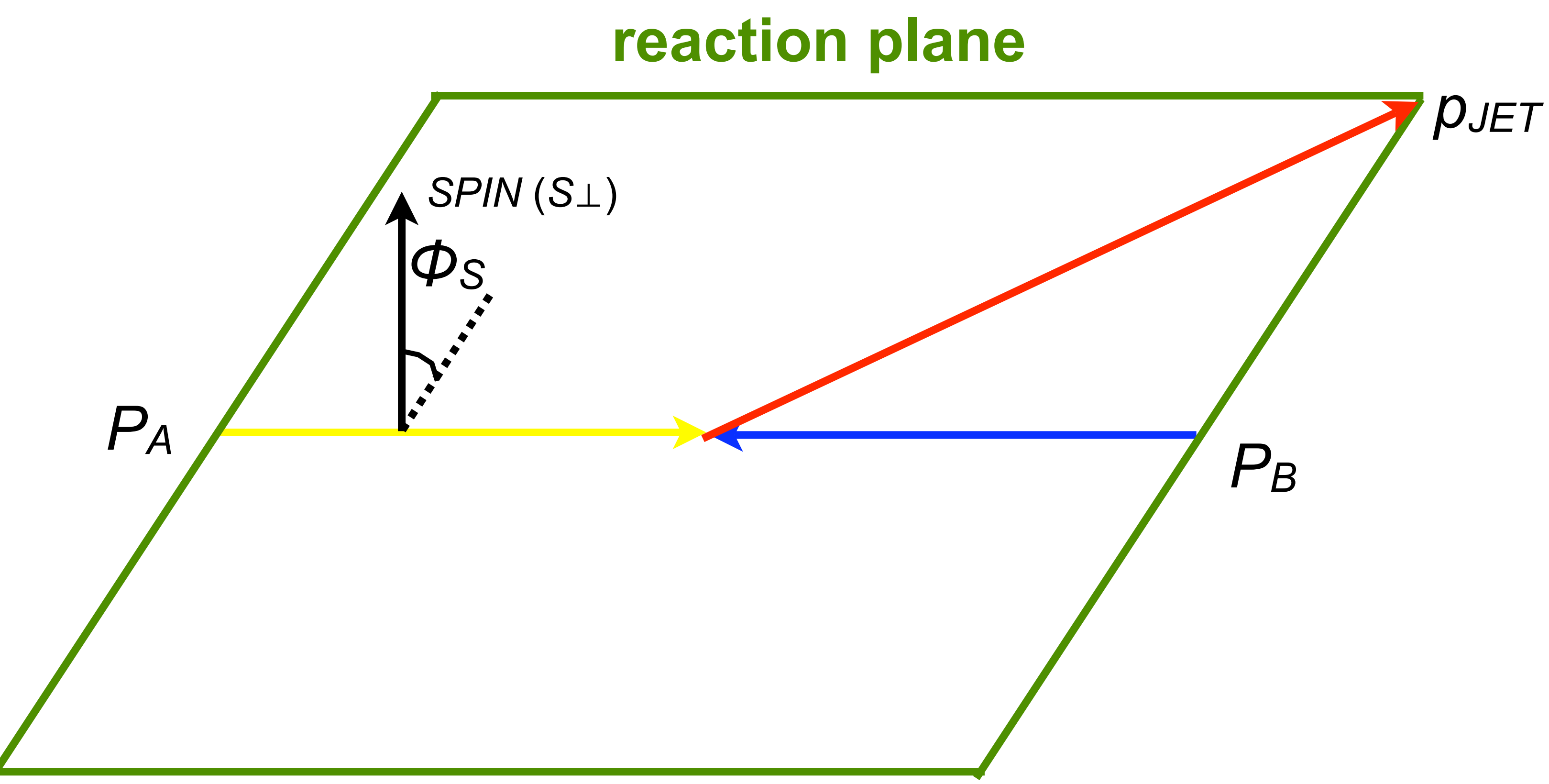

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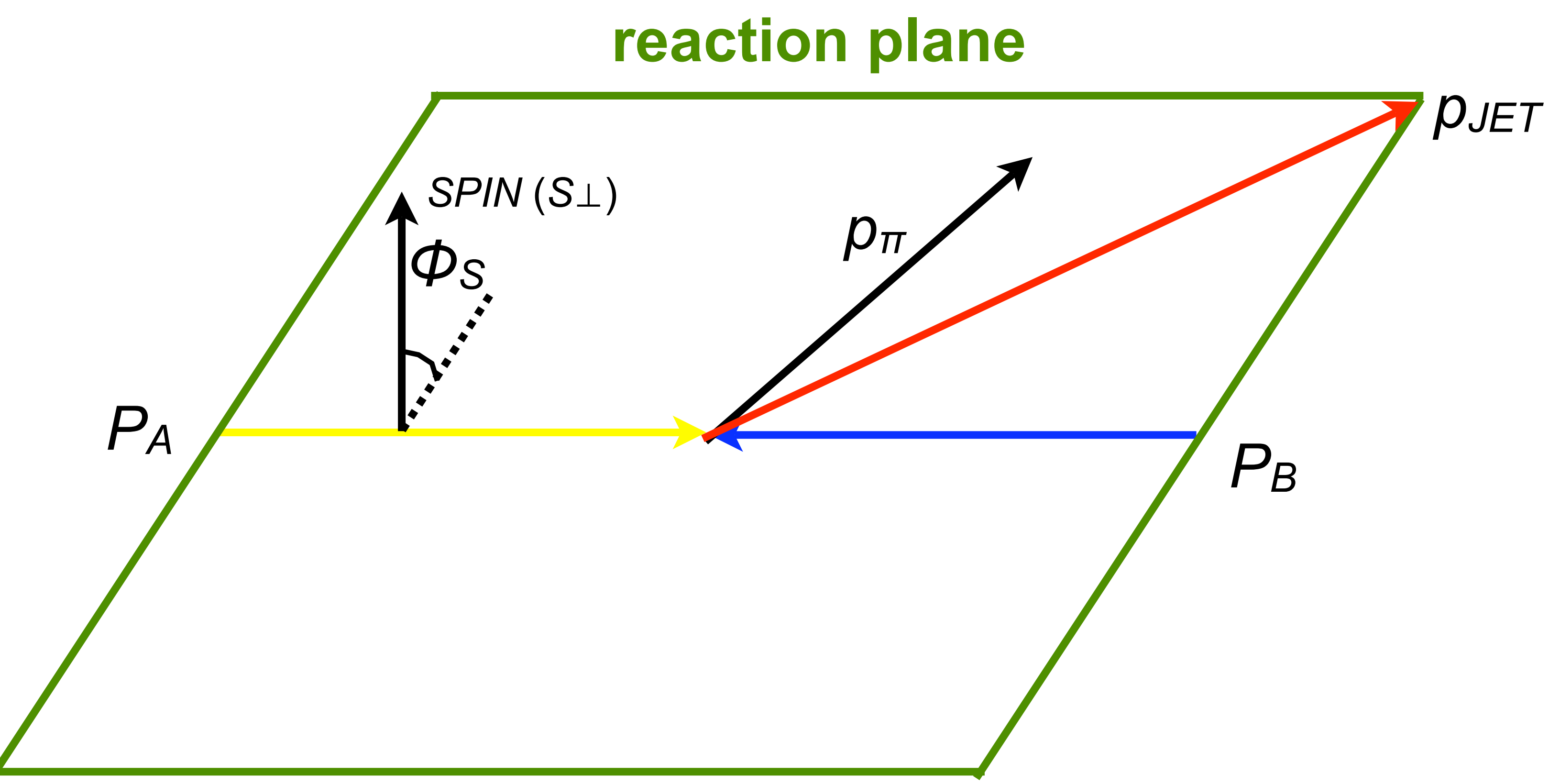
Leading pions give us the most direct access to the quark initiating the event.



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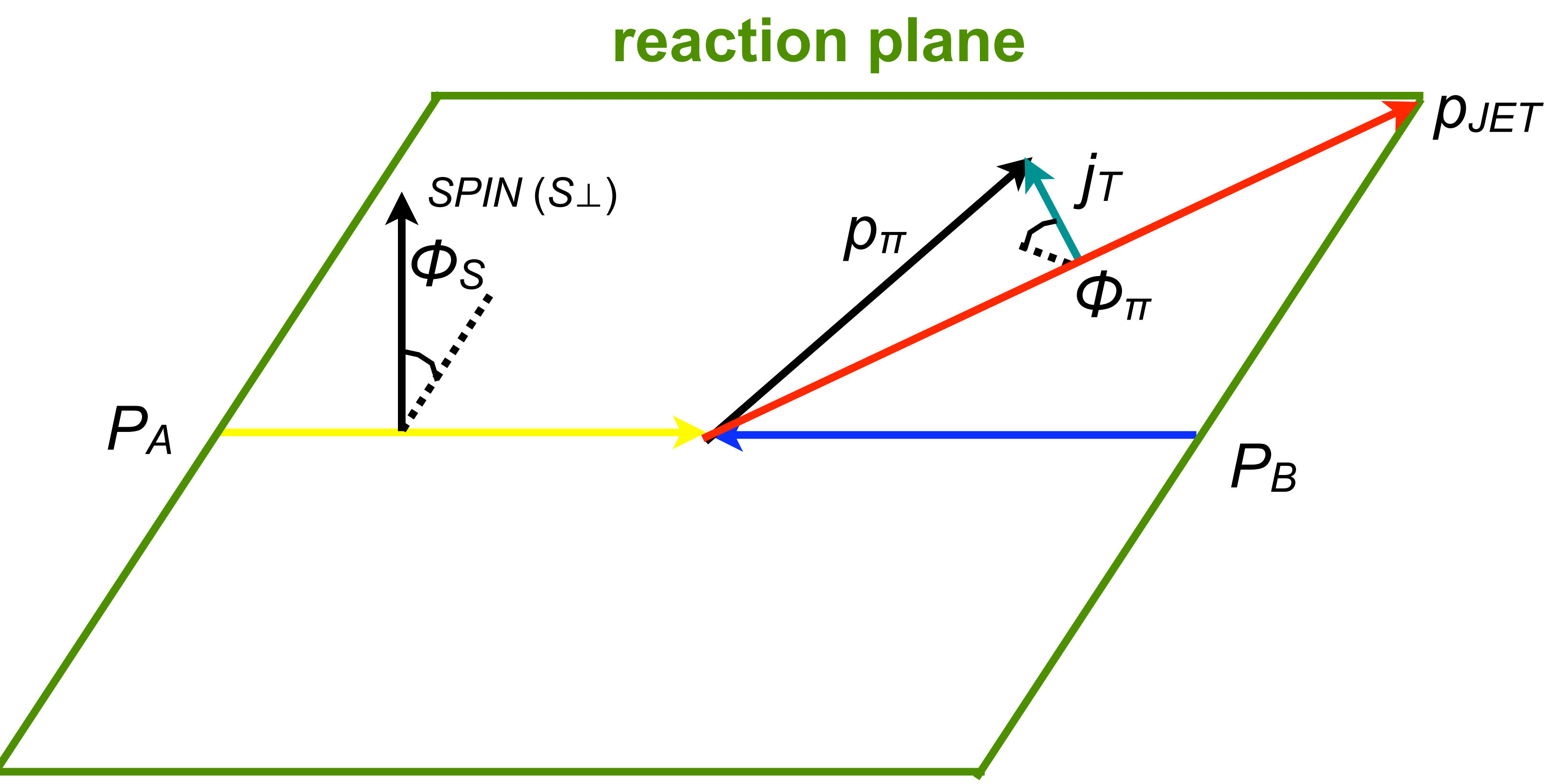

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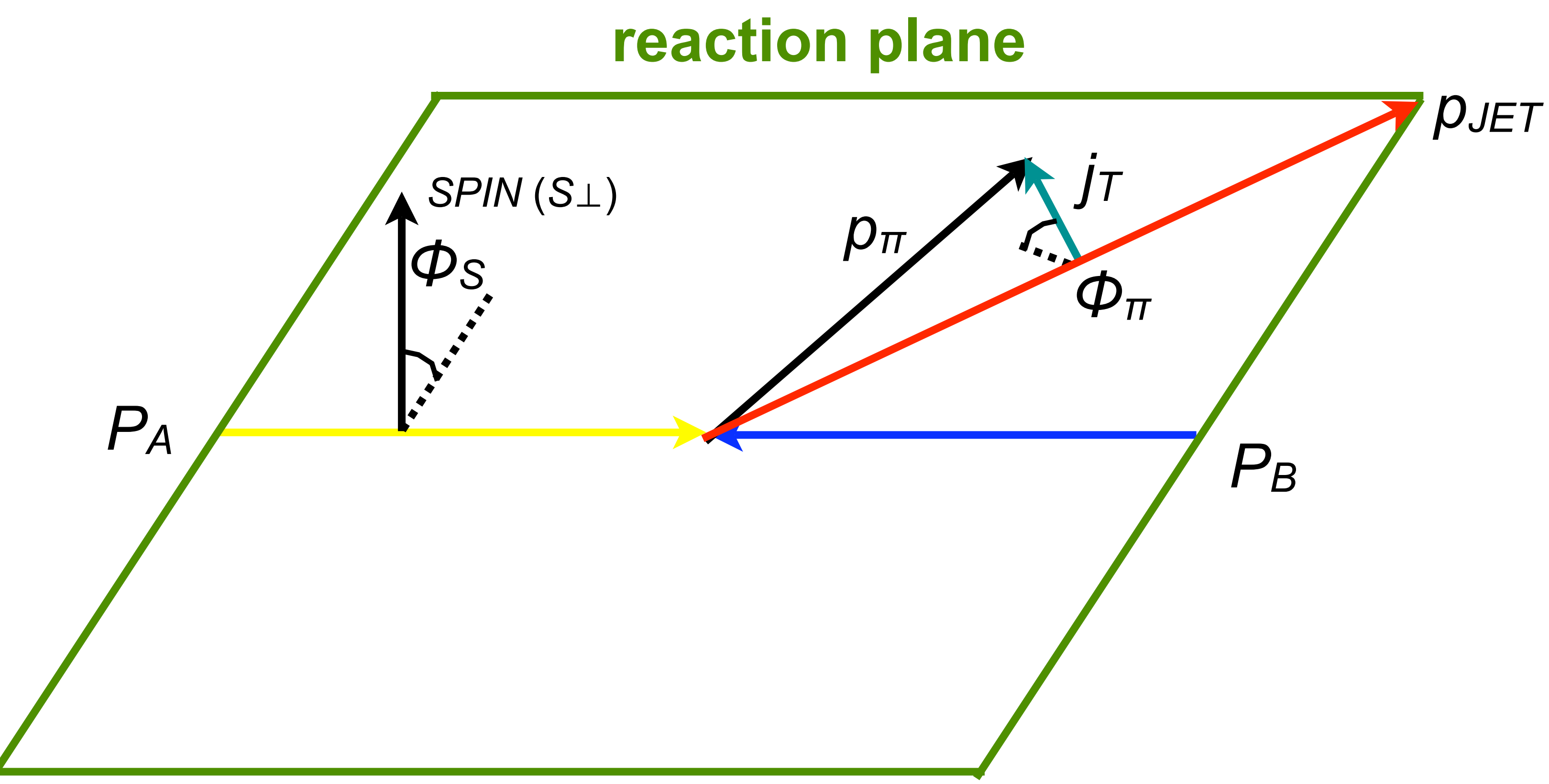

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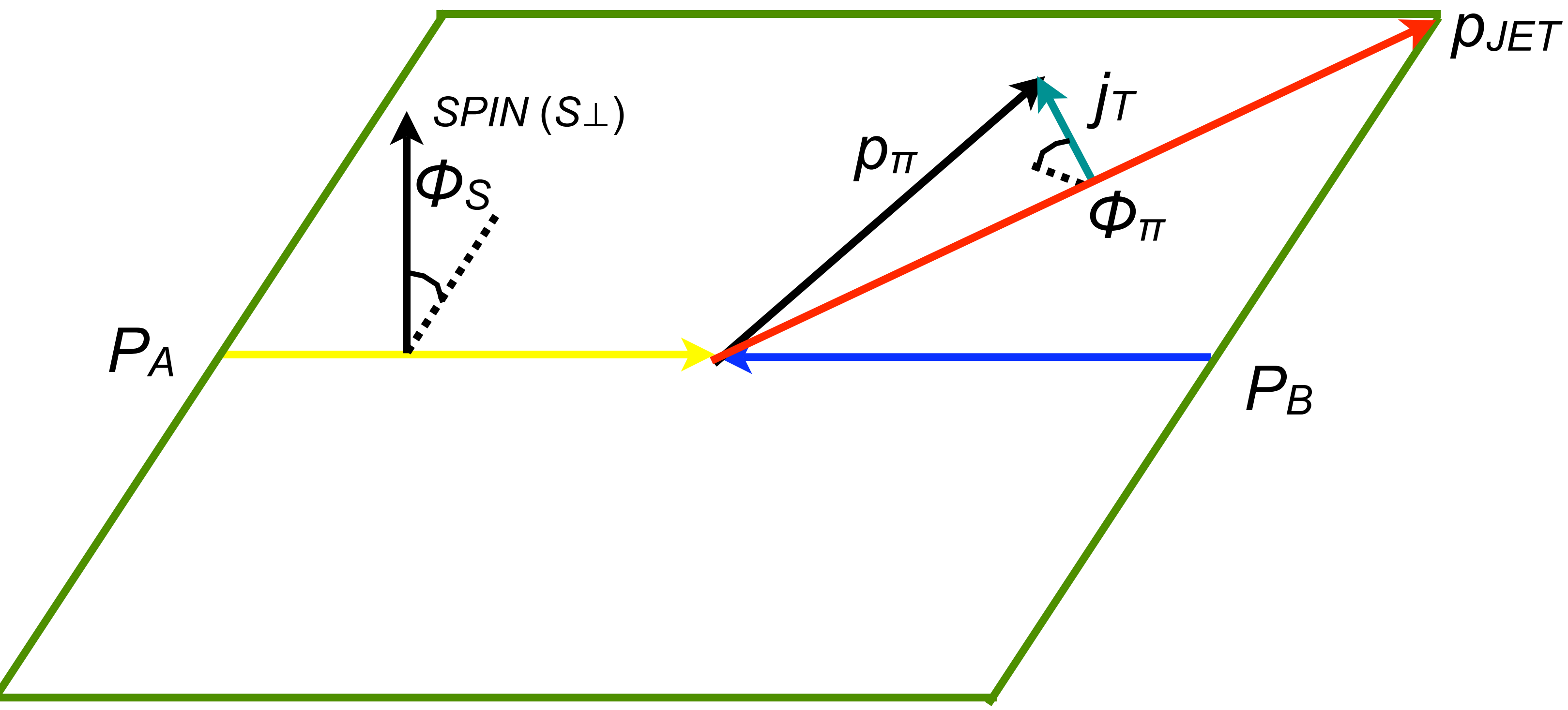

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polarized quark → jet ⇒

spin-dependence in fragmentation of the polarized quark ⇒

Φ_π-dependence of pion production rate, relative to $S_\perp^\pm$

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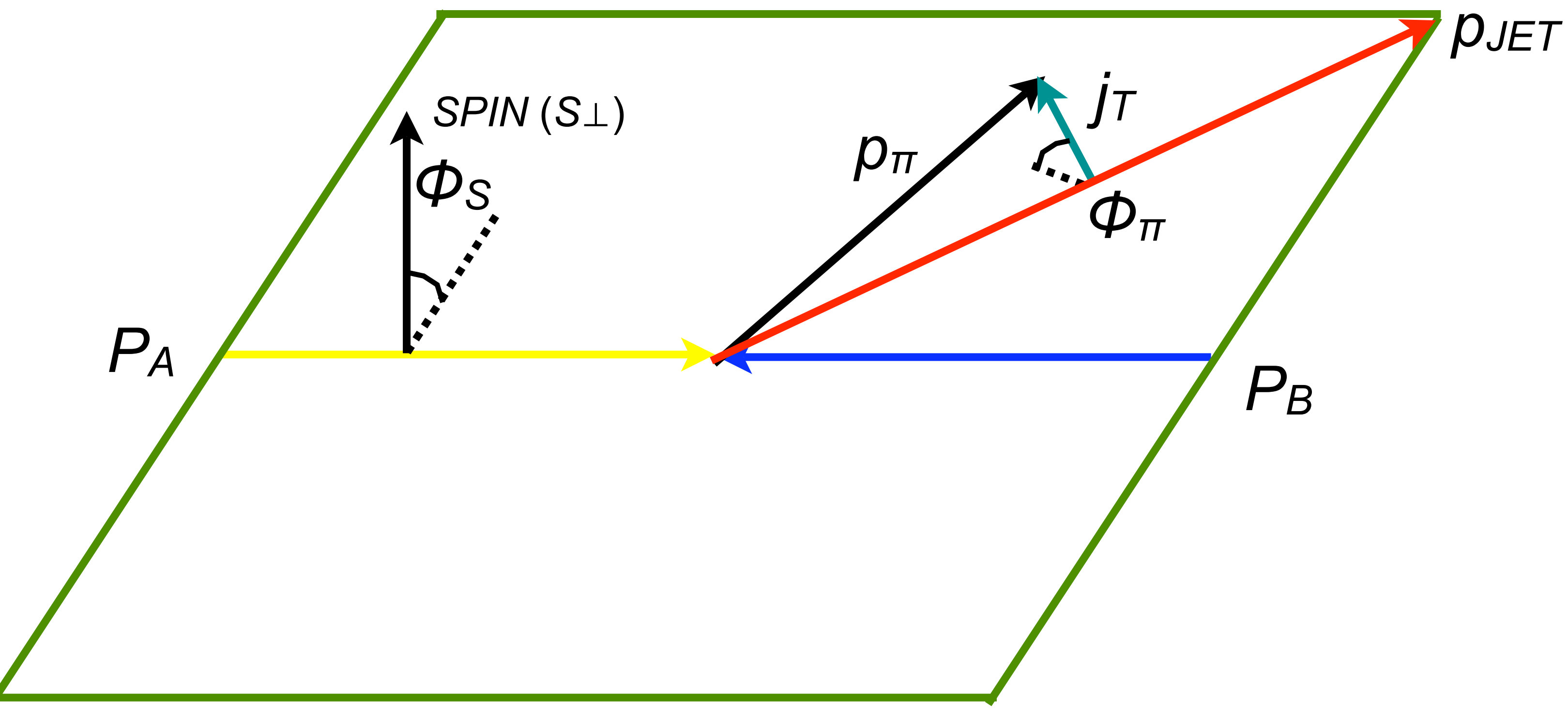

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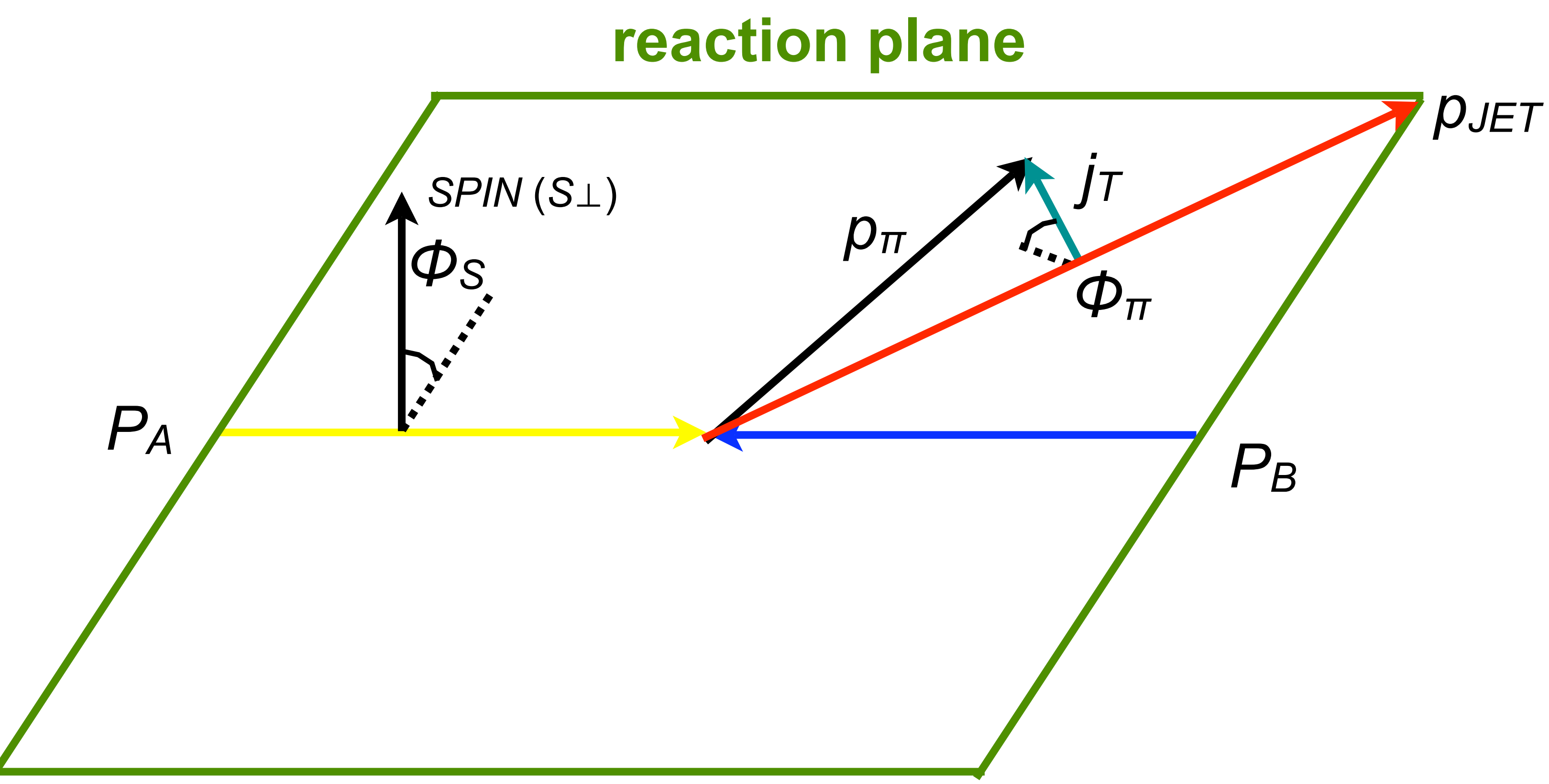

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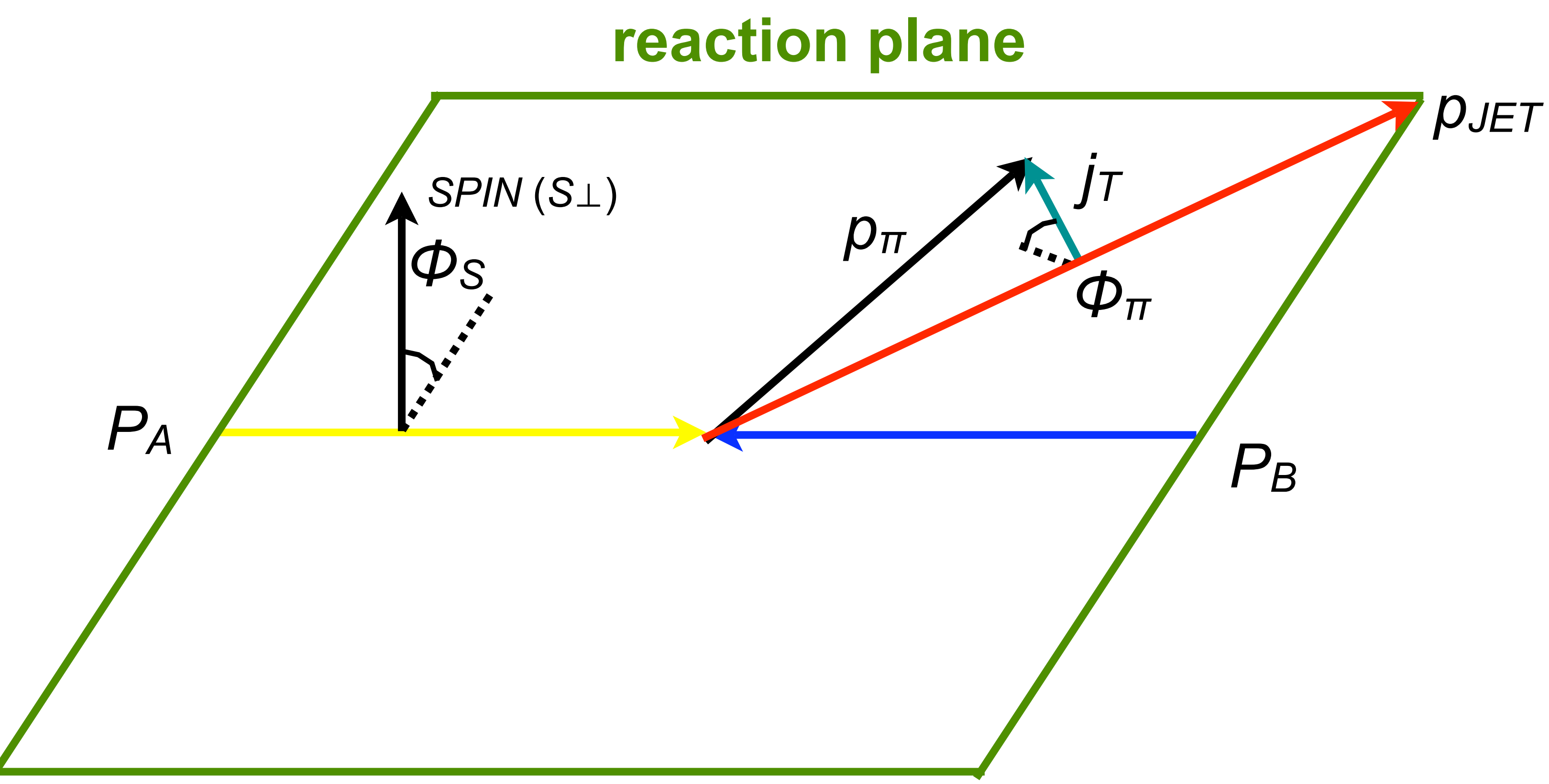

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Spin transfer coefficient

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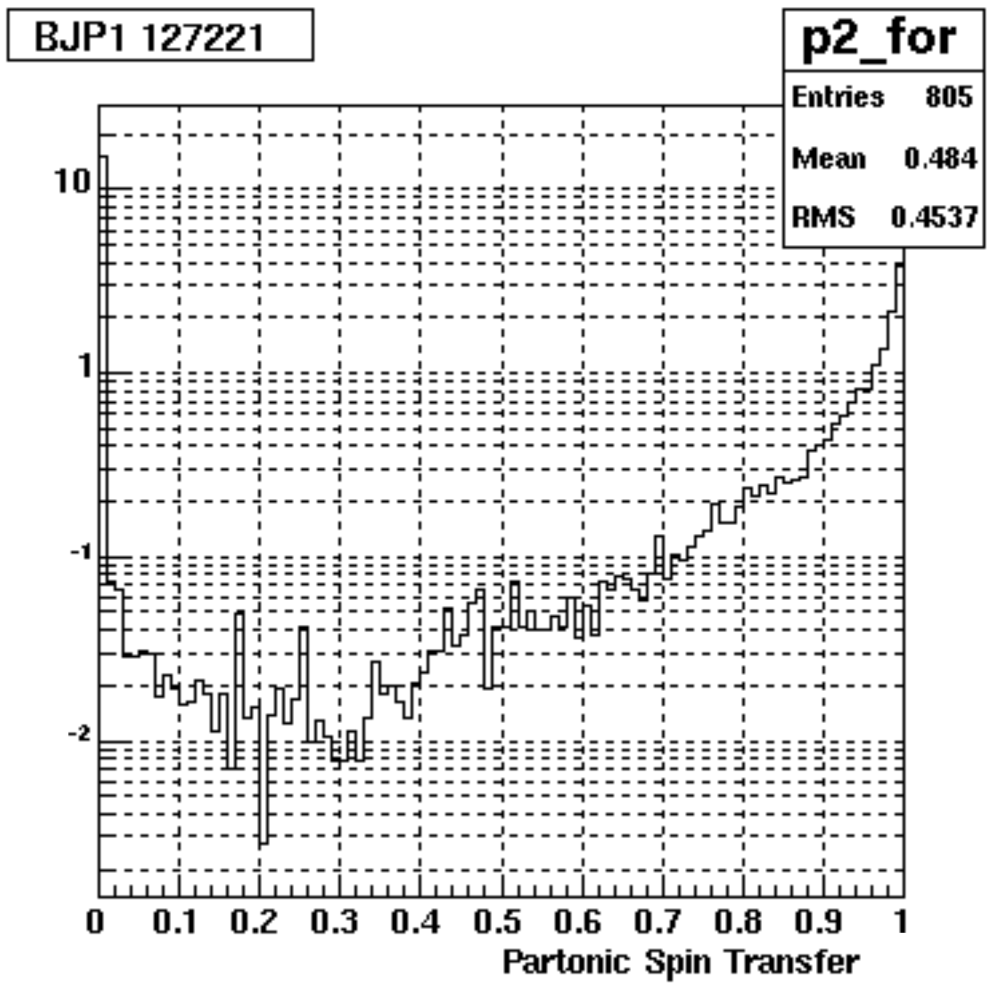

(GEANT + PYTHIA) simulation

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Collins, Sivers *fragmentation functions*

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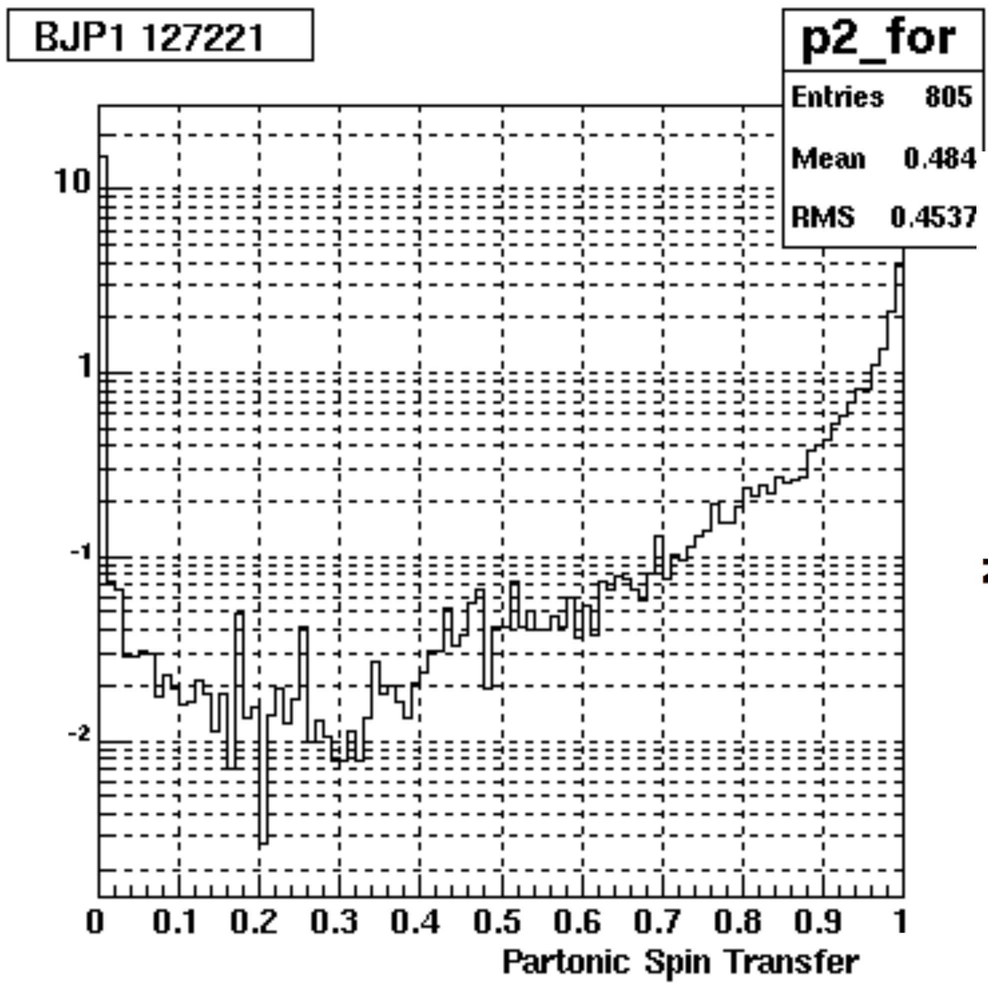

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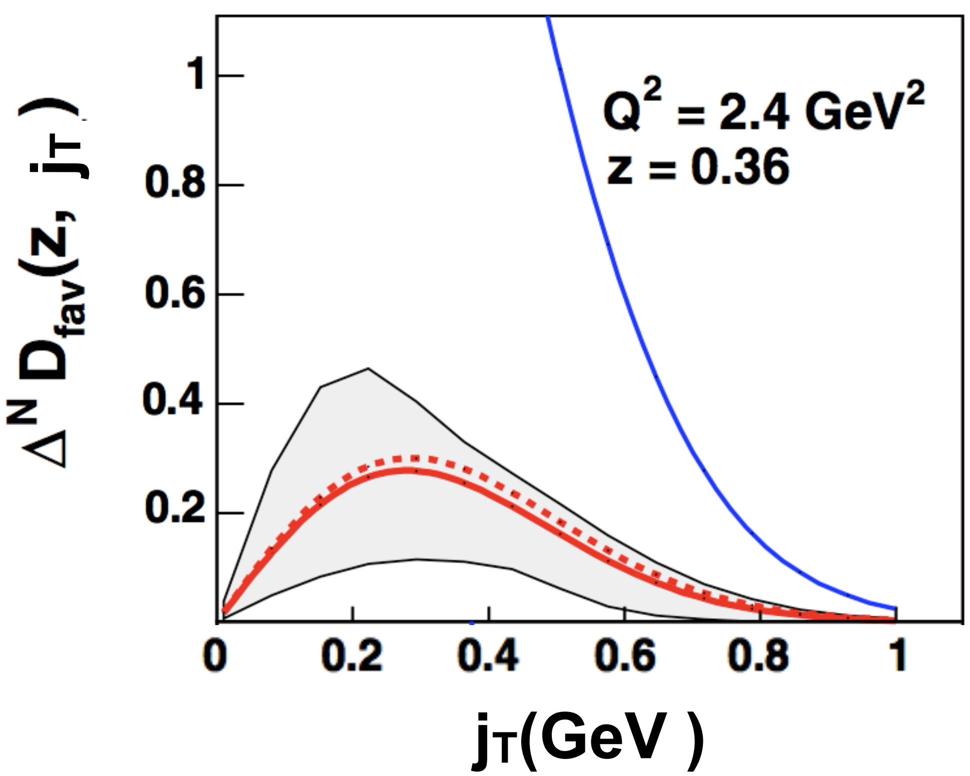

Isospin-favored Collins frag. function

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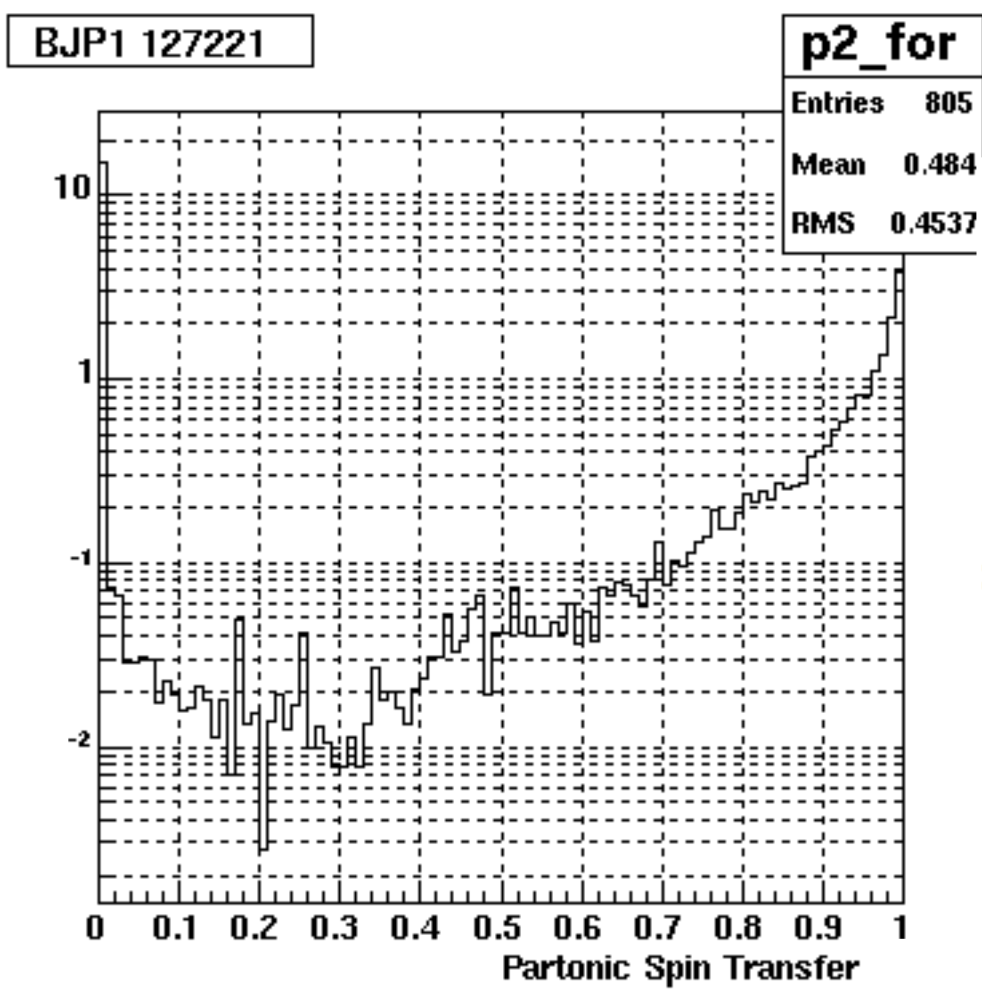

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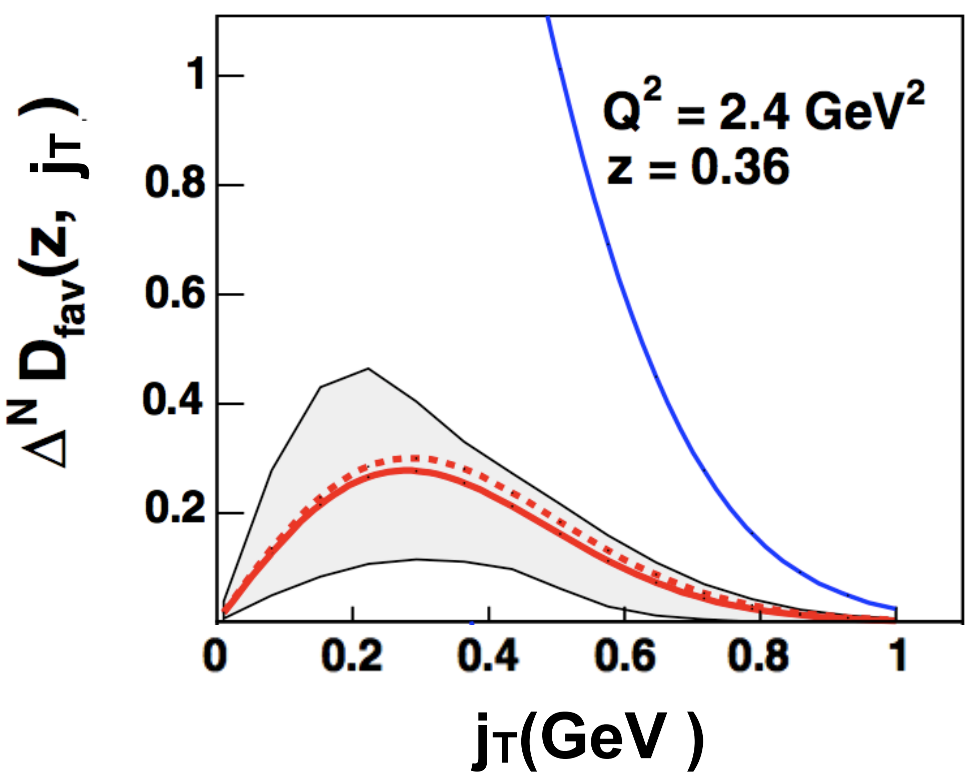

Extraction of Collins fragmentation function from fit to SIDIS data (HERMES, COMPASS) and Belle Collab. data (KEK)
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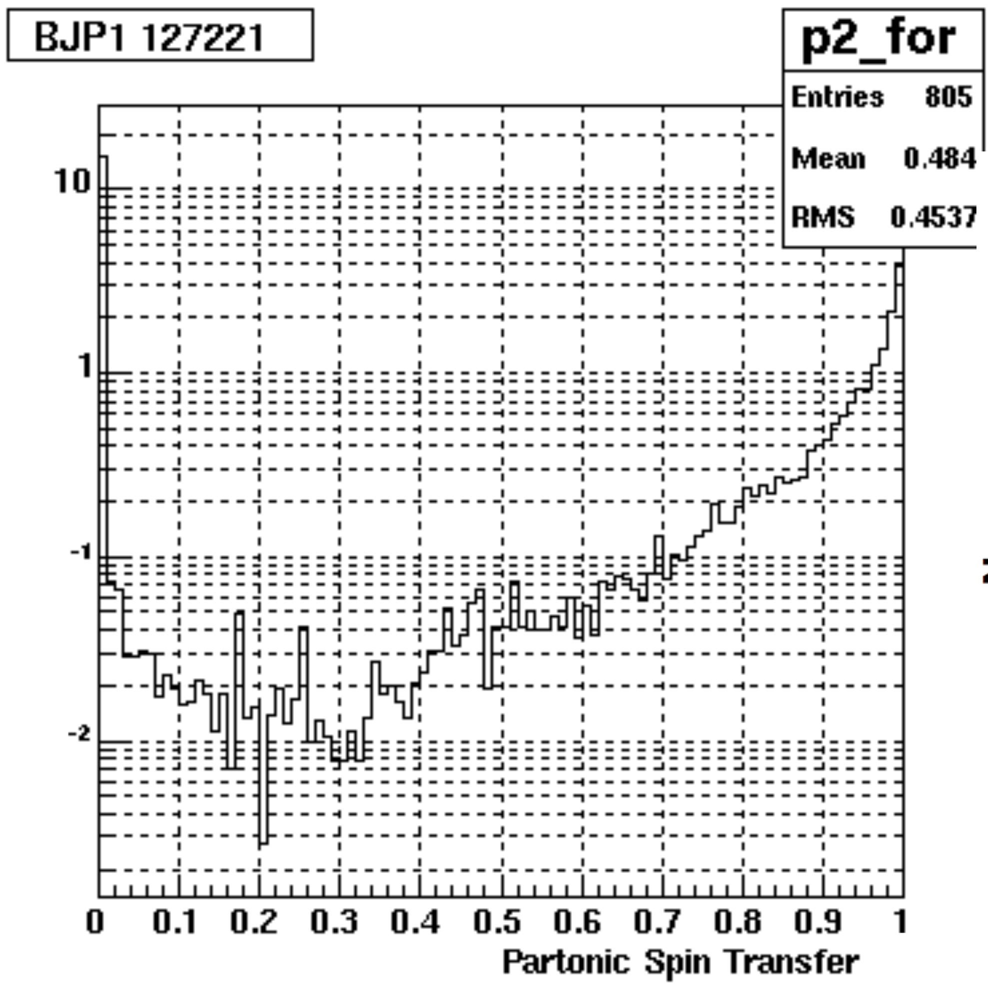

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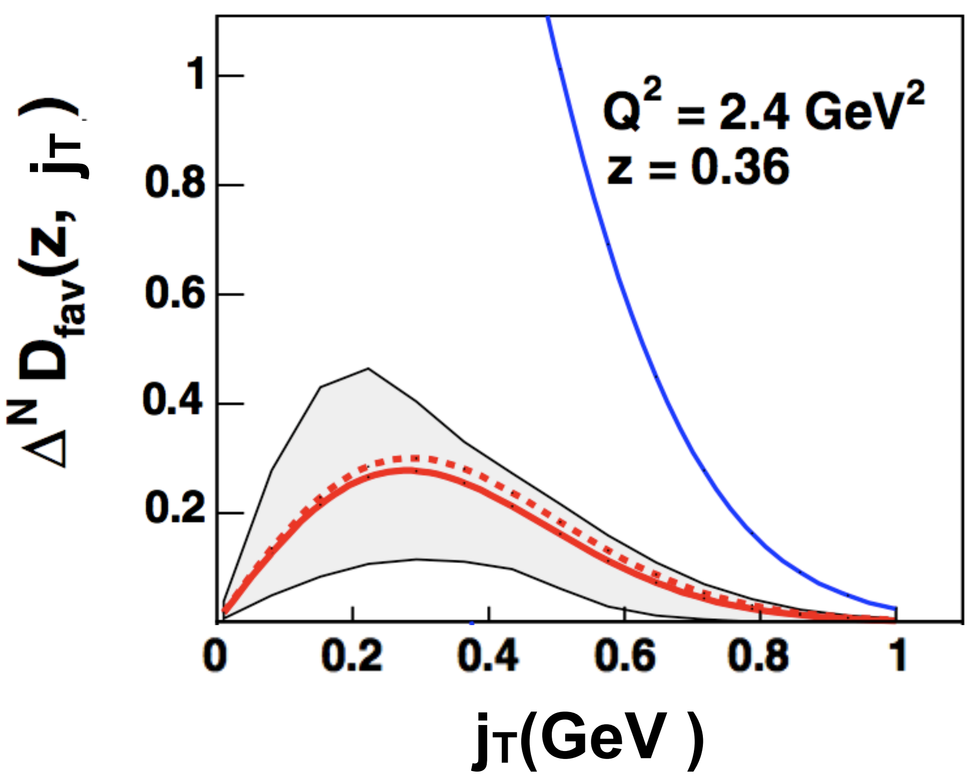

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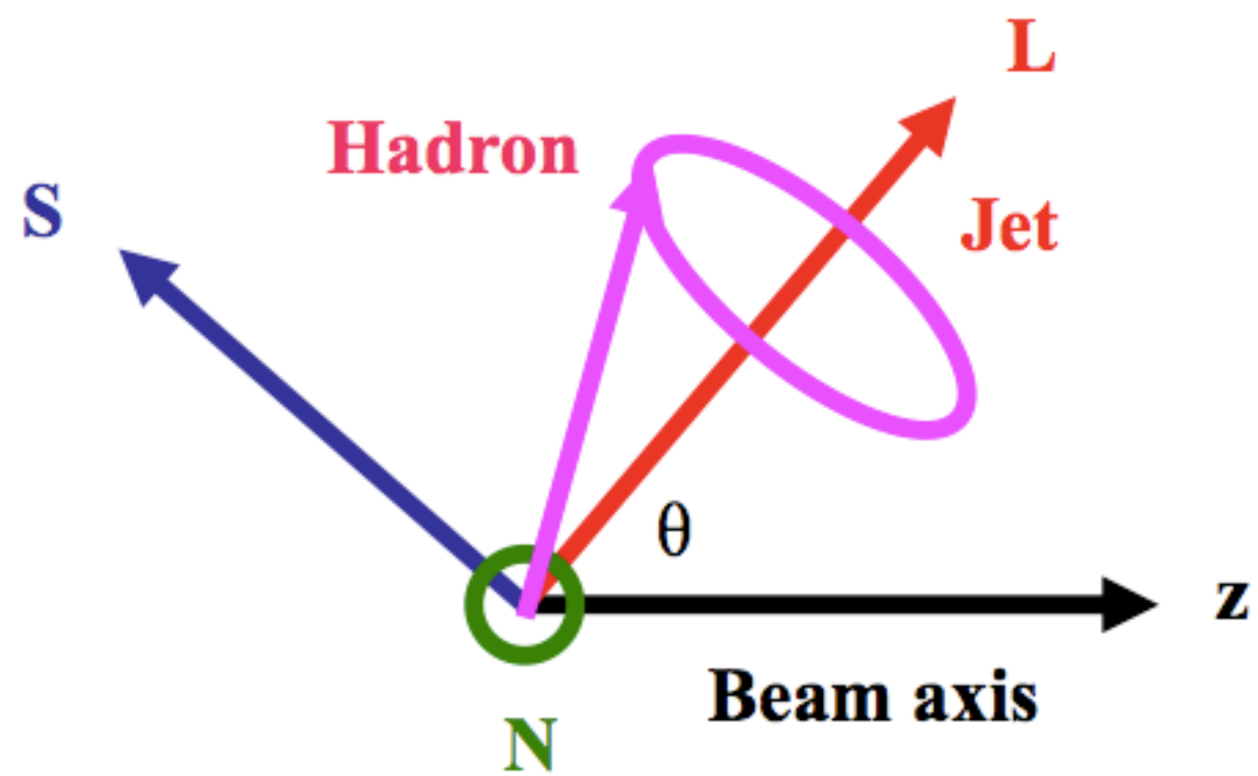
Isospin-favored Collins frag. function

Prediction (estimate): $A\ (\pi^\pm) \approx \pm 0.03$

The Collins Asymmetry

The Collins Asymmetry

Φ_π is defined in NLS coordinates



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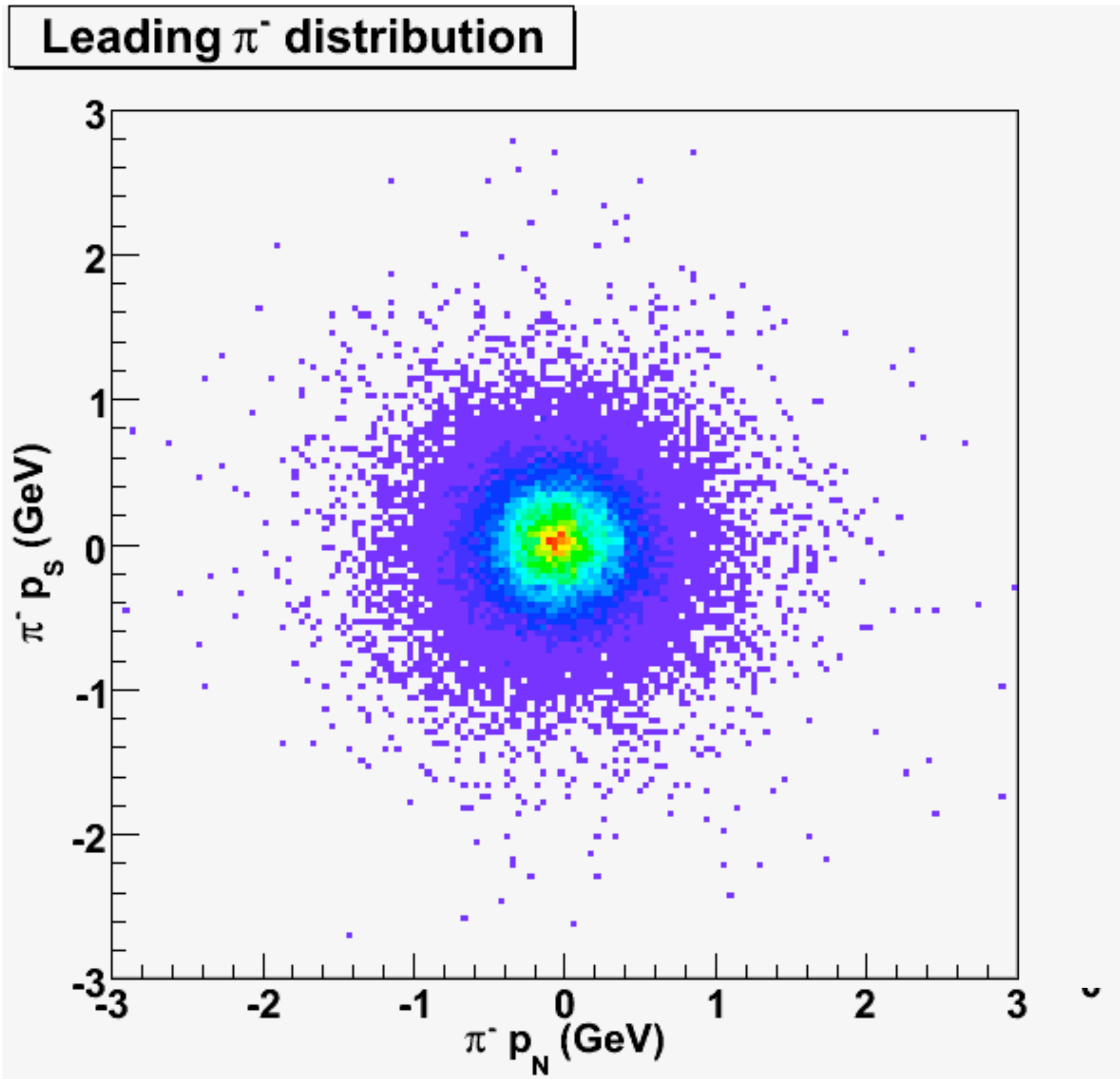

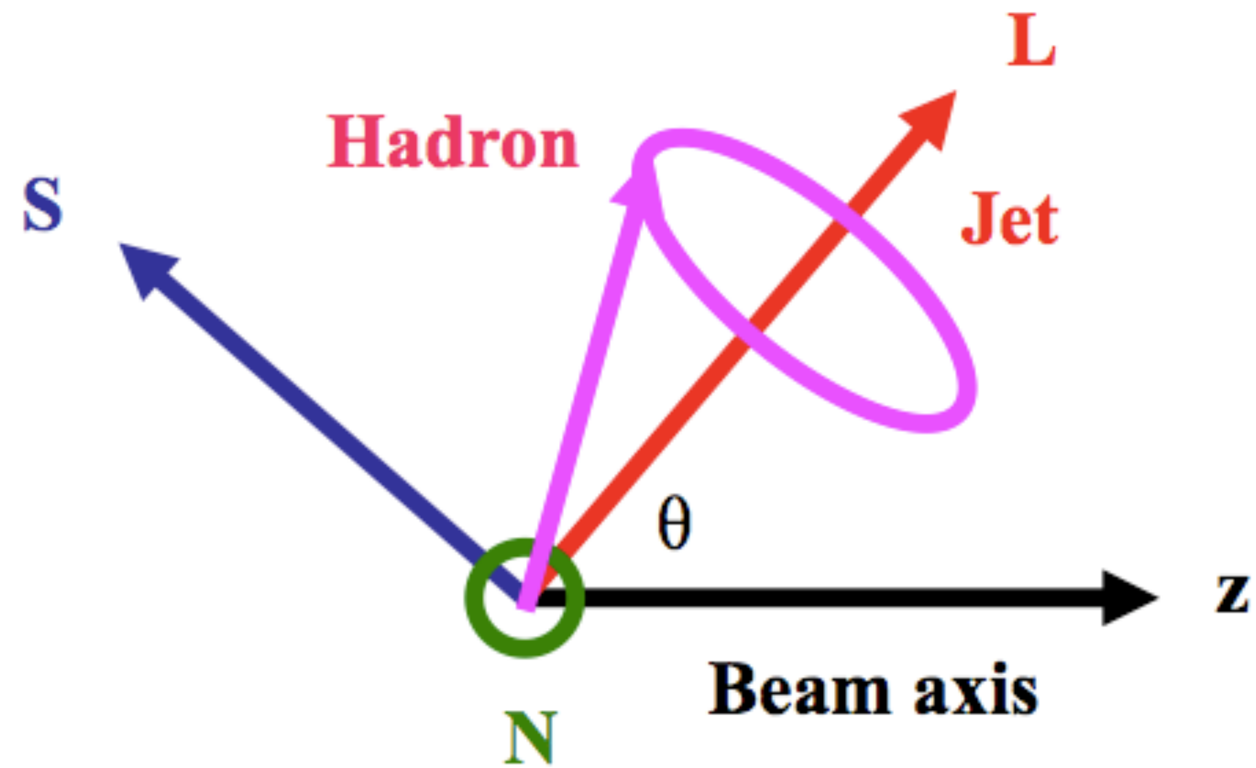

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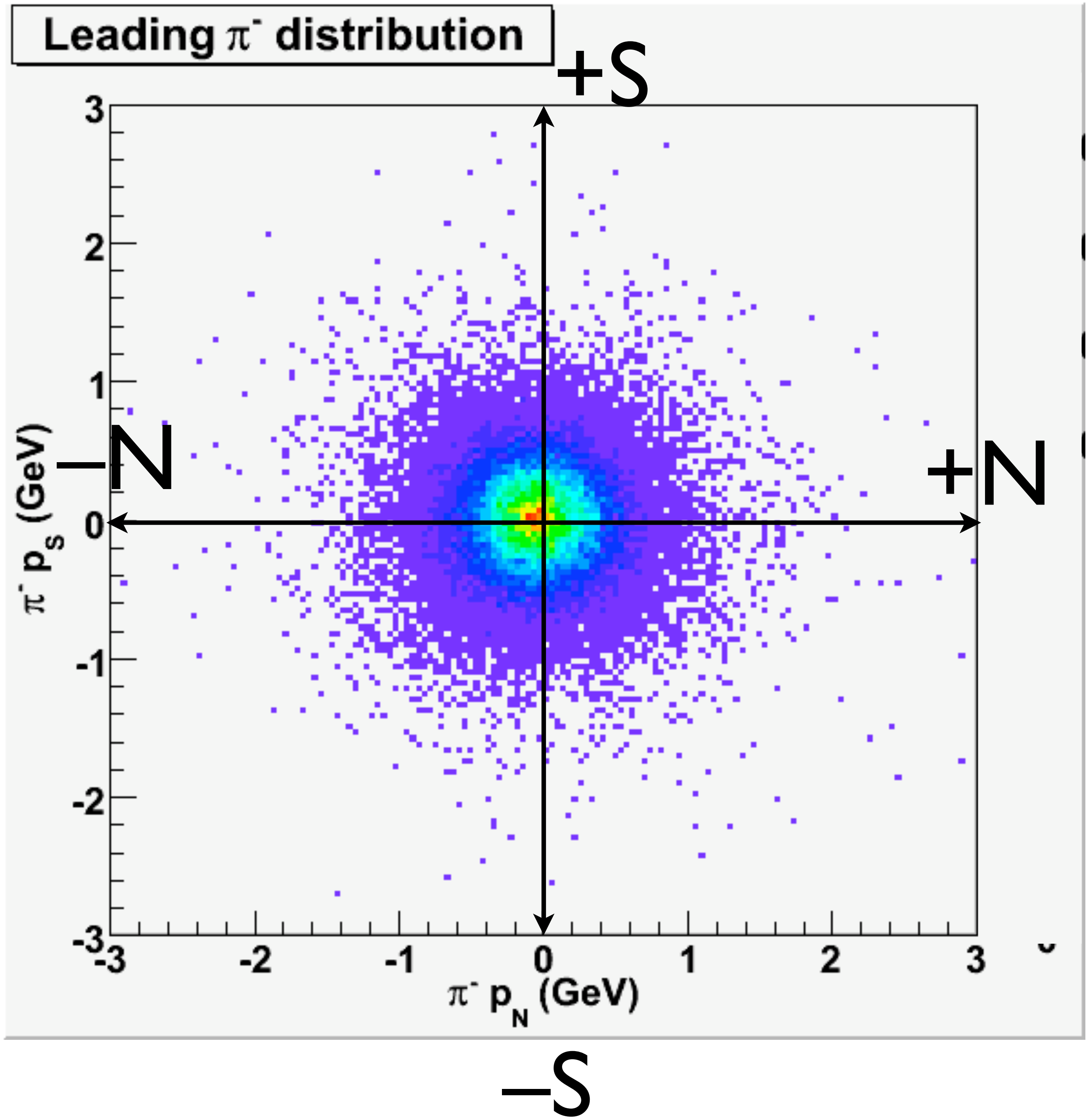

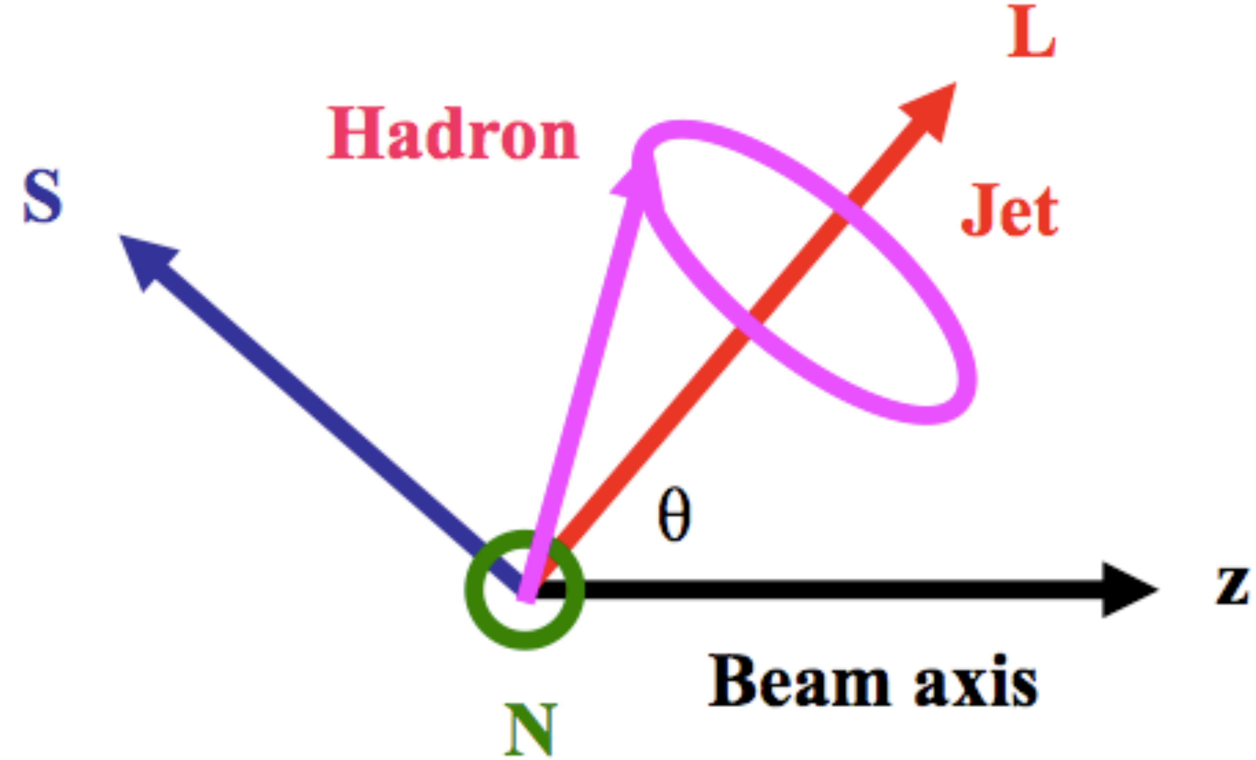

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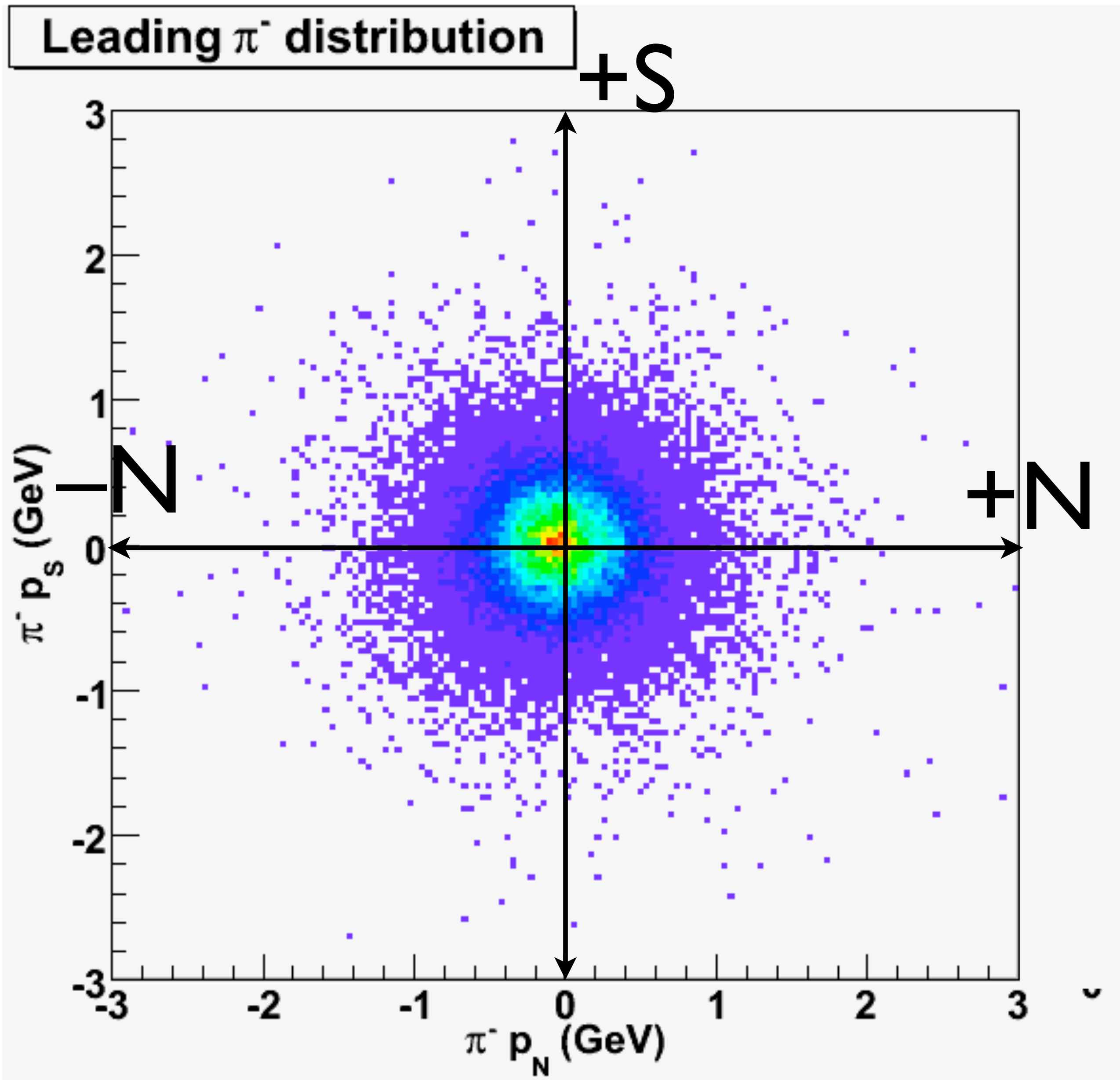

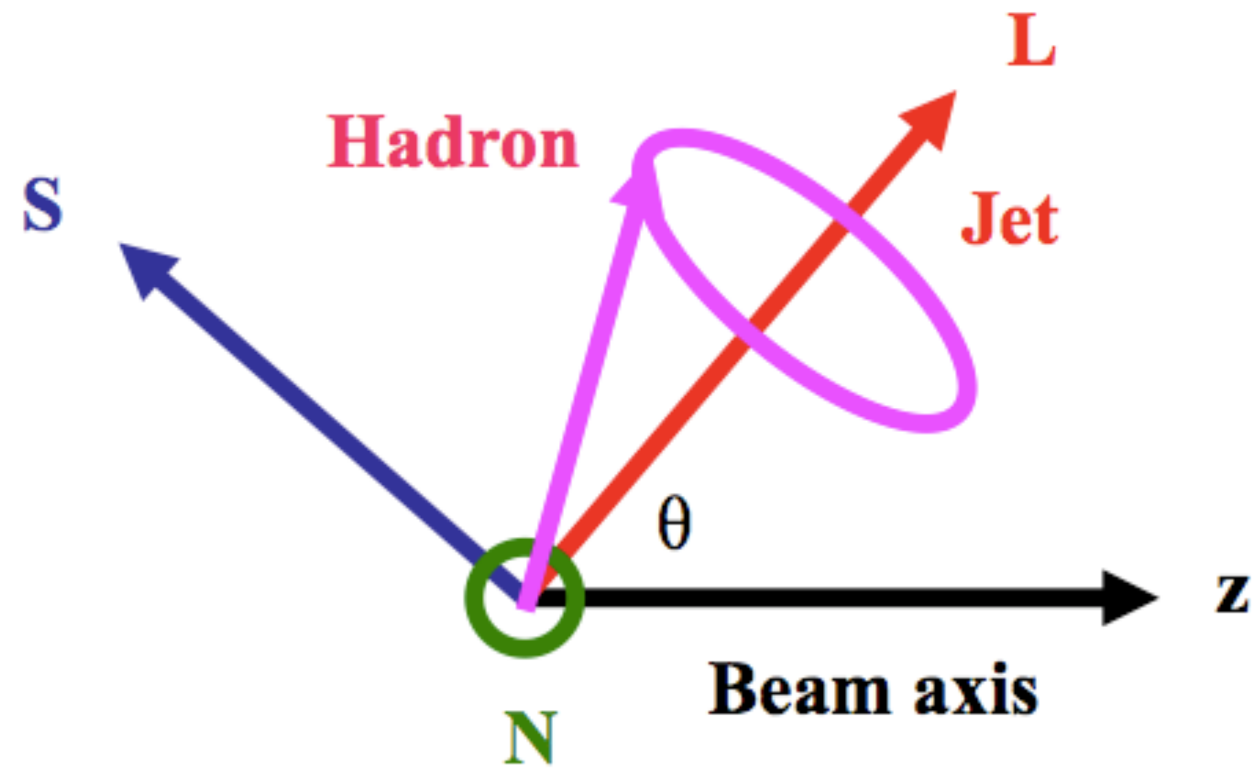

(L is 3rd axis; L = S × N)

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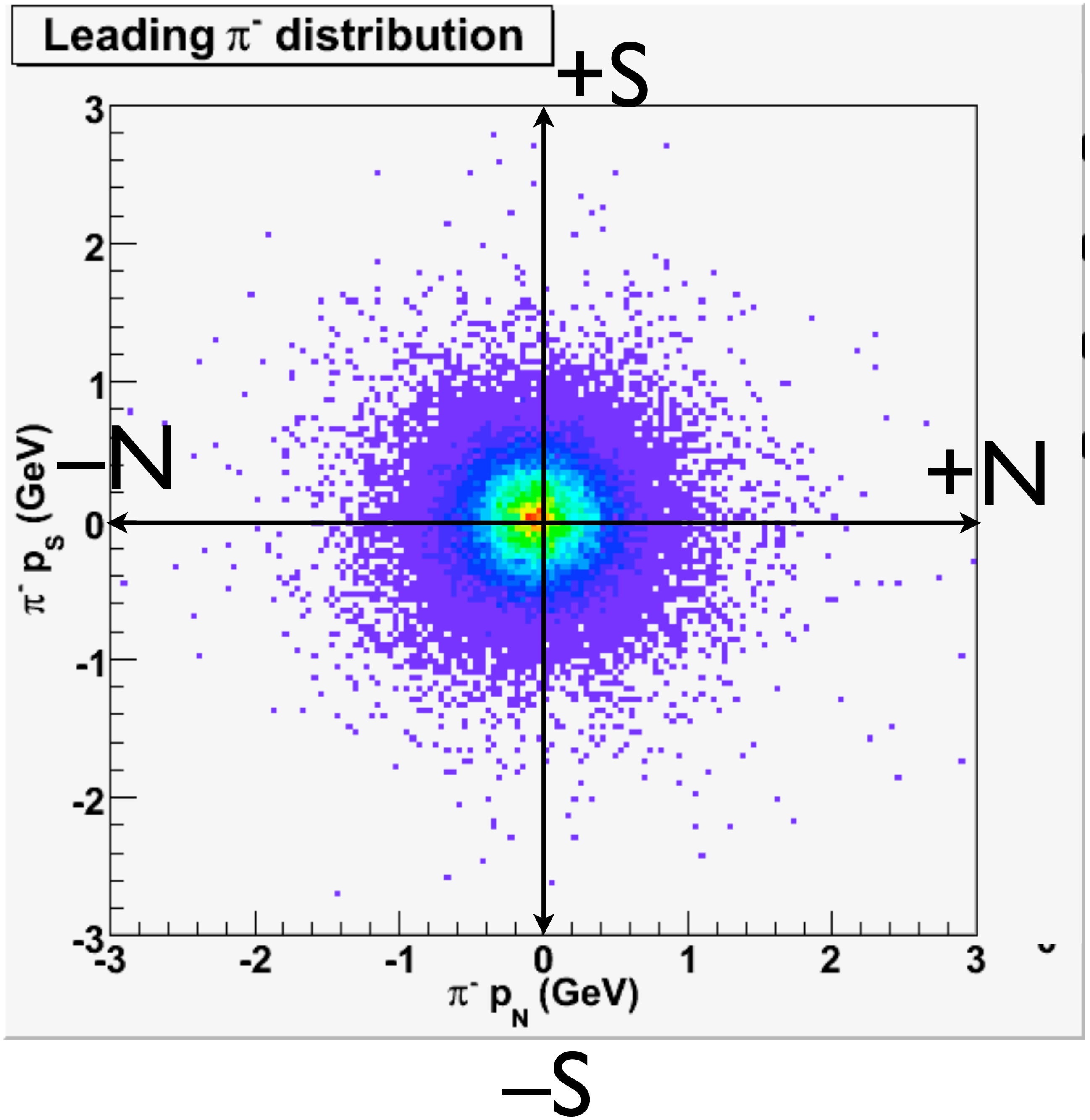

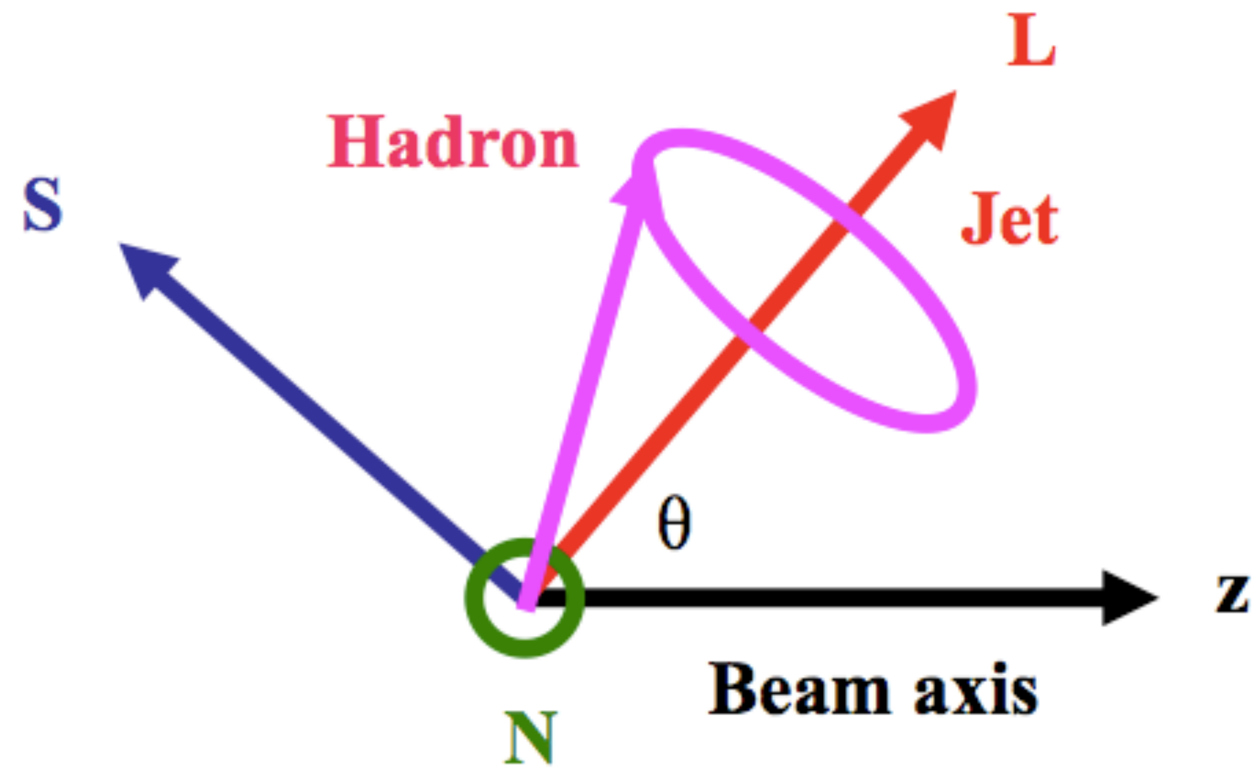

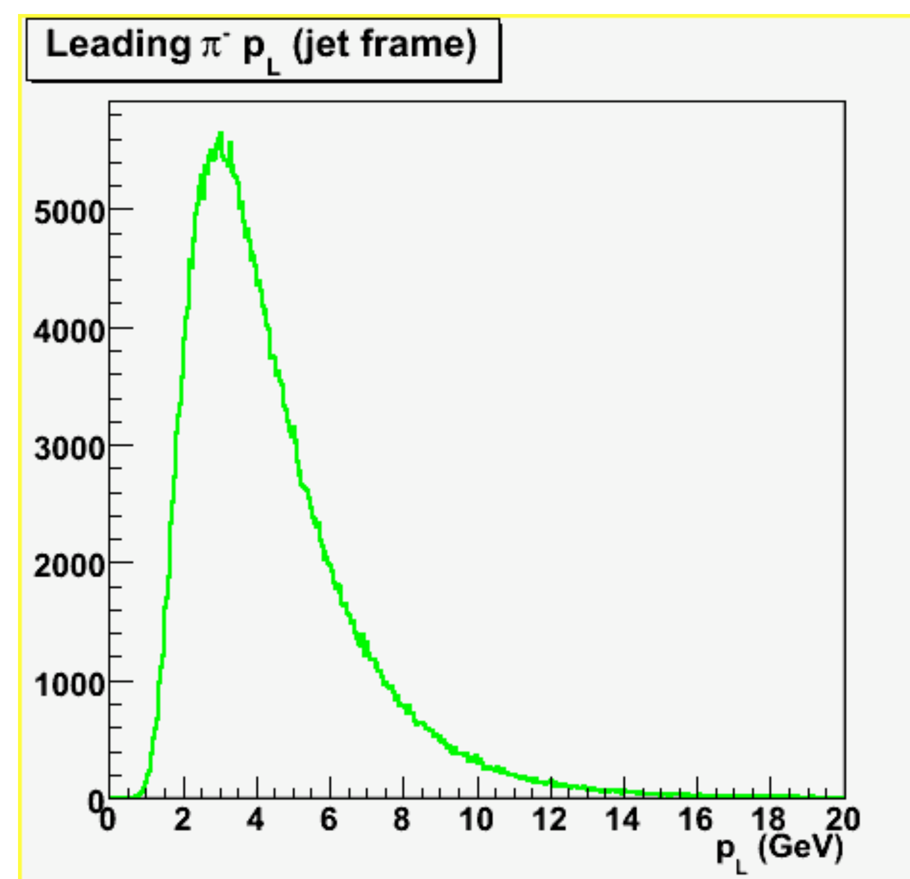

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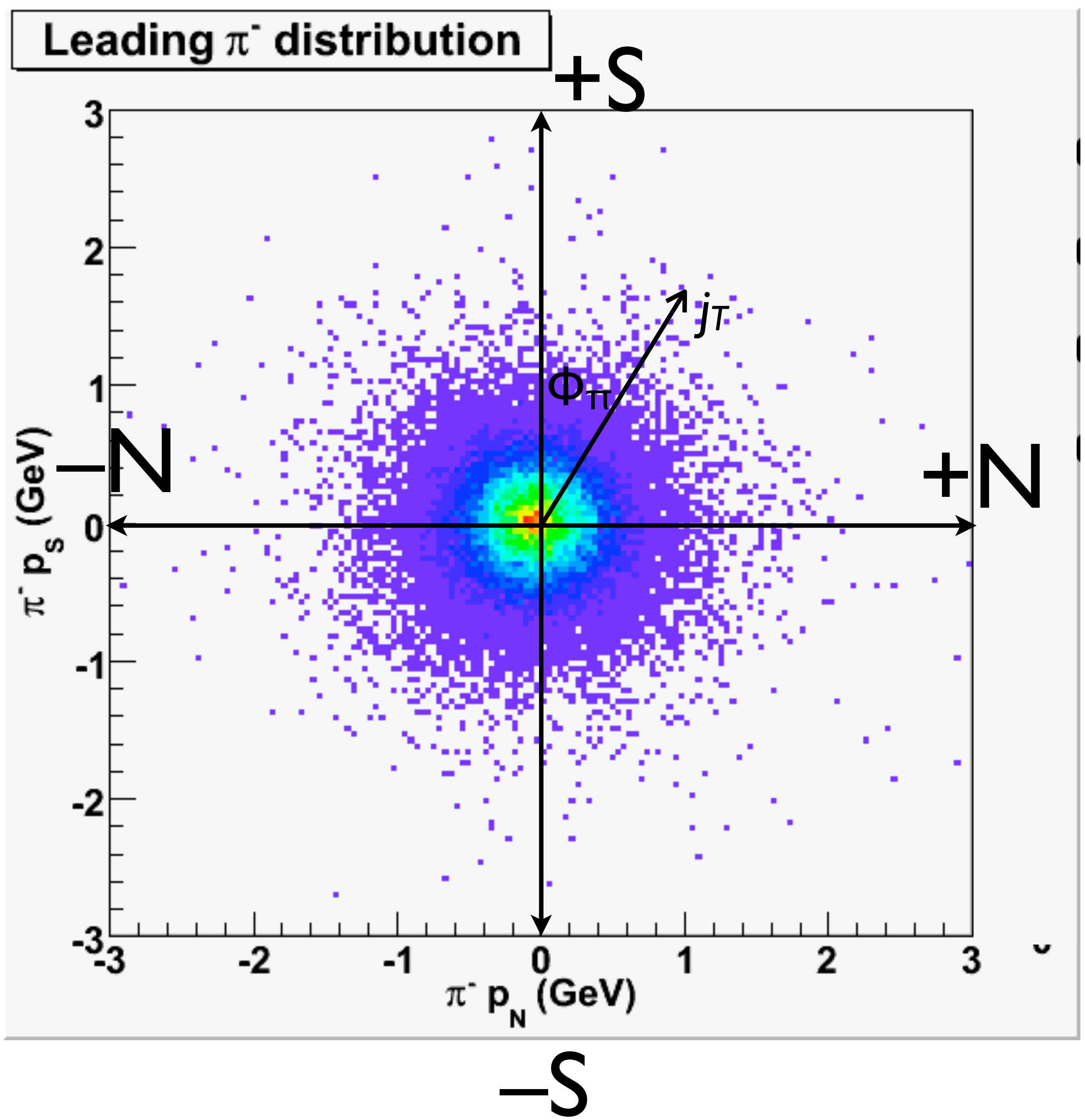

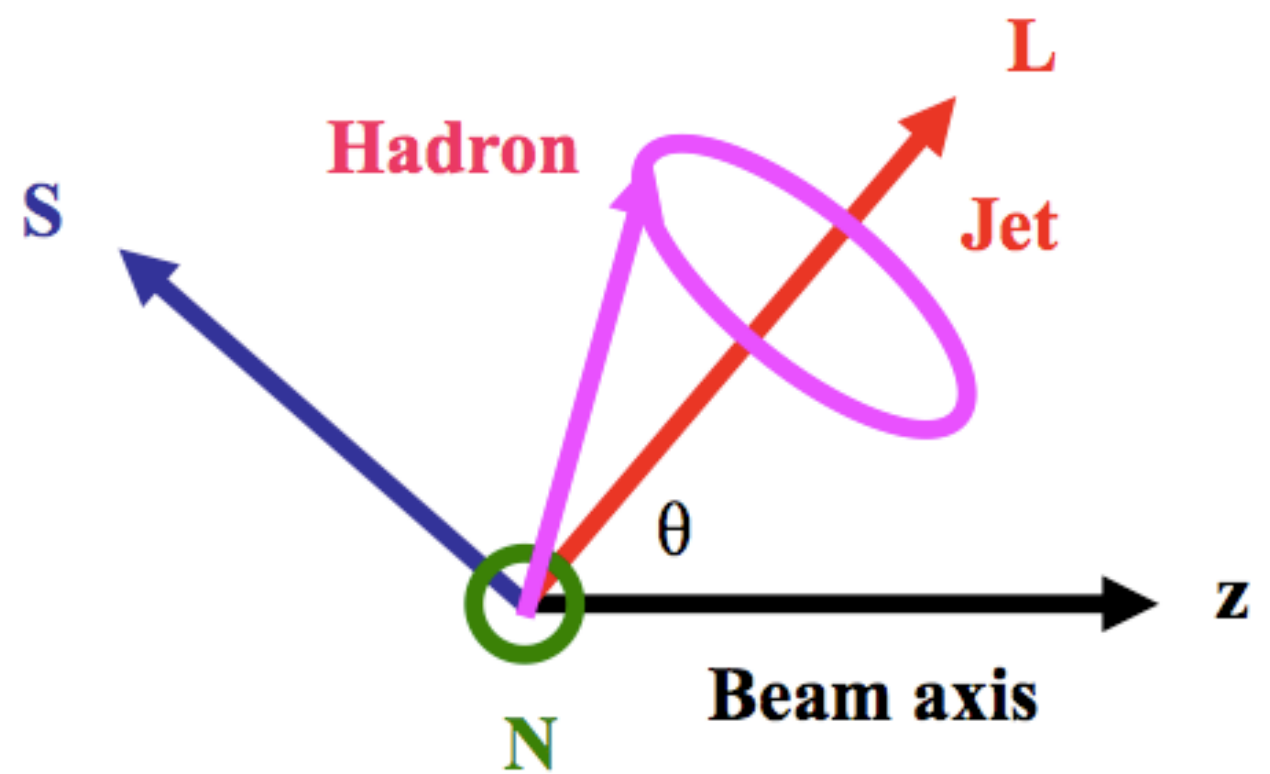

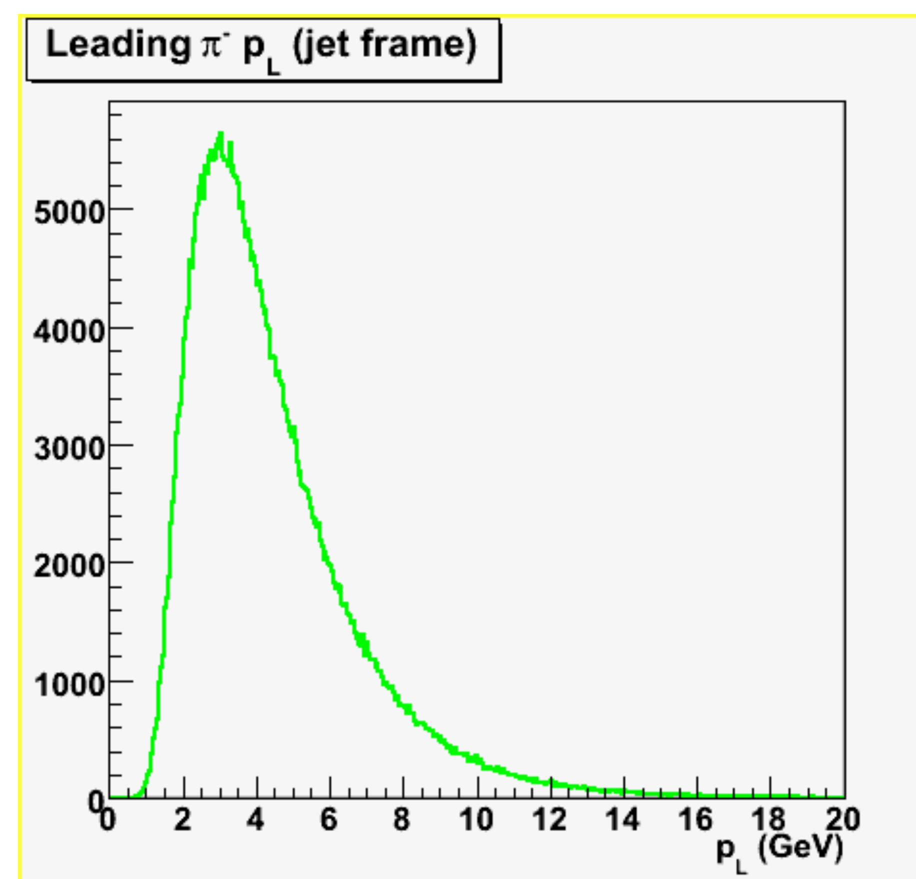

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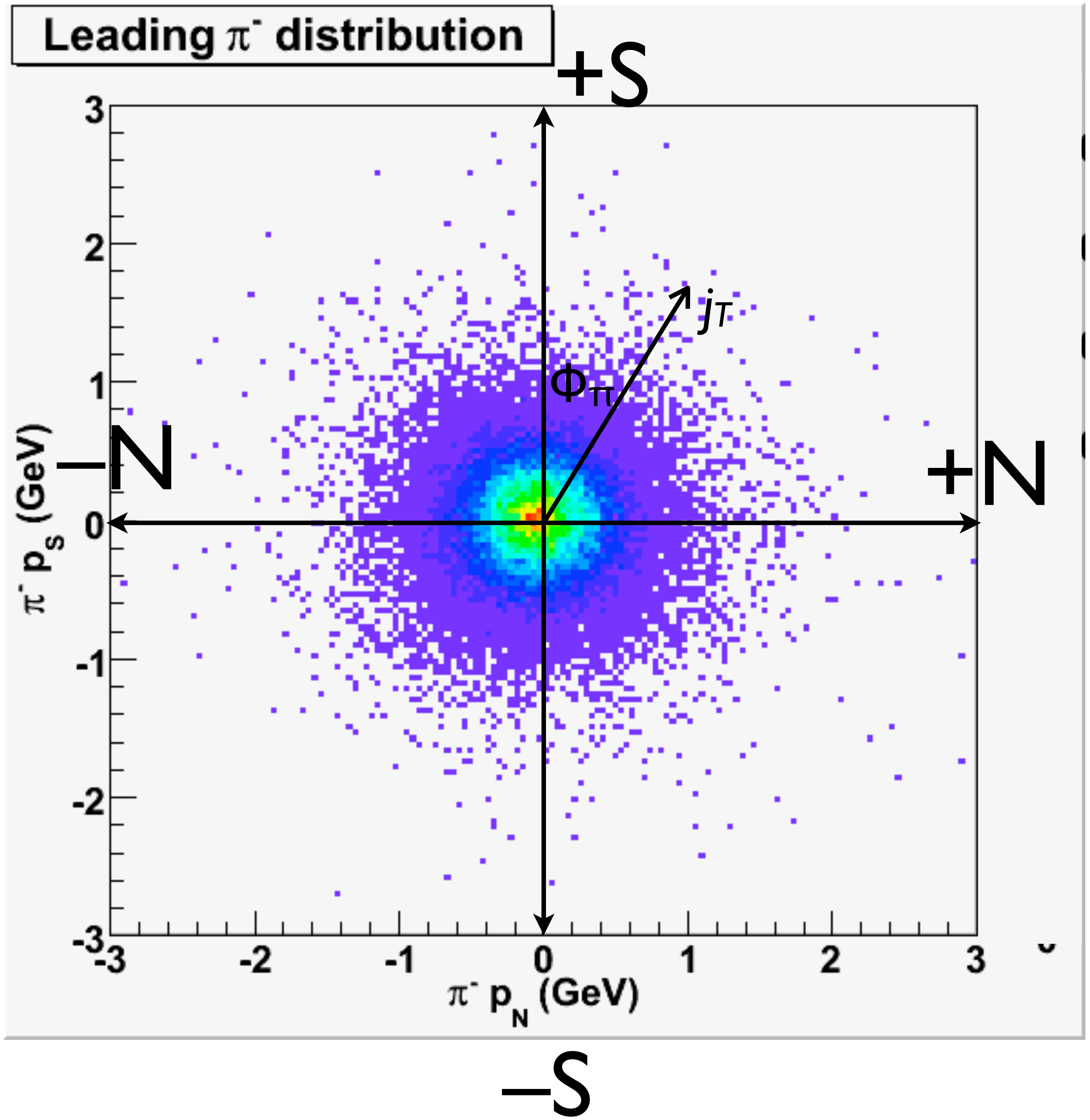

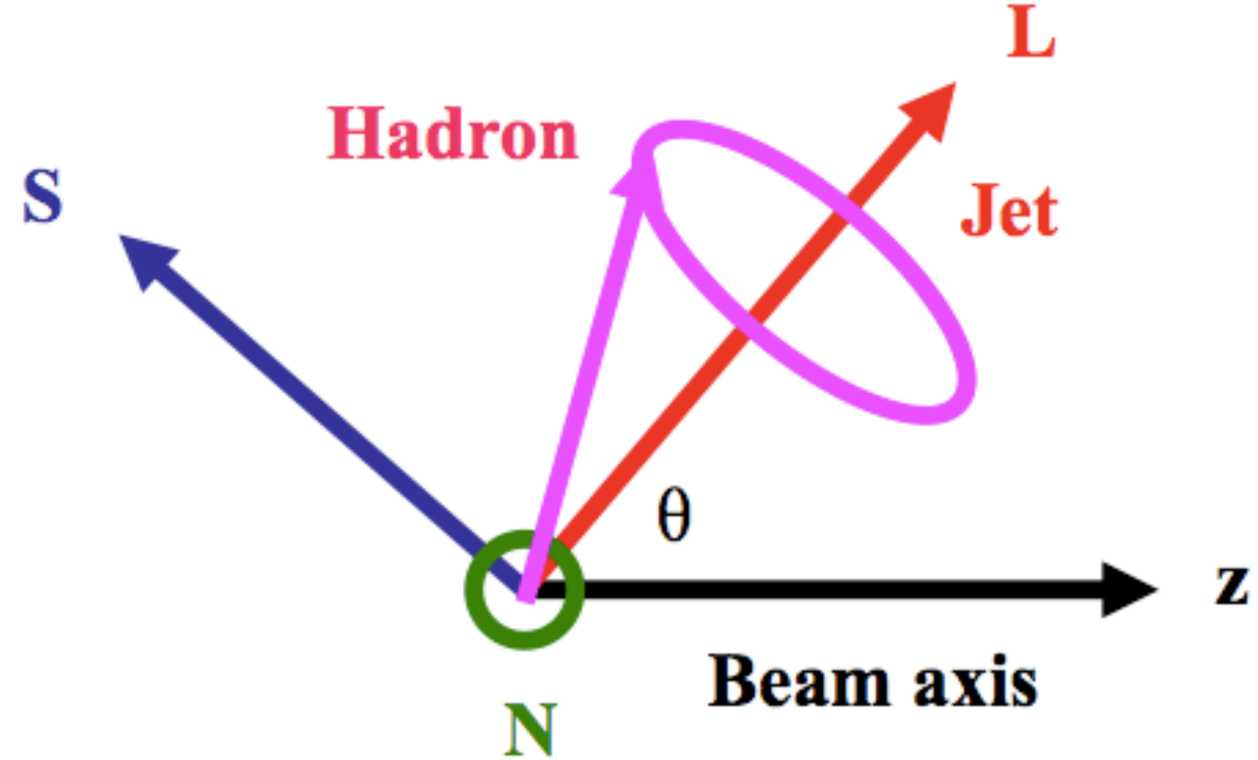

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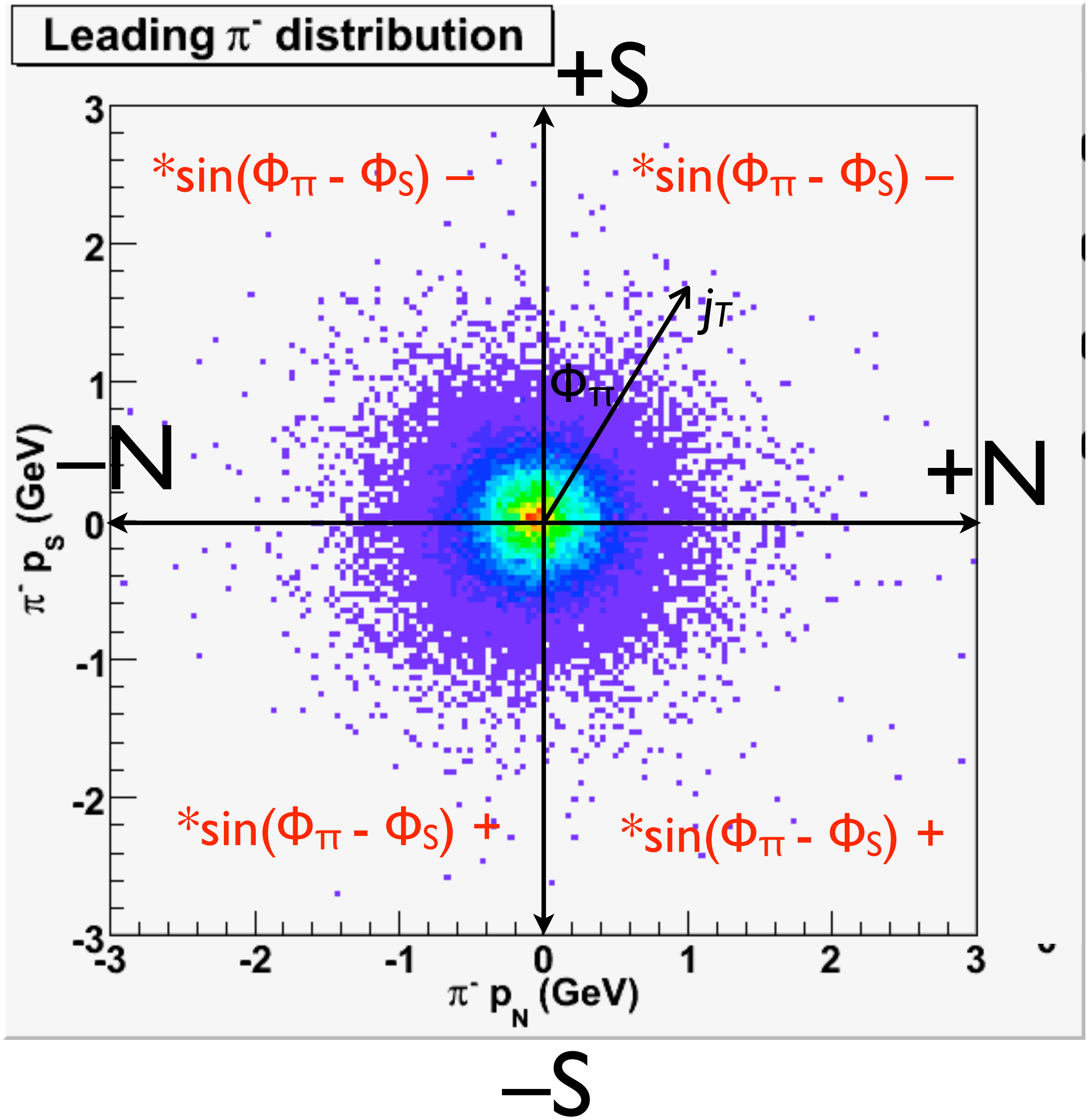

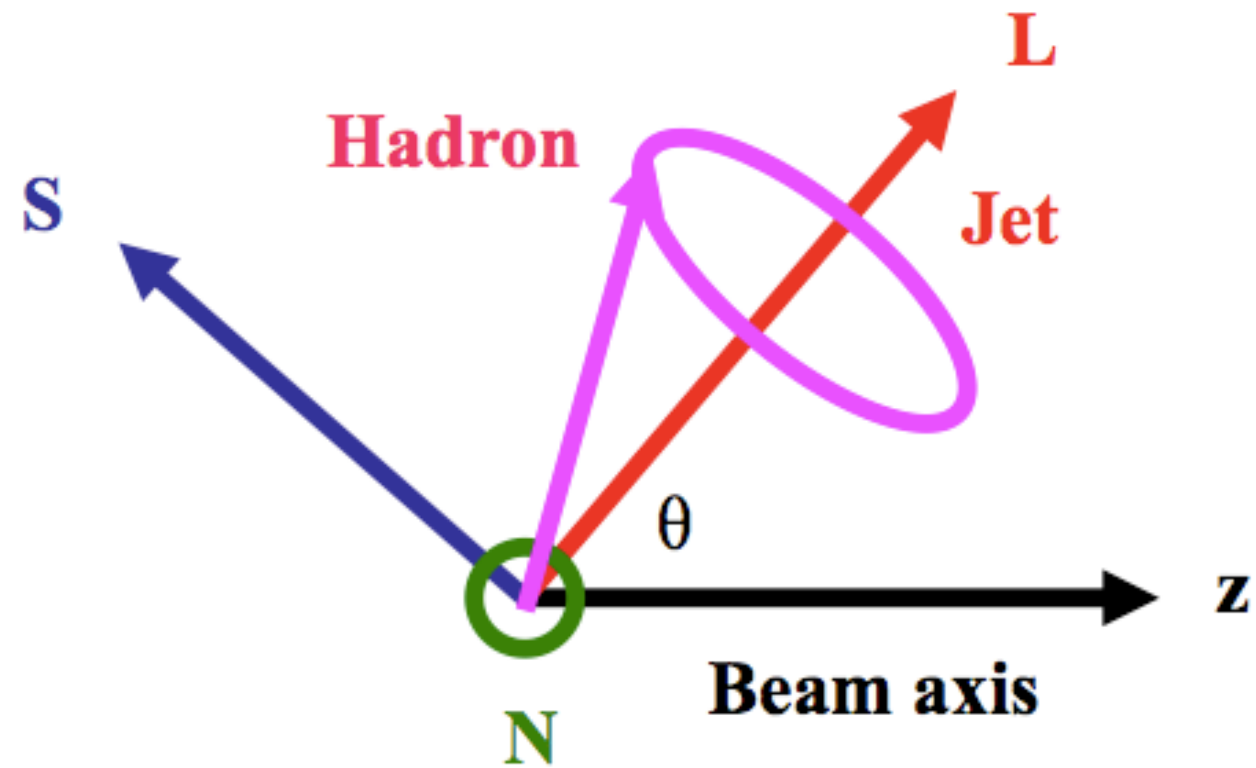

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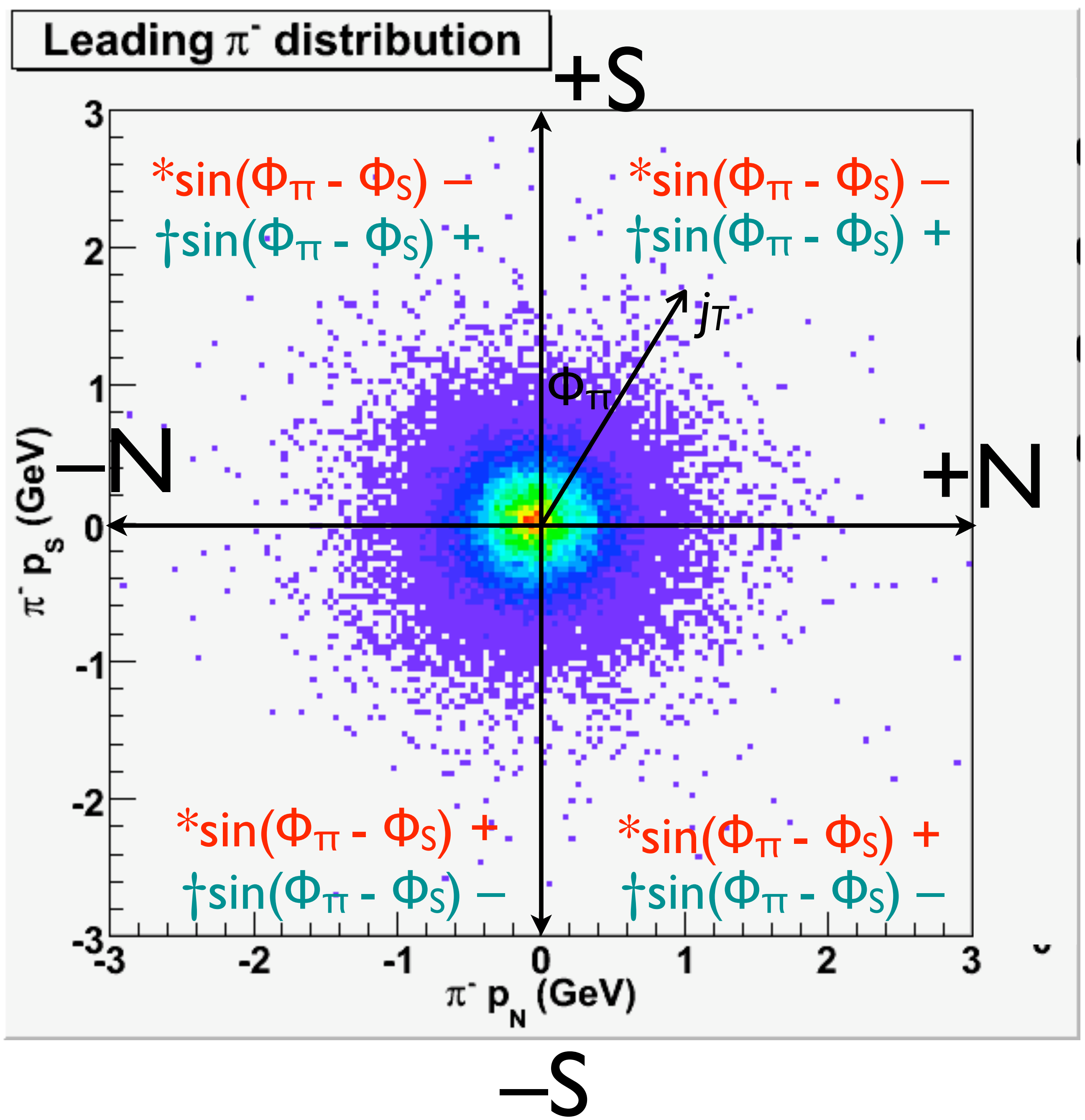

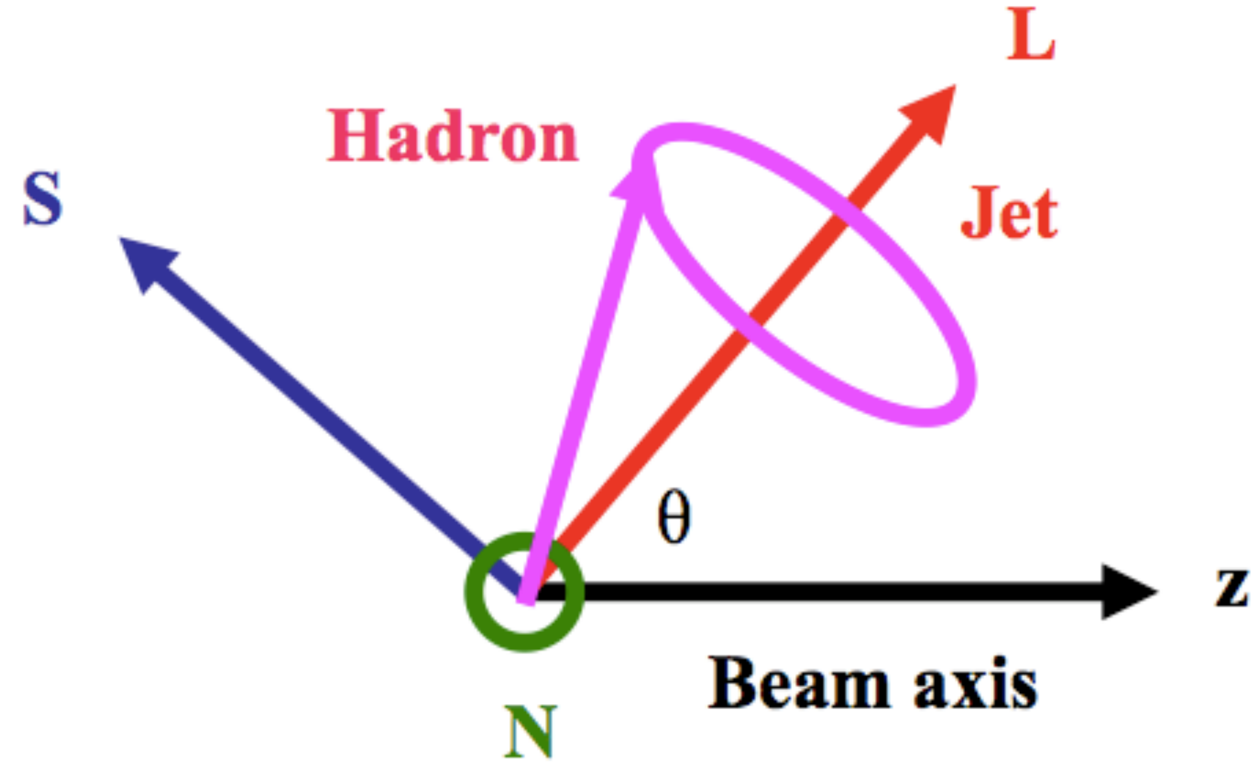

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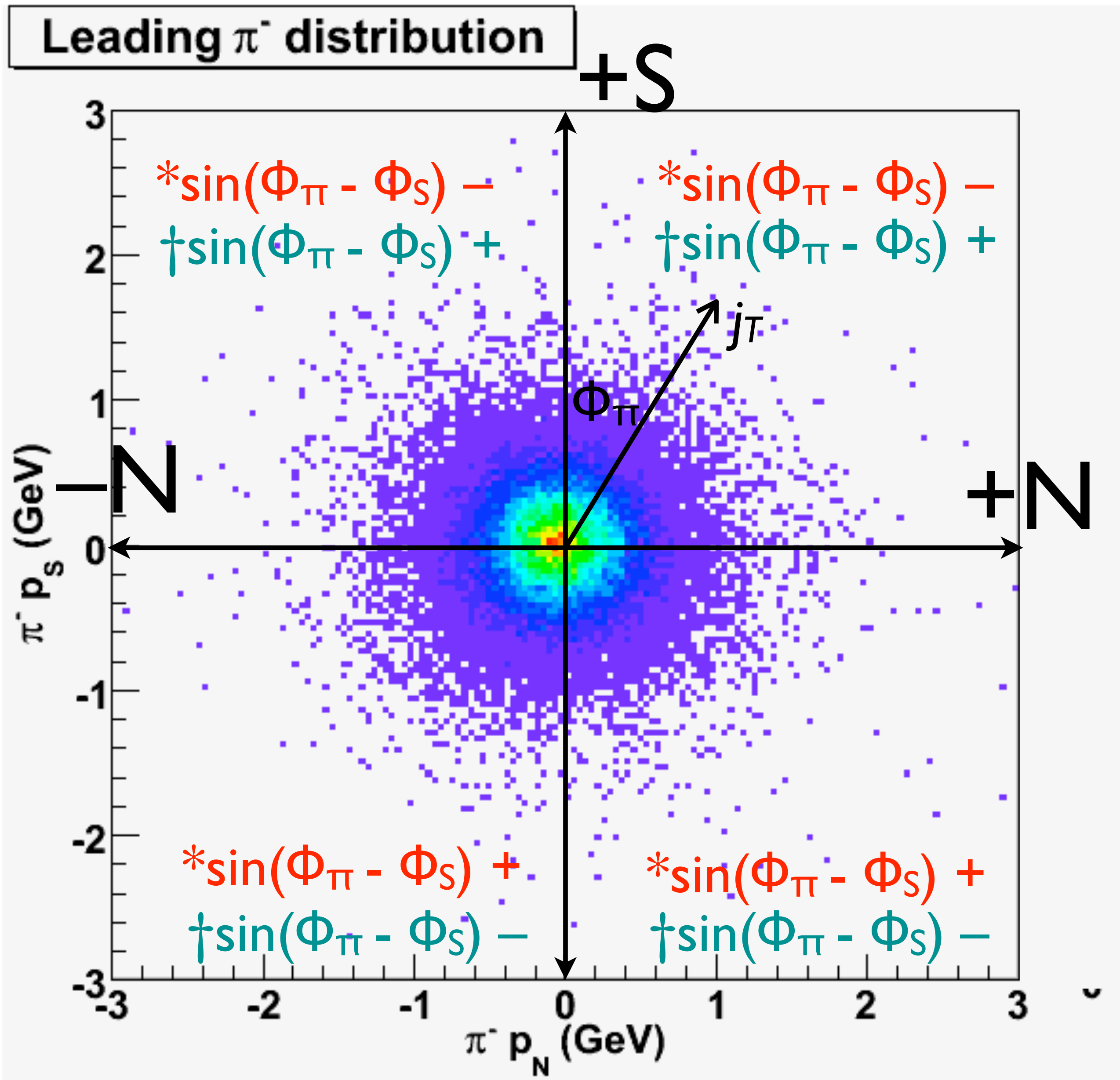

–S

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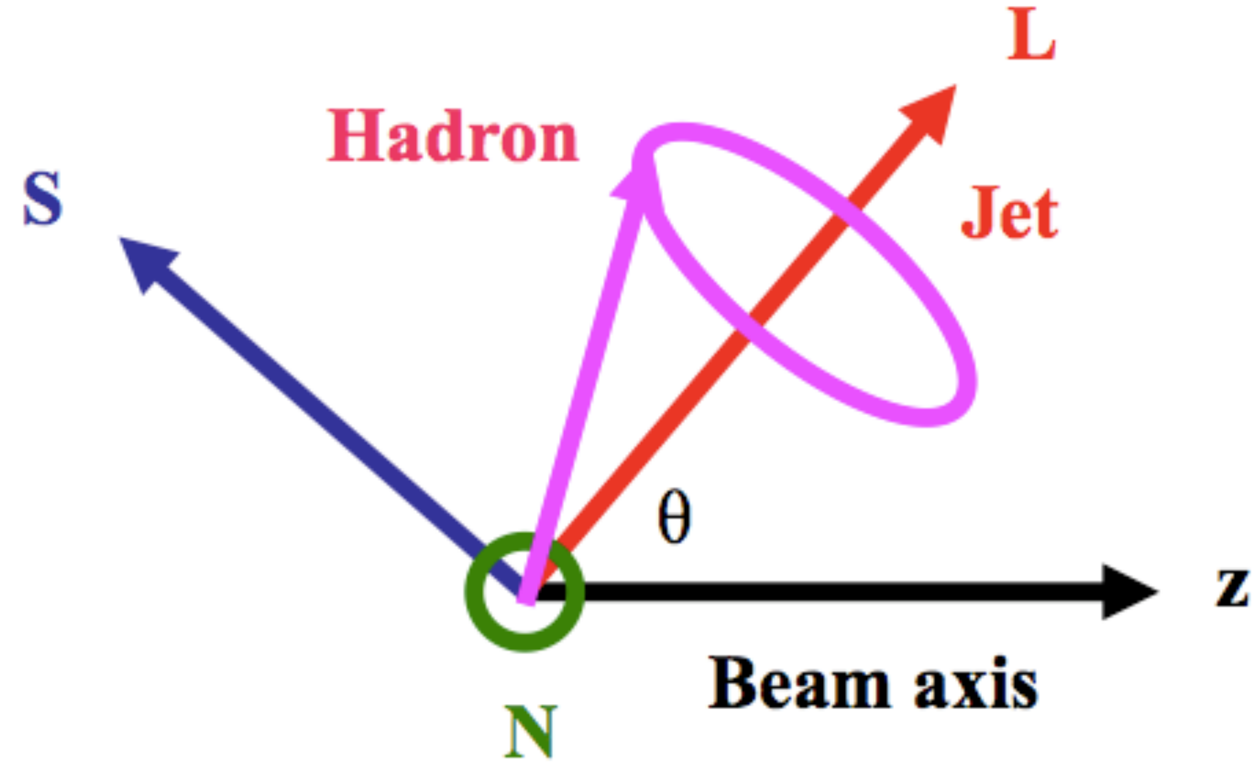

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Geometry dictates these cancel along the N-axis; leaving a possible top-bottom asymmetry *A* along the S-axis

Data analyzed separately for blue and yellow beams in forward hemisphere only:

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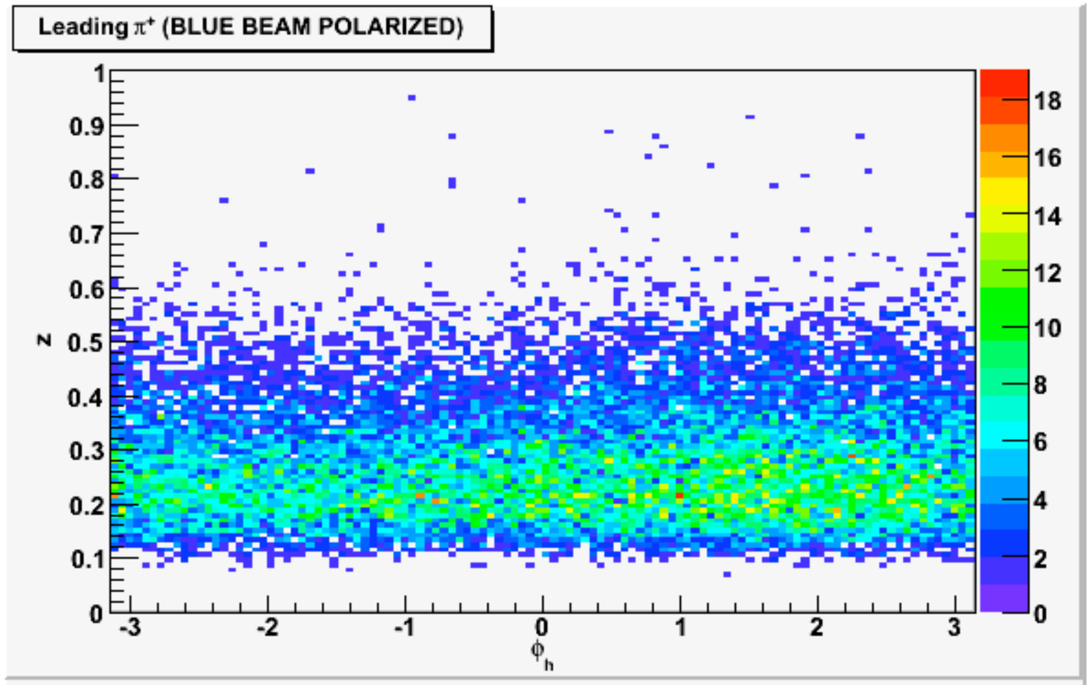
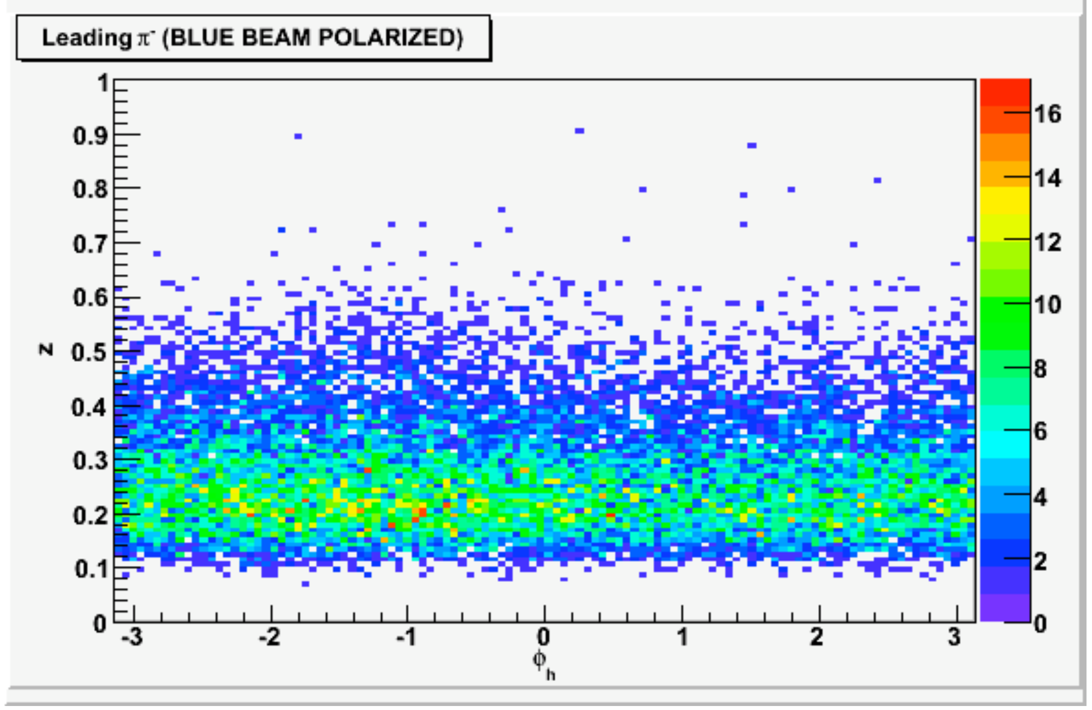
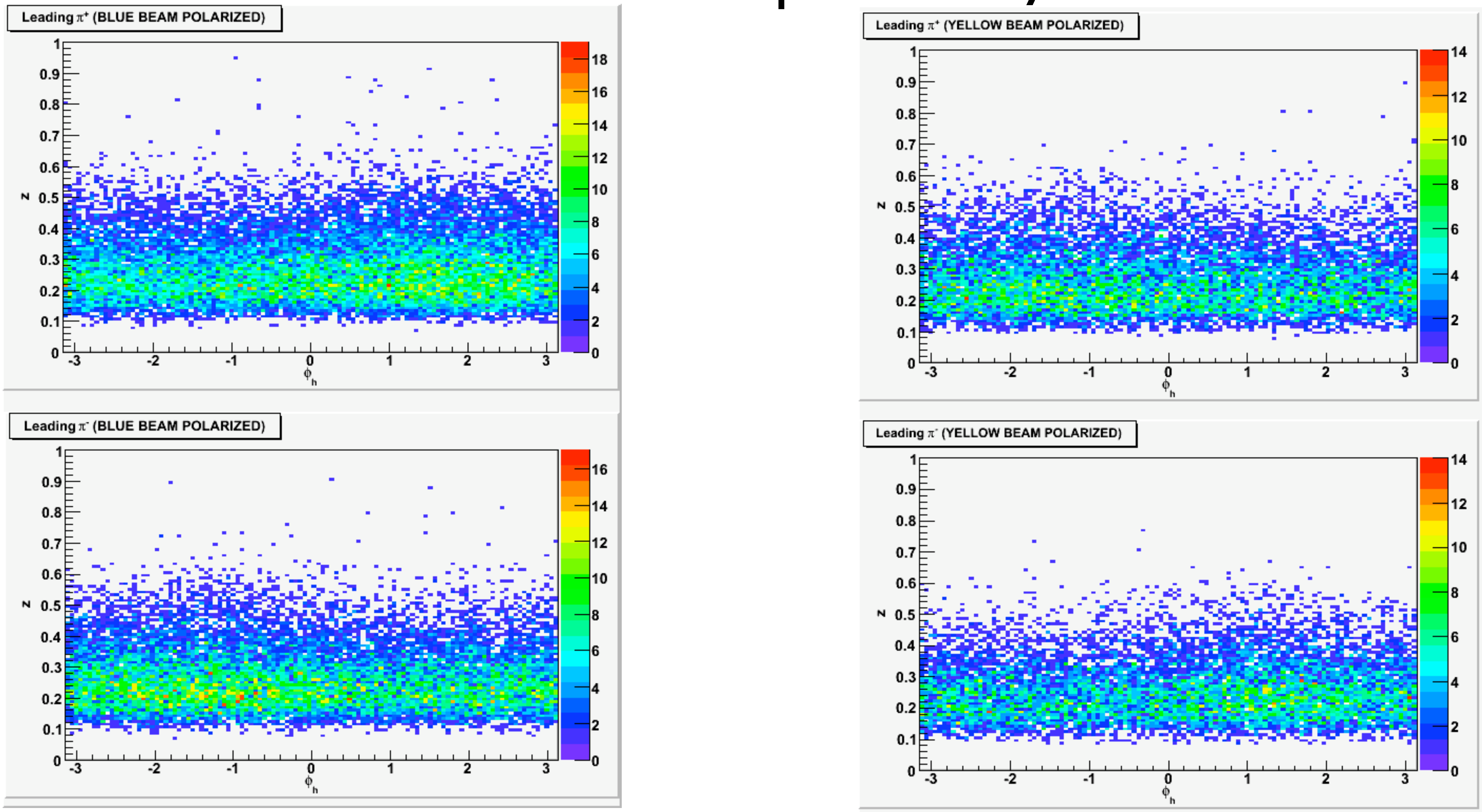




Data analyzed separately for blue and yellow beams in forward hemisphere only:



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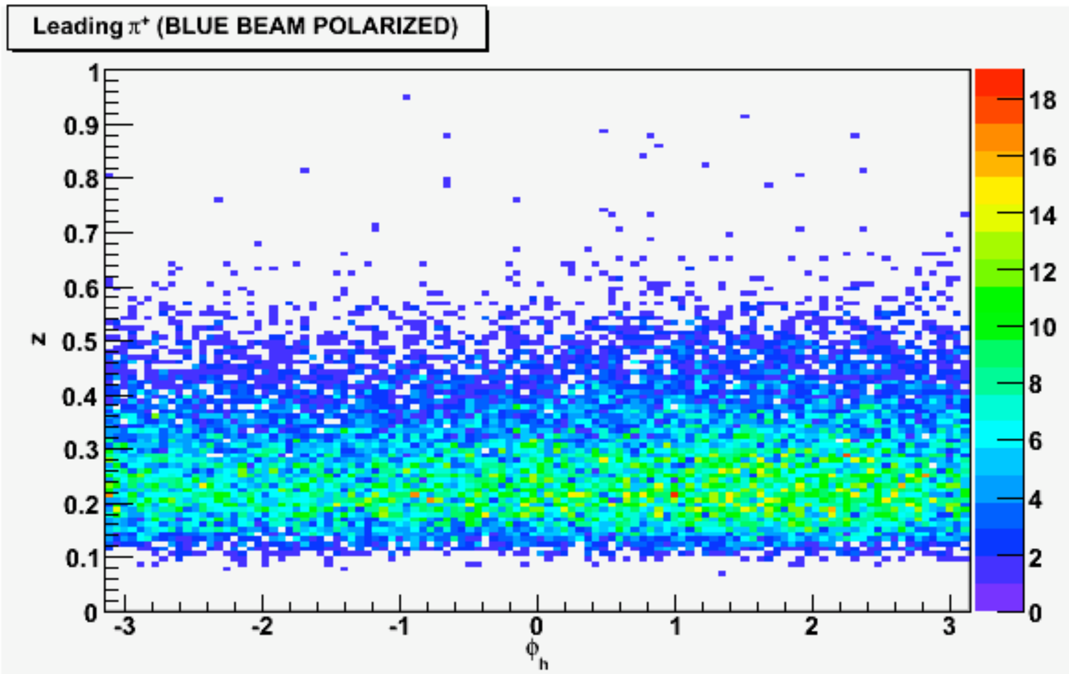
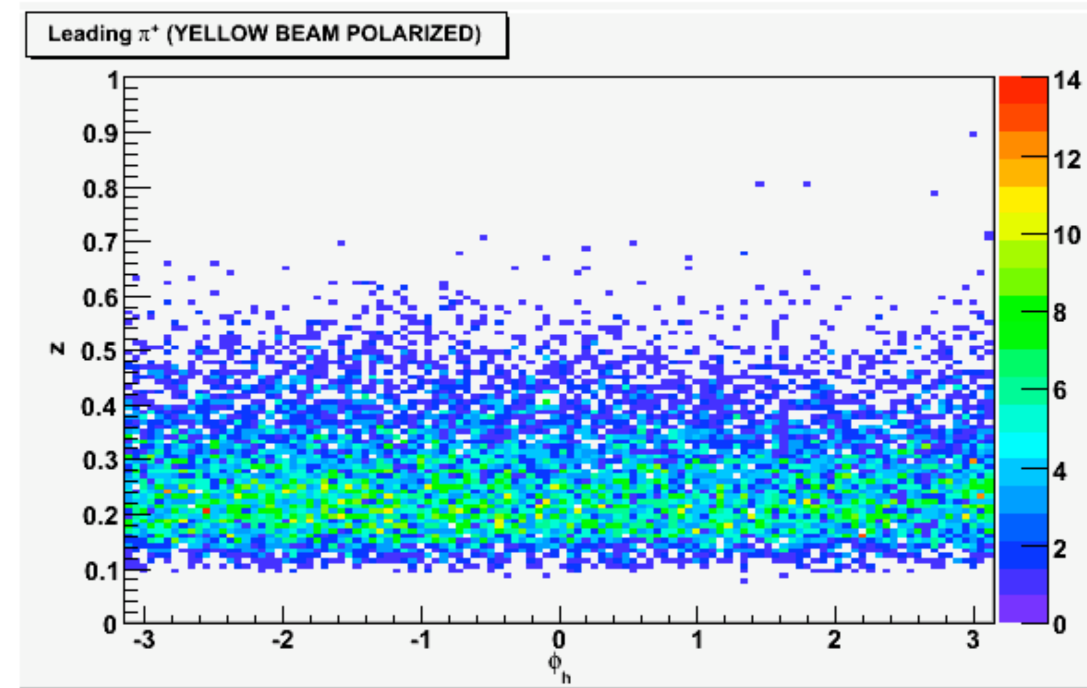
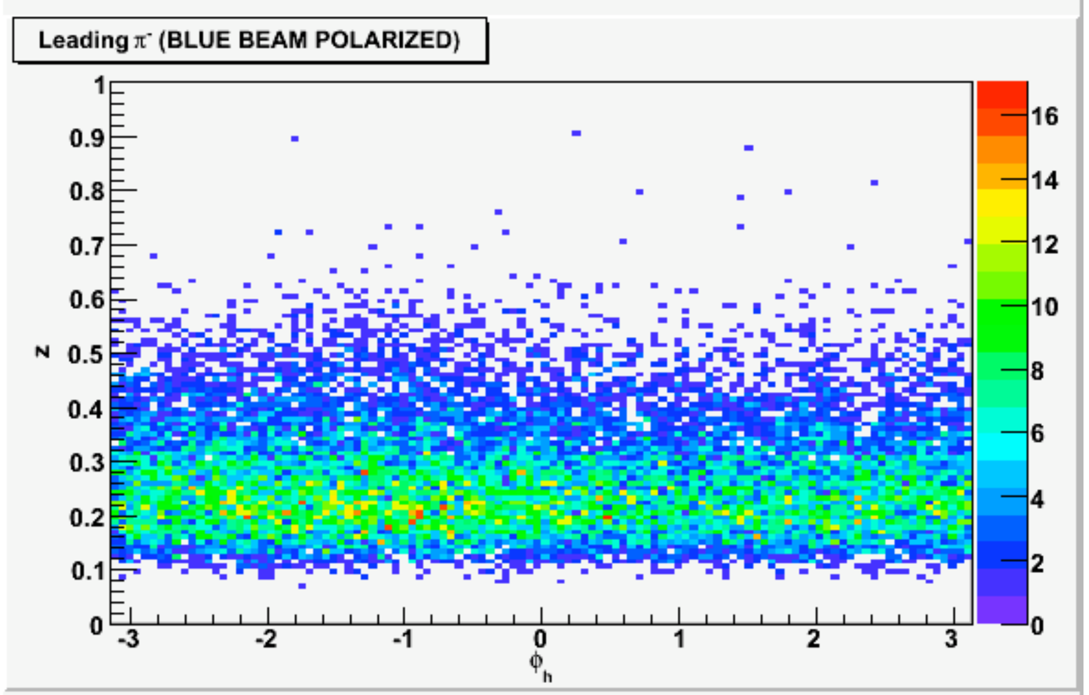
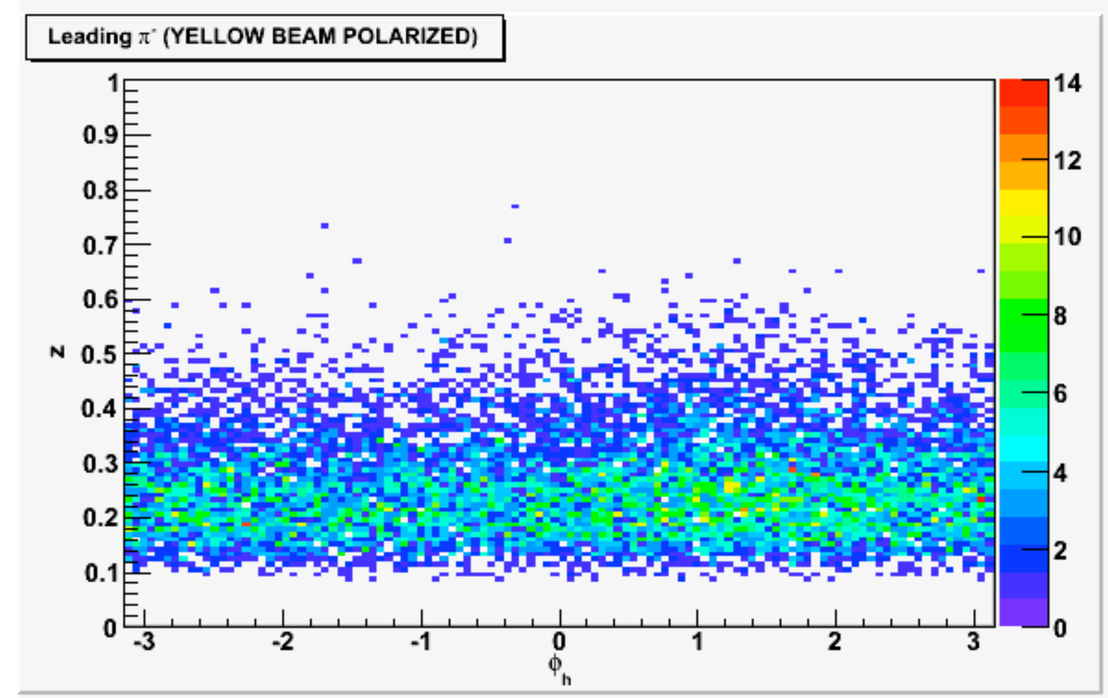






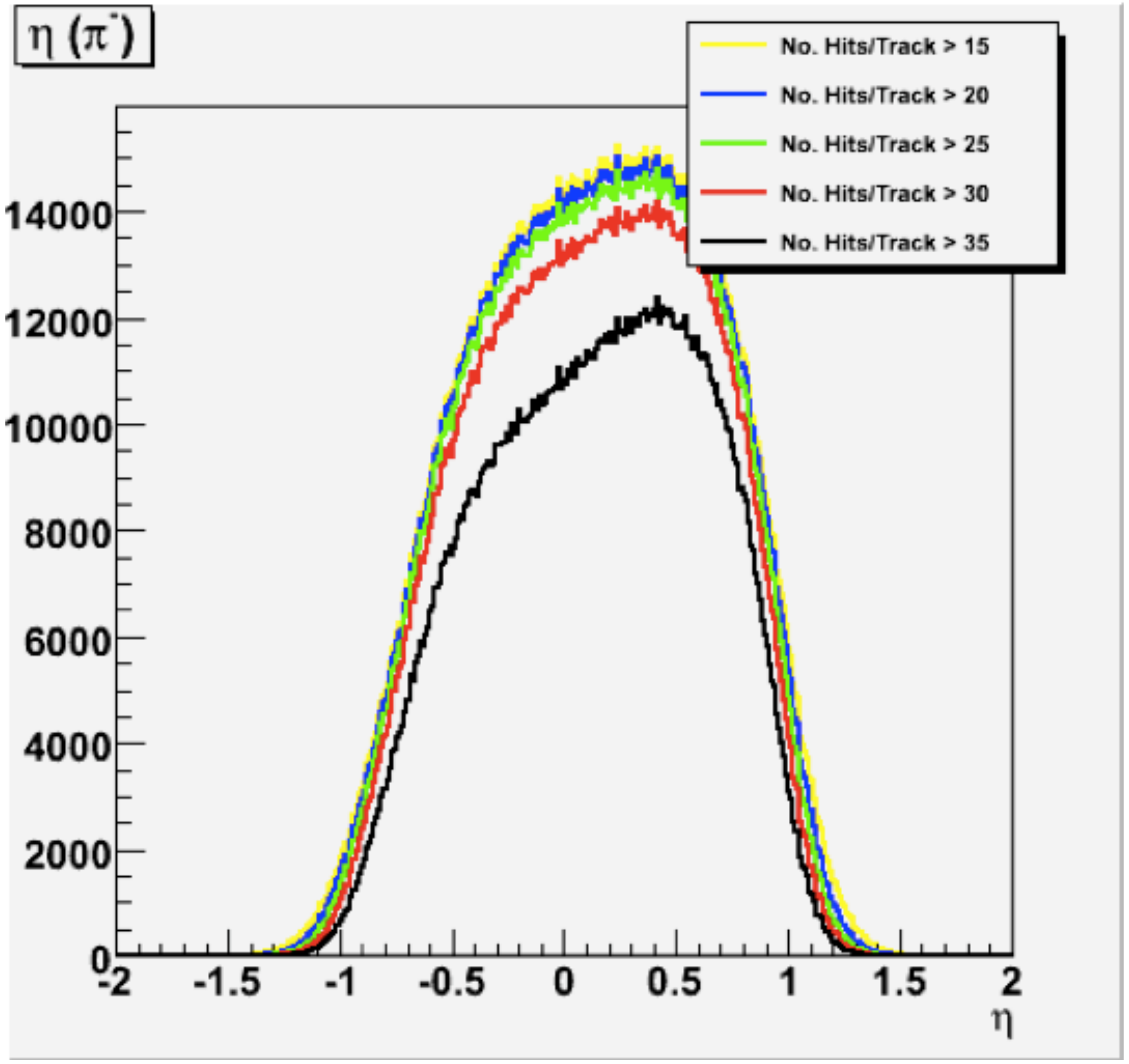


* Asymmetric distributions shown here are NOT a result of the Collins Asymmetry, they are a relic of track curvatures between TPC sectors; they are opposite for blue, yellow beam measurements & are symmetric with respect to the S-axis

Goals of this Presentation:

- Demonstrate kinematic coverage of the data and physics in terms of p_T

Charged $\pi^{\pm}$ reconstruction



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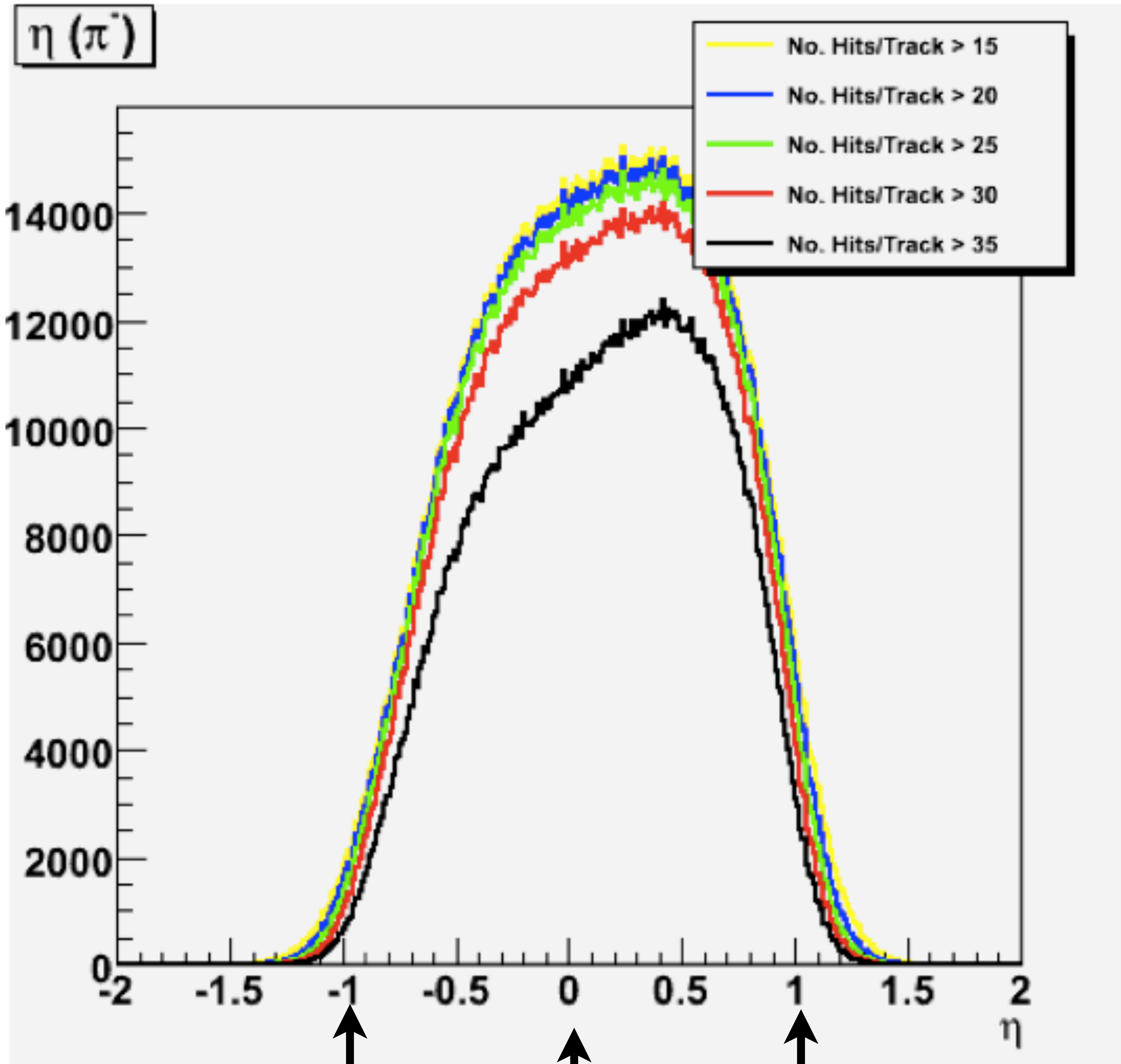
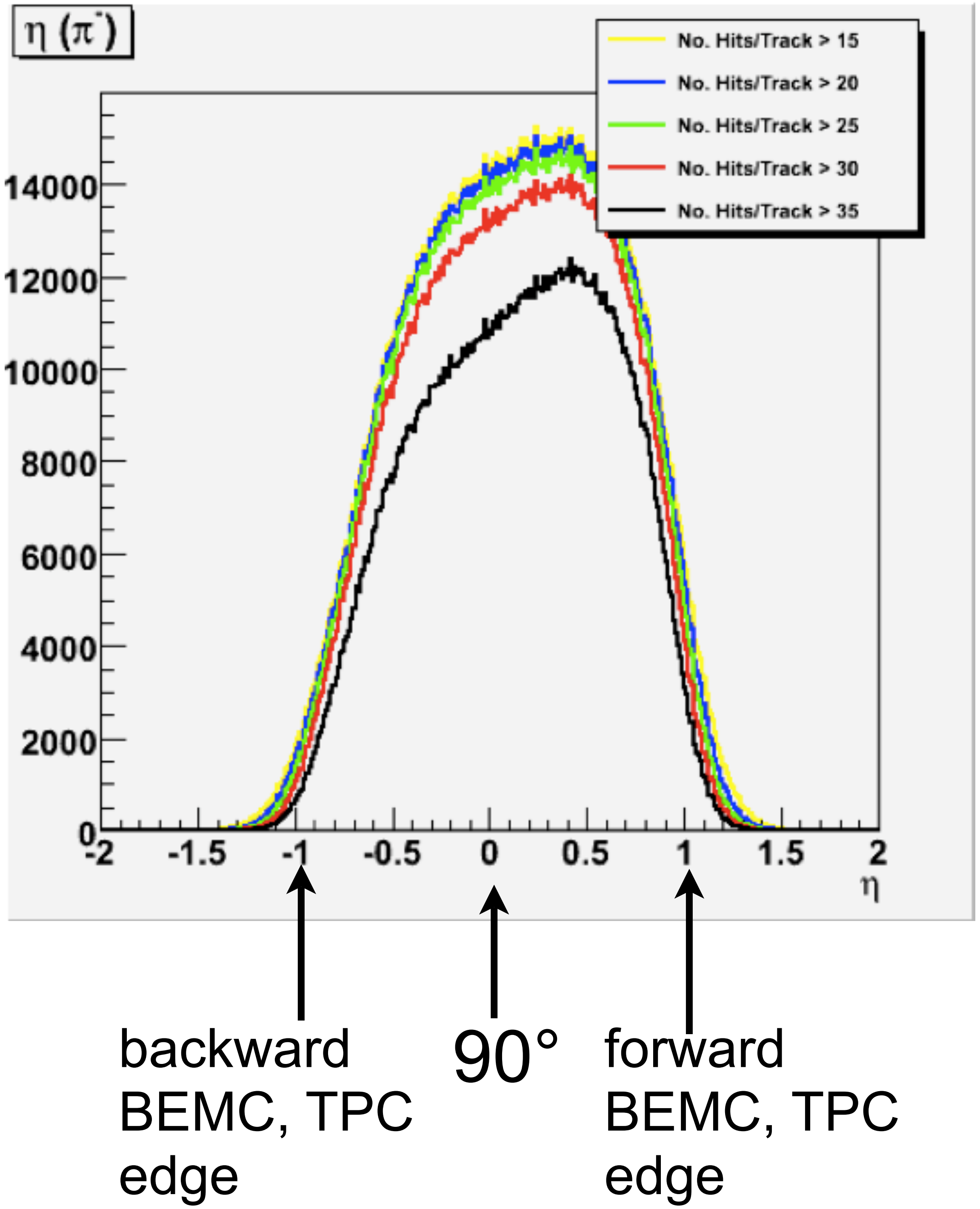


backward BEMC, TPC edge

90°

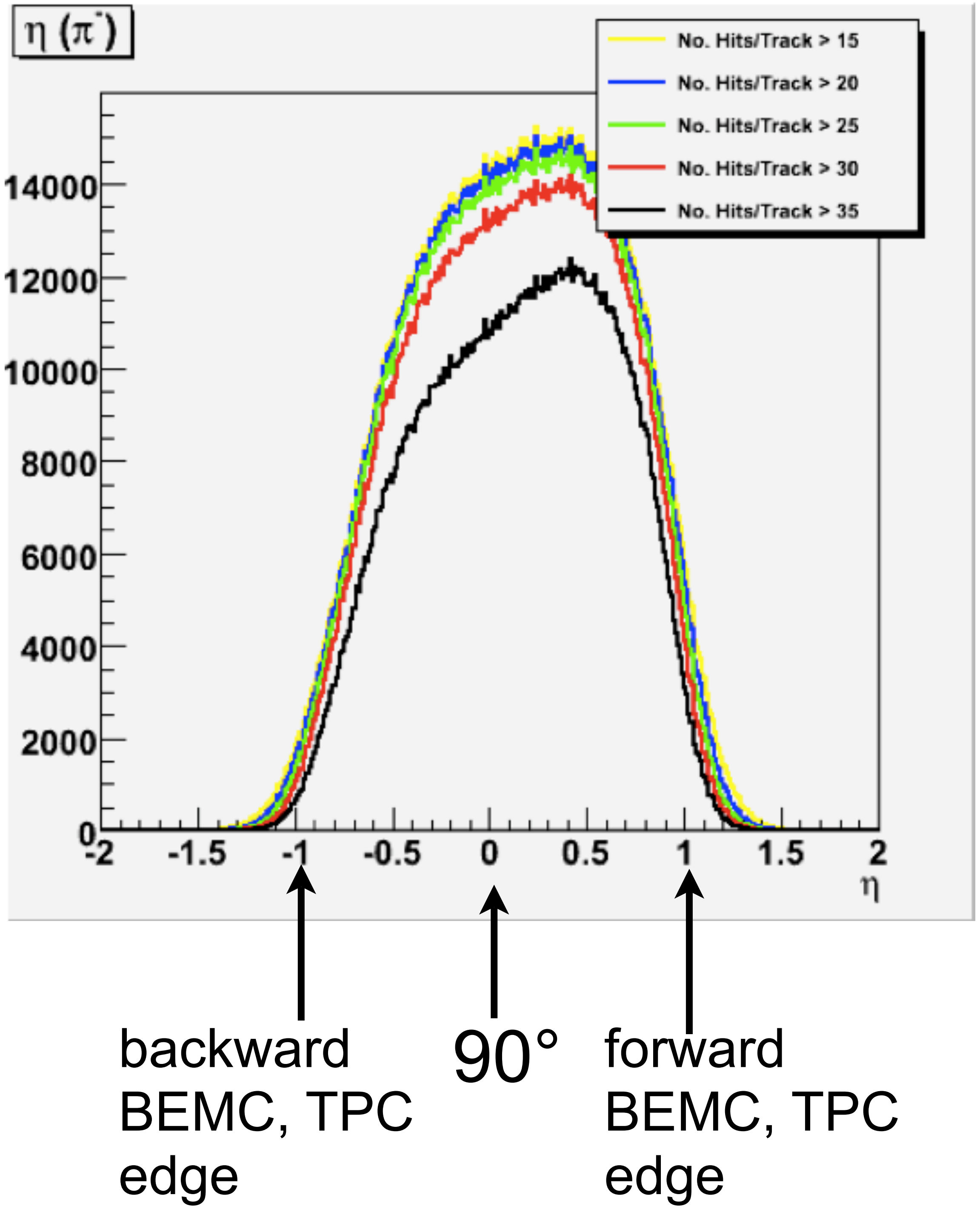
forward BEMC, TPC edge

Charged π± reconstruction



Determined by momentum and dE/dx in the TPC (≥25 fit points required)

Charged π± reconstruction

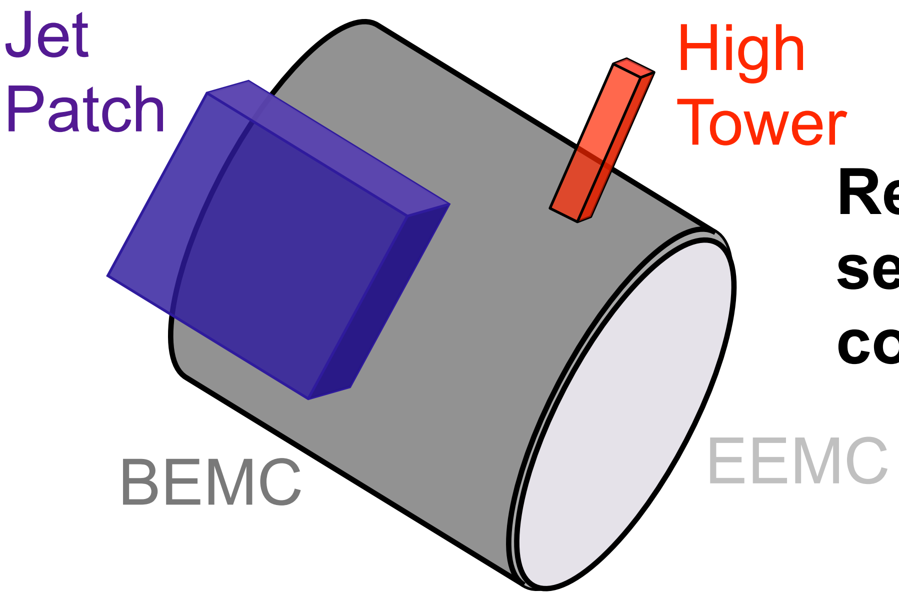


Determined by momentum and dE/dx in the TPC (≥25 fit points required)

Only *Leading* pions (highest momentum fraction *z*) are kept

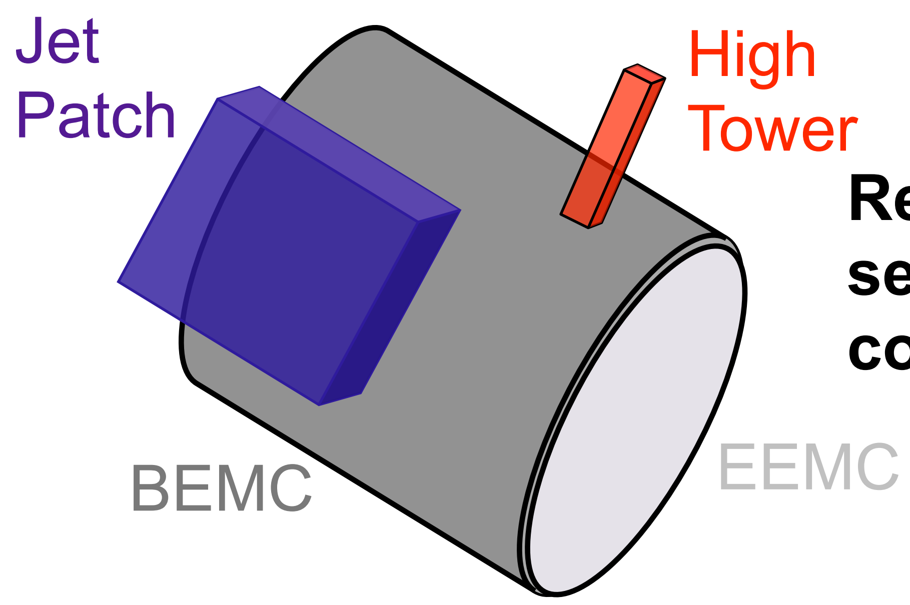
Jet reconstruction

Jet reconstruction



Results from several triggers compared

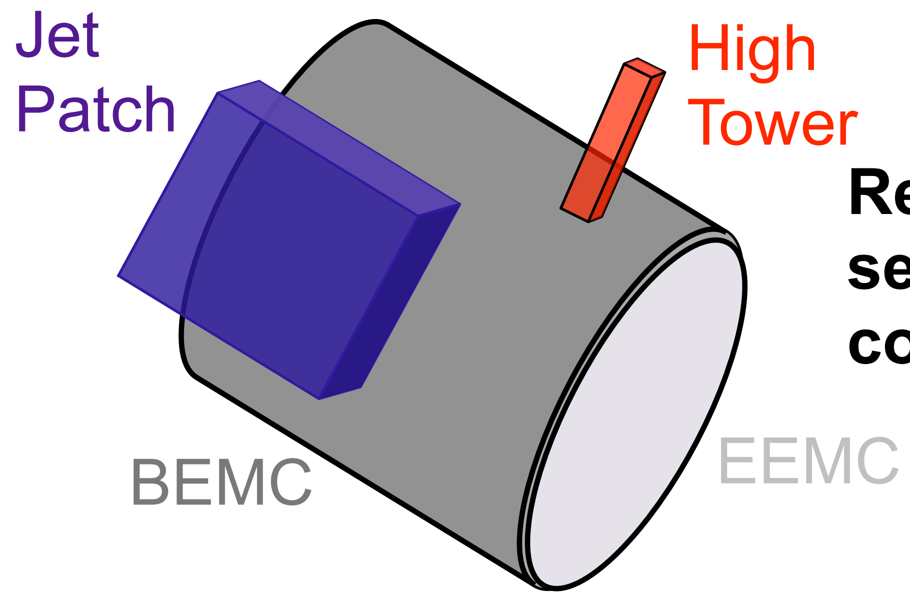
Jet reconstruction



Results from several triggers compared

Jet Patch trigger:
Requires sum of 400 localized "patches" above a threshold as a cluster for soft fragmentation (total coverage $\Delta\Phi = \Delta\eta = 1$)

Jet reconstruction



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Uses a single ADC channel as a jet "seed" and totals energy in surrounding trigger "patch"

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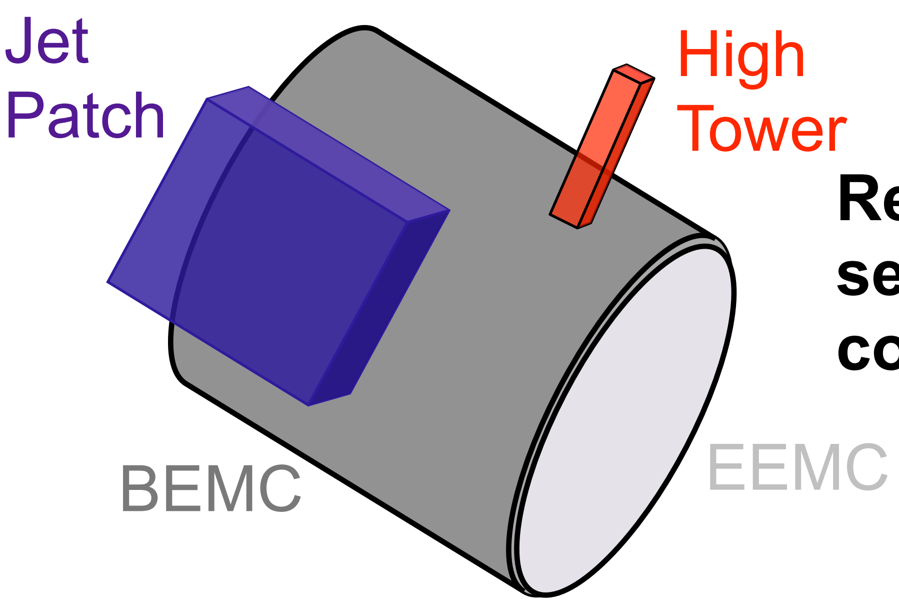

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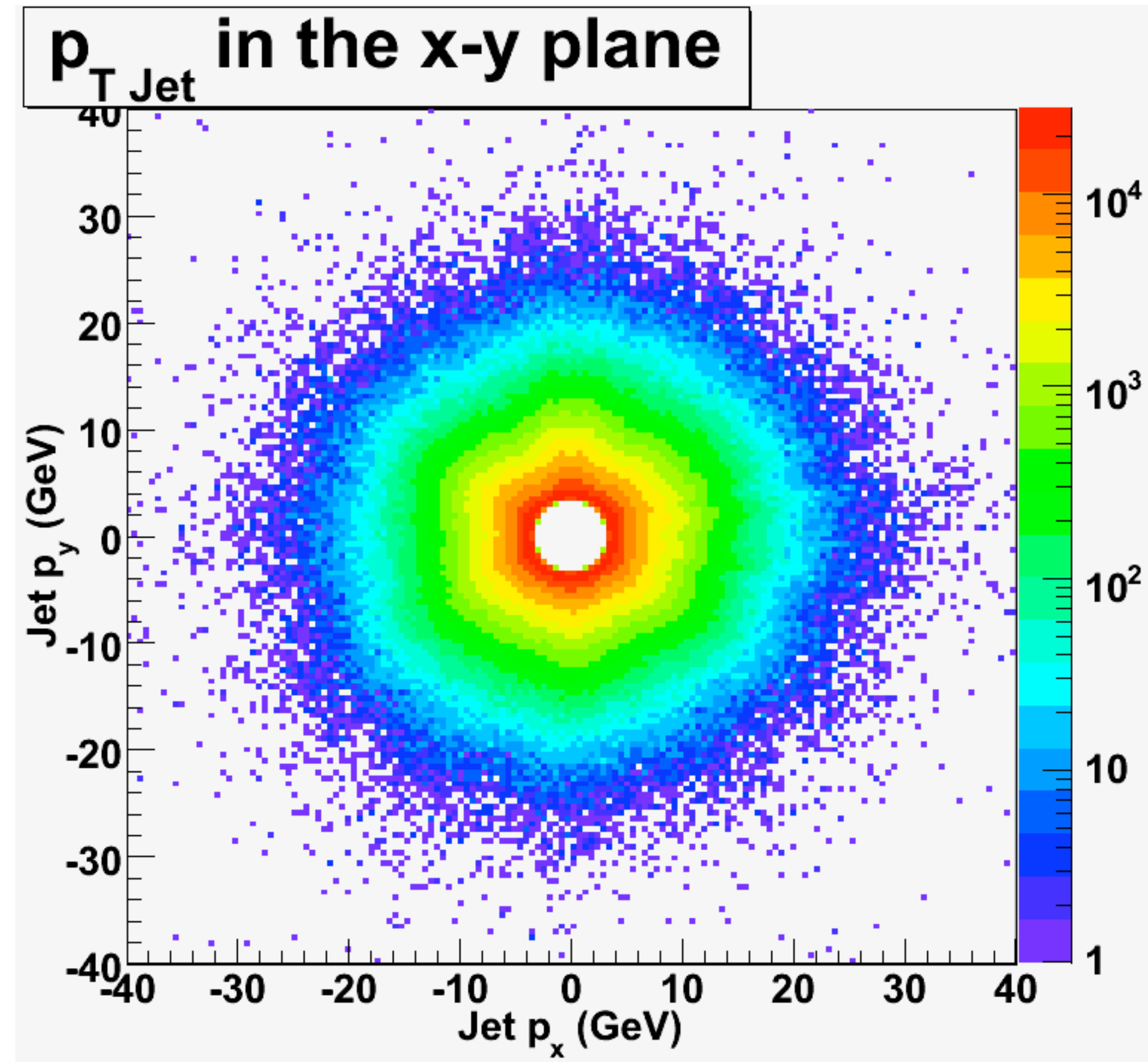

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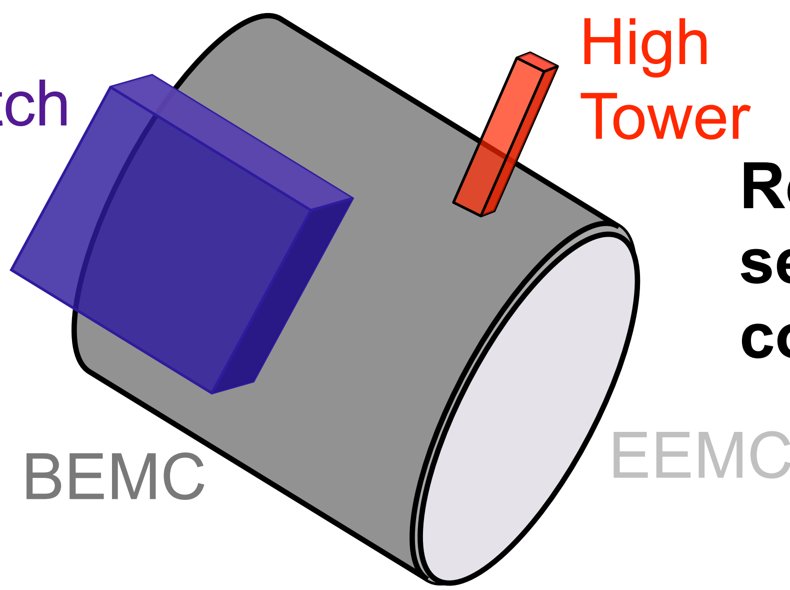

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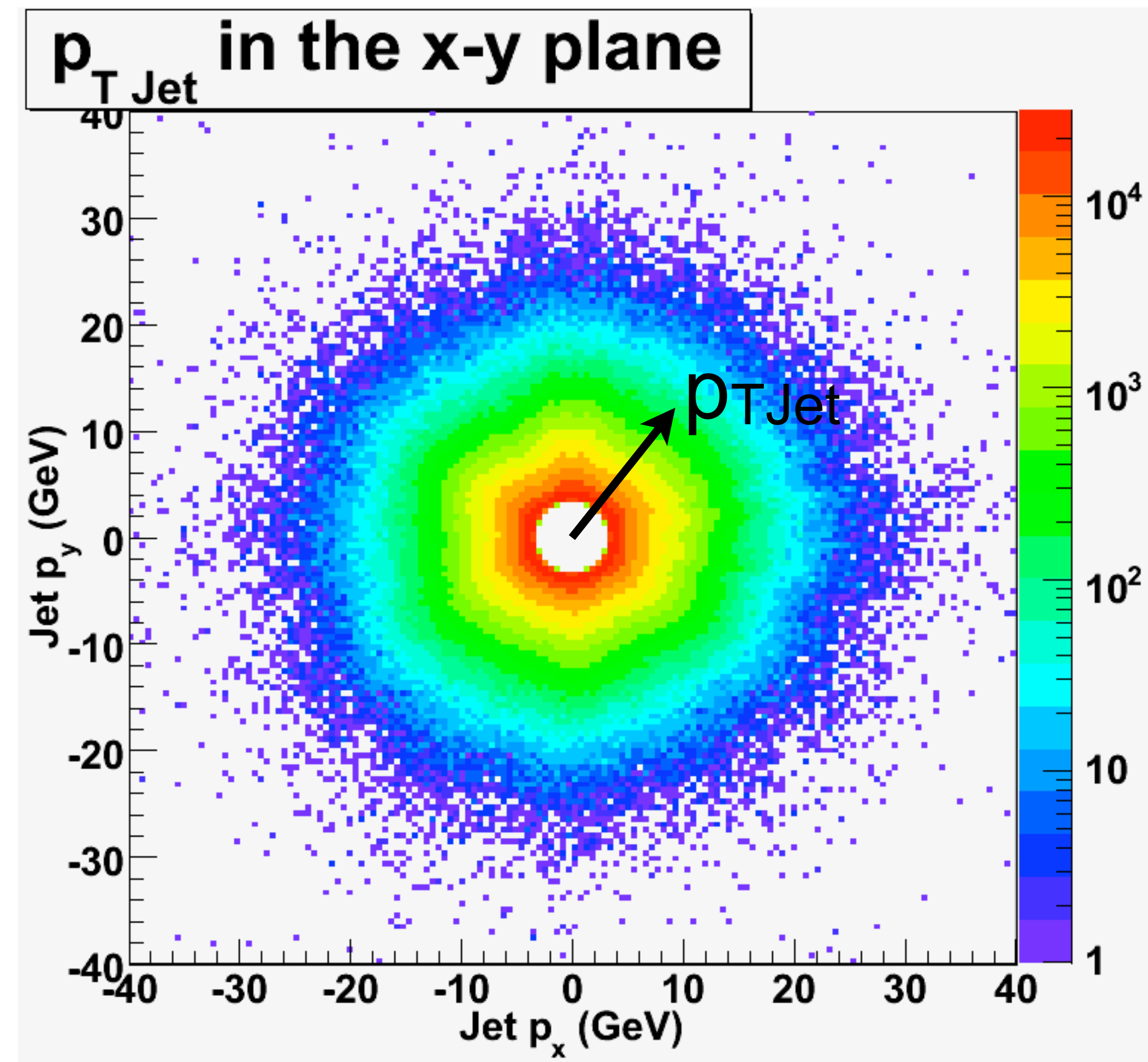

full azimuthal (Φ) coverage

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Jet physics in terms of p_T

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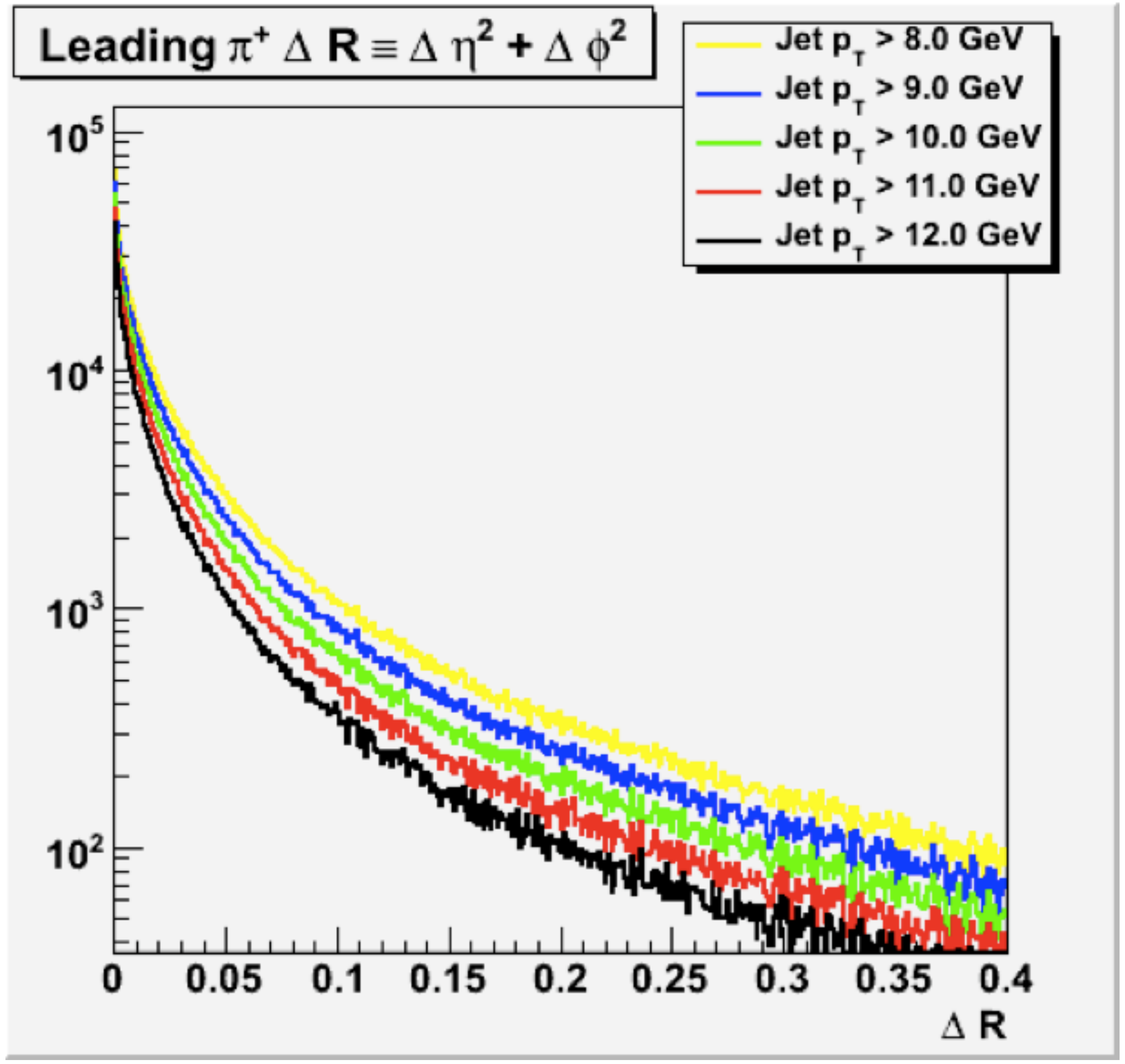
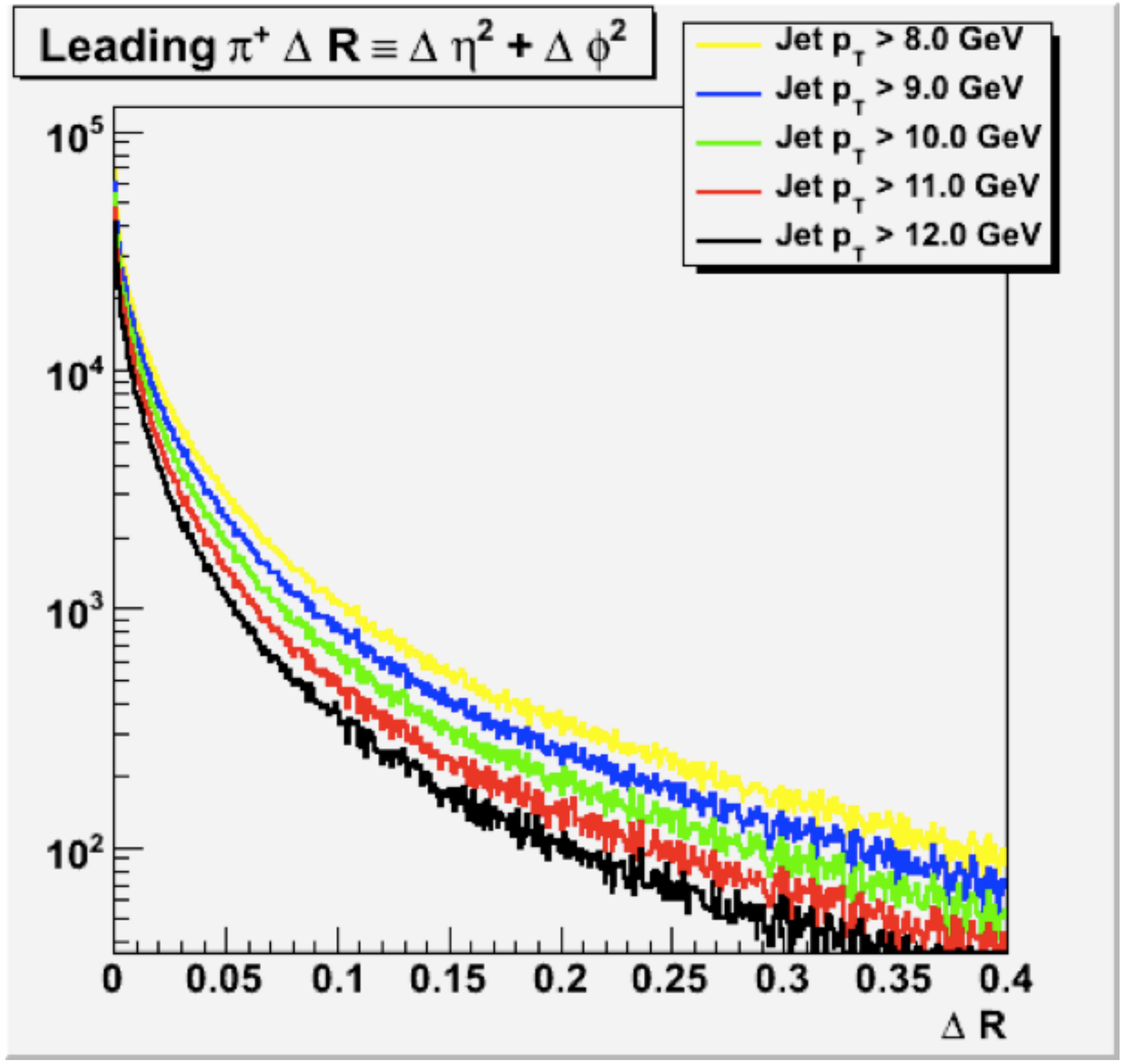


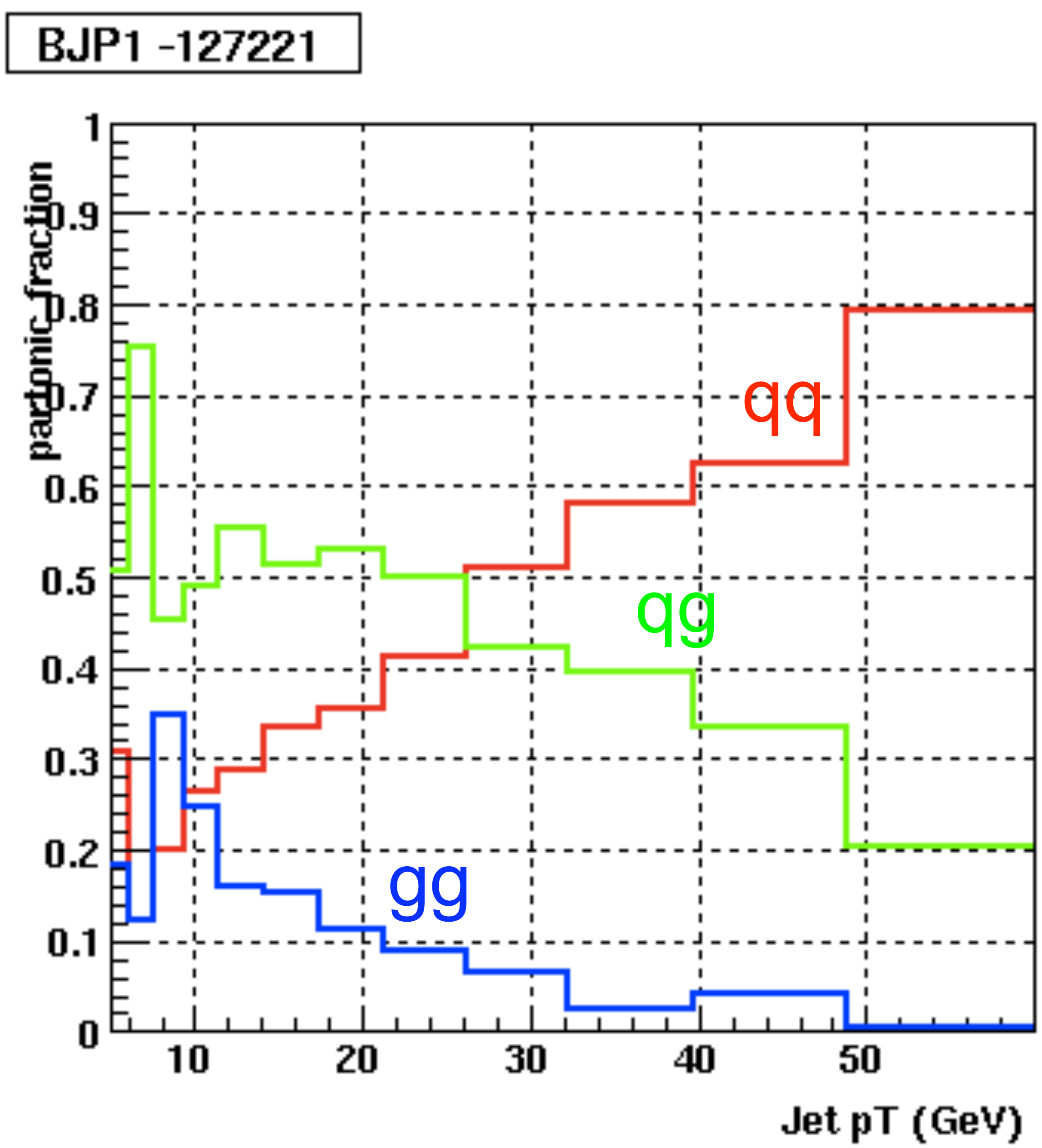
ΔR measures collimation of particles within jet

Jet physics in terms of p_T



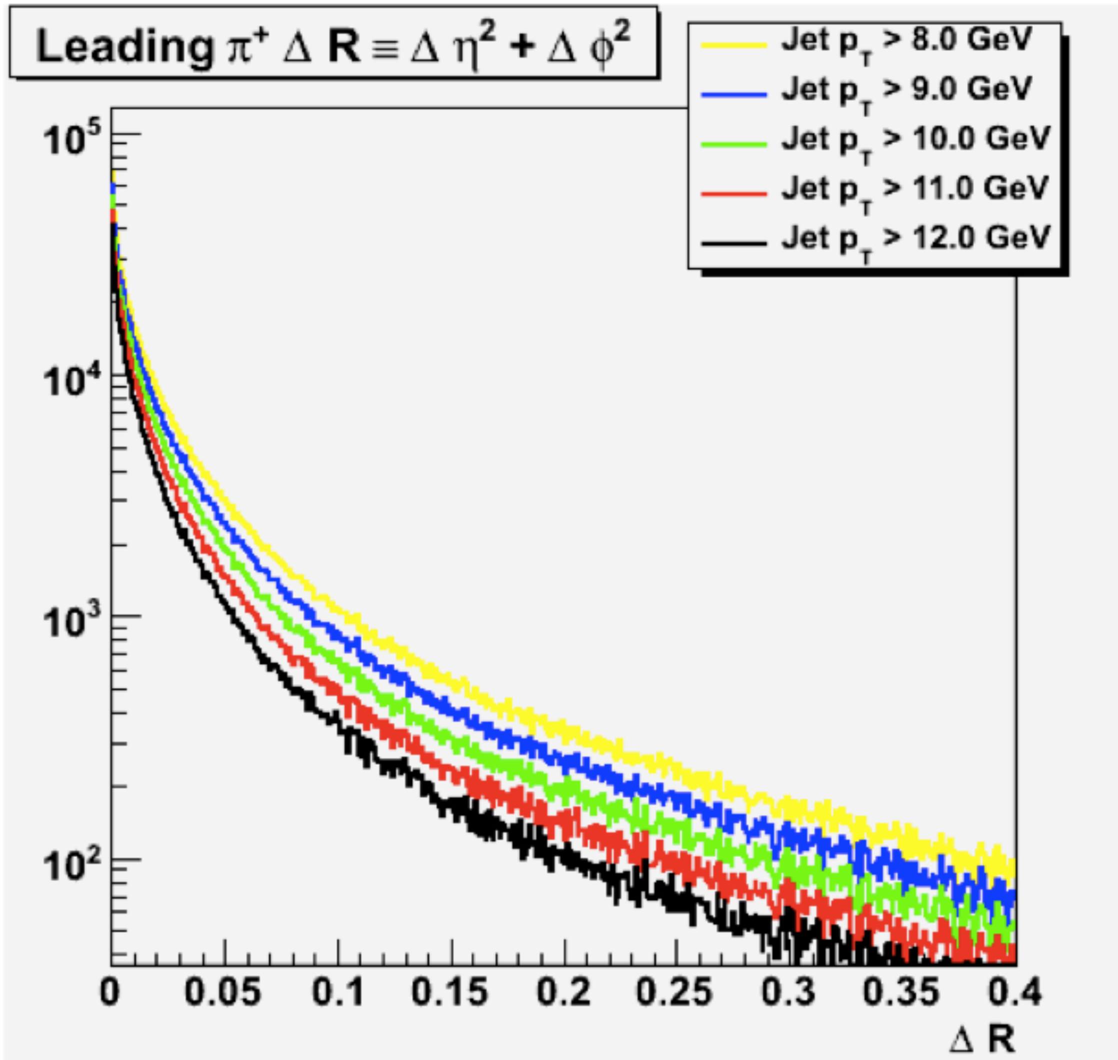
ΔR measures collimation of particles within jet

Lower p_T cut is a tradeoff between statistics and gluon event contamination:



STAR simulation (PYTHIA + GEANT) at $\sqrt{s}$ = 200 GeV

Jet physics in terms of p_T



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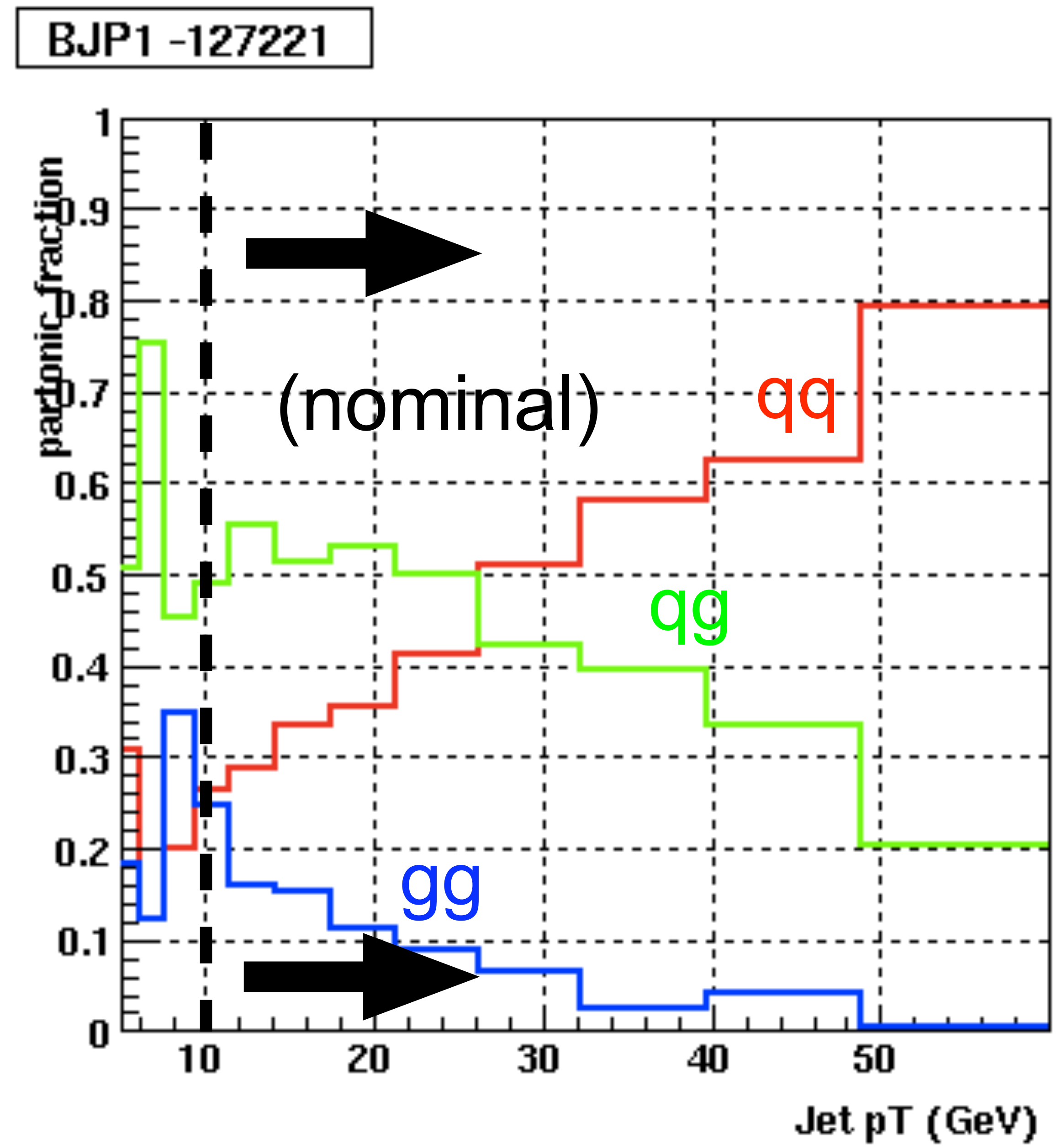
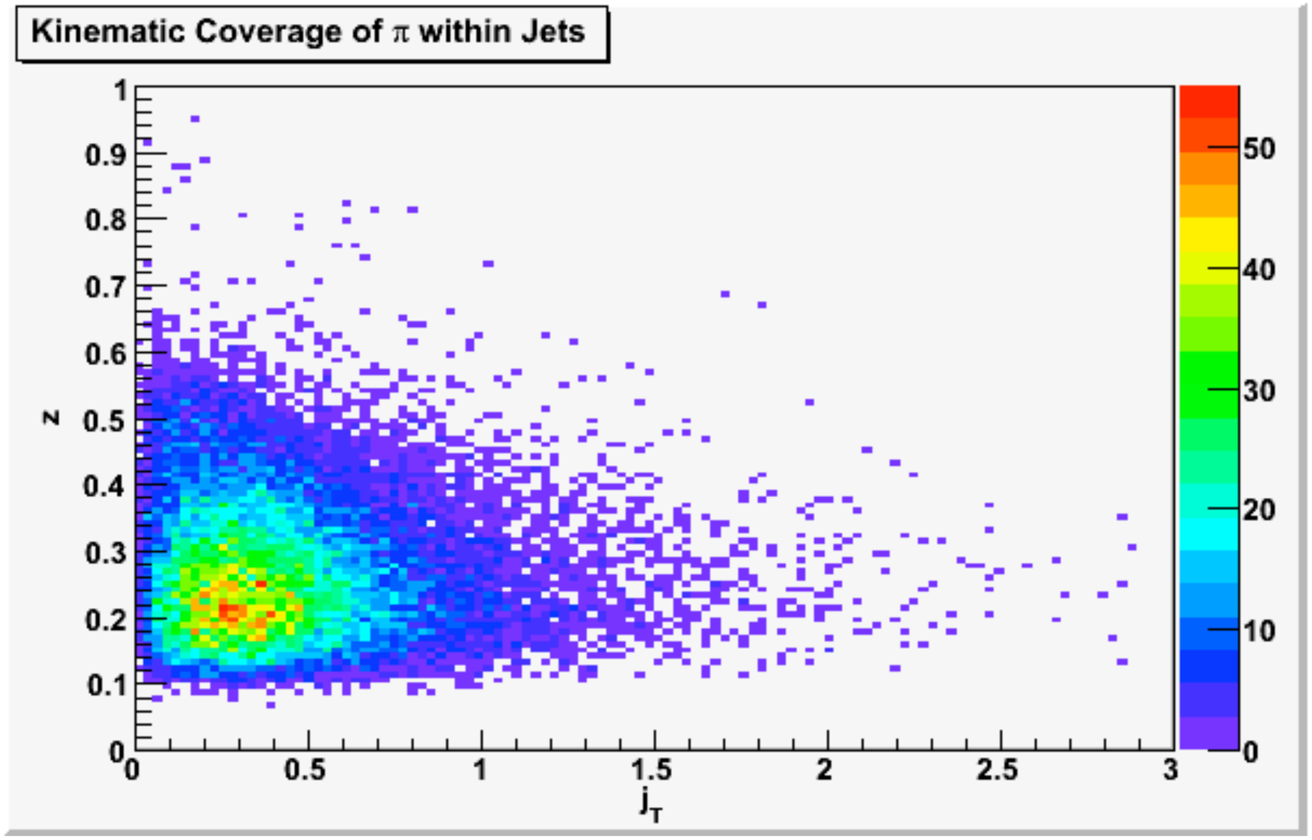


STAR simulation (PYTHIA + GEANT) at √s = 200 GeV

Data separated by z and j_T ;



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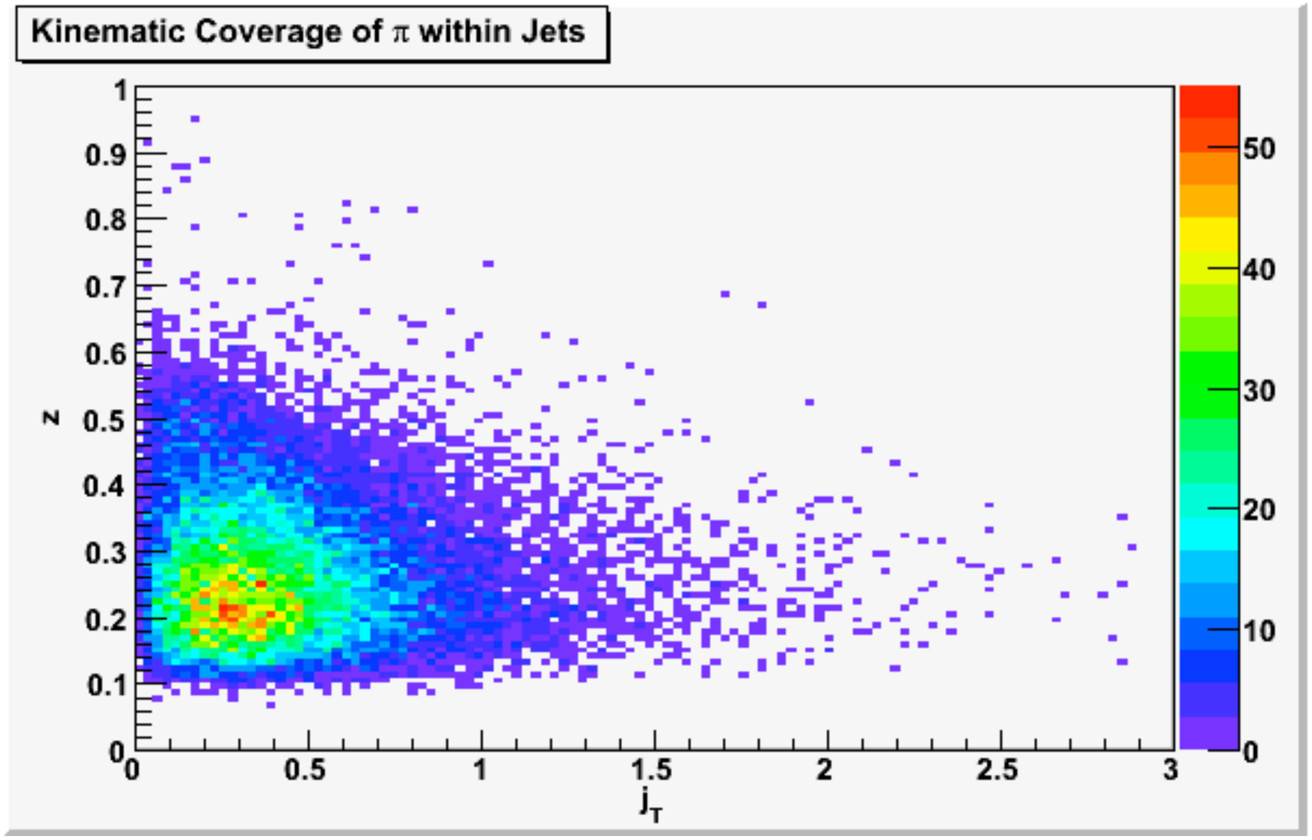
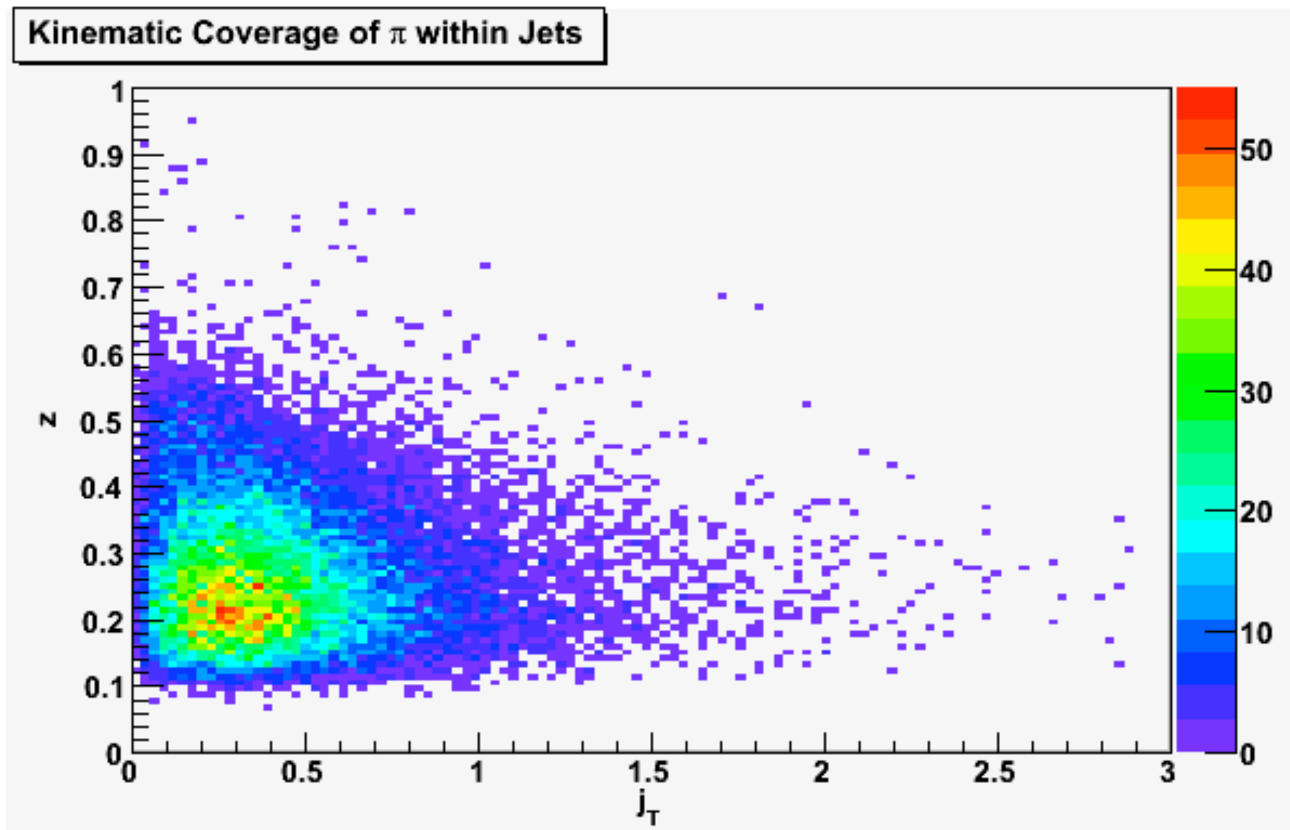


Asymmetry can be measured in terms of either z or j_T

Data separated by z and j_T; azimuthal angles calculated:



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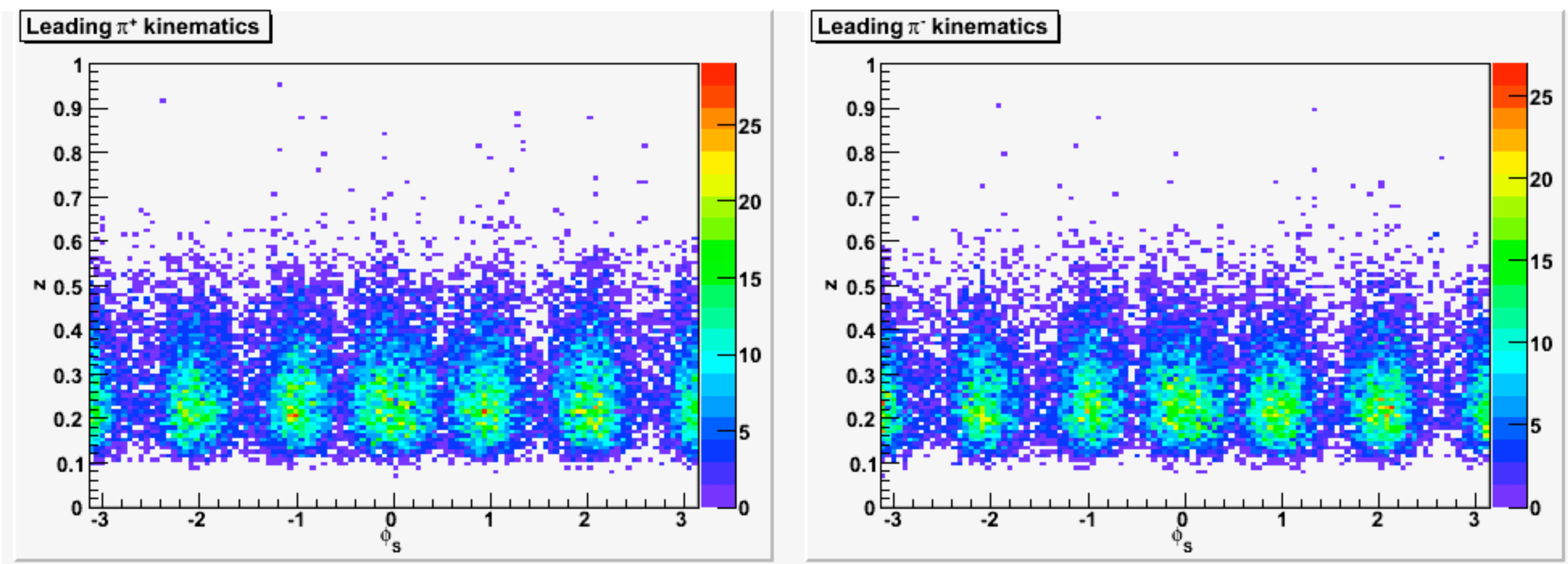

Goals of this Presentation:

- Show statistical expectations of measured asymmetries and summarize systematic concerns

$\sin(\Phi_S - \Phi_\pi)$ spectrum

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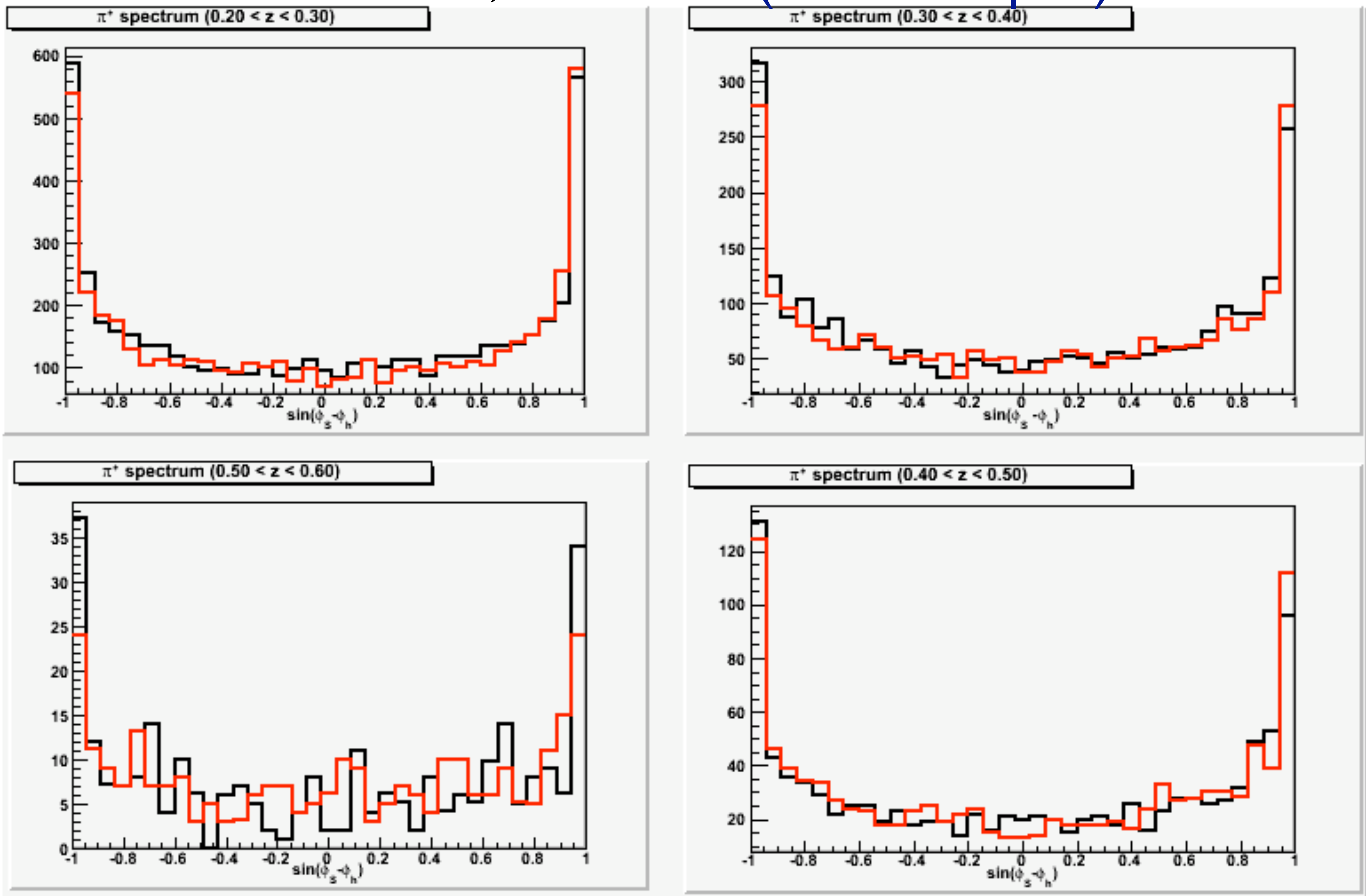
Red = ↑ , Black = ↓ (lab frame pol.)



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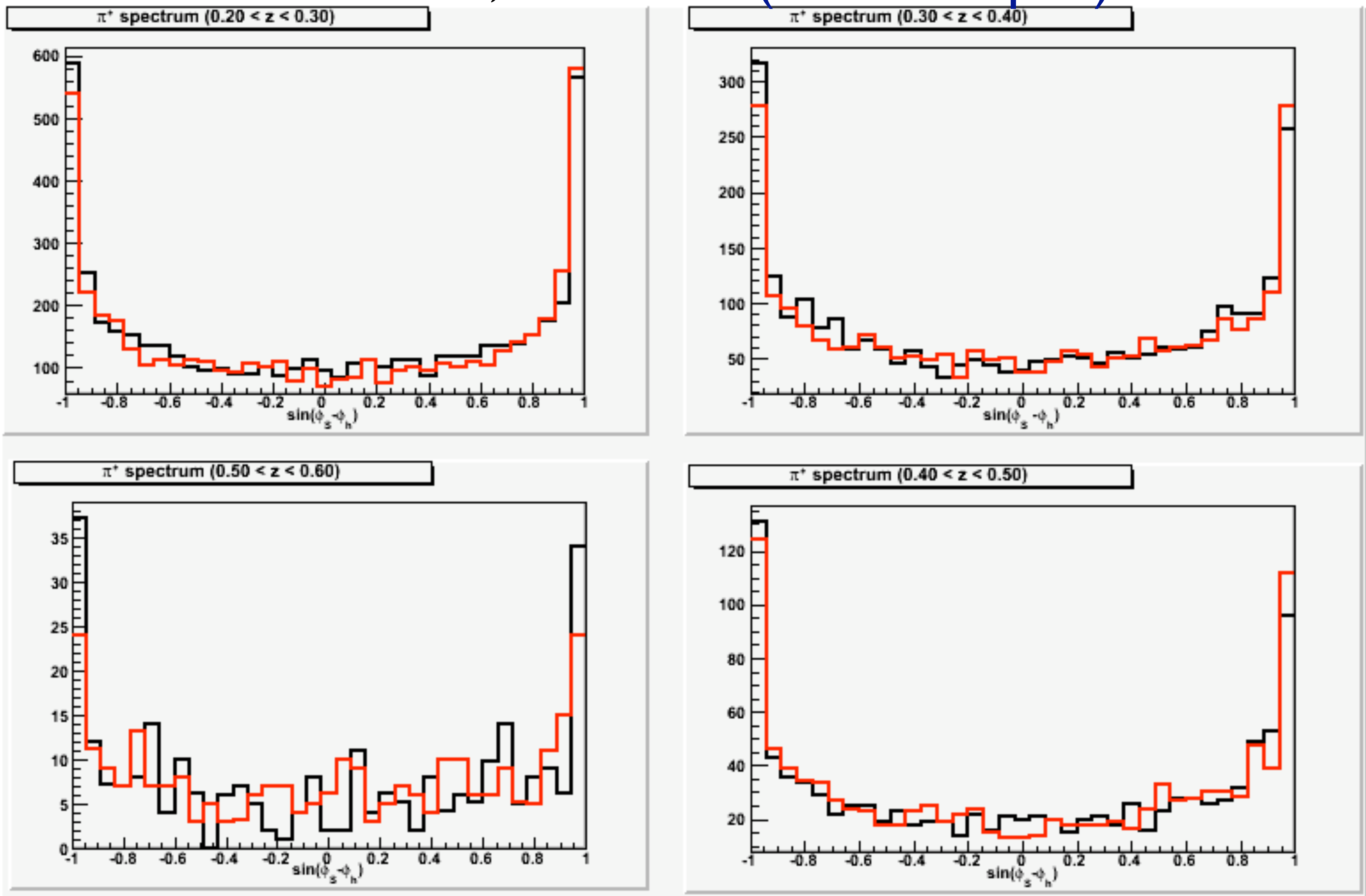

(Use of opposing polarizations, weighted by beam luminosity, ensures that detector acceptances cancel in the asymmetry.)

Asymmetry Statistics

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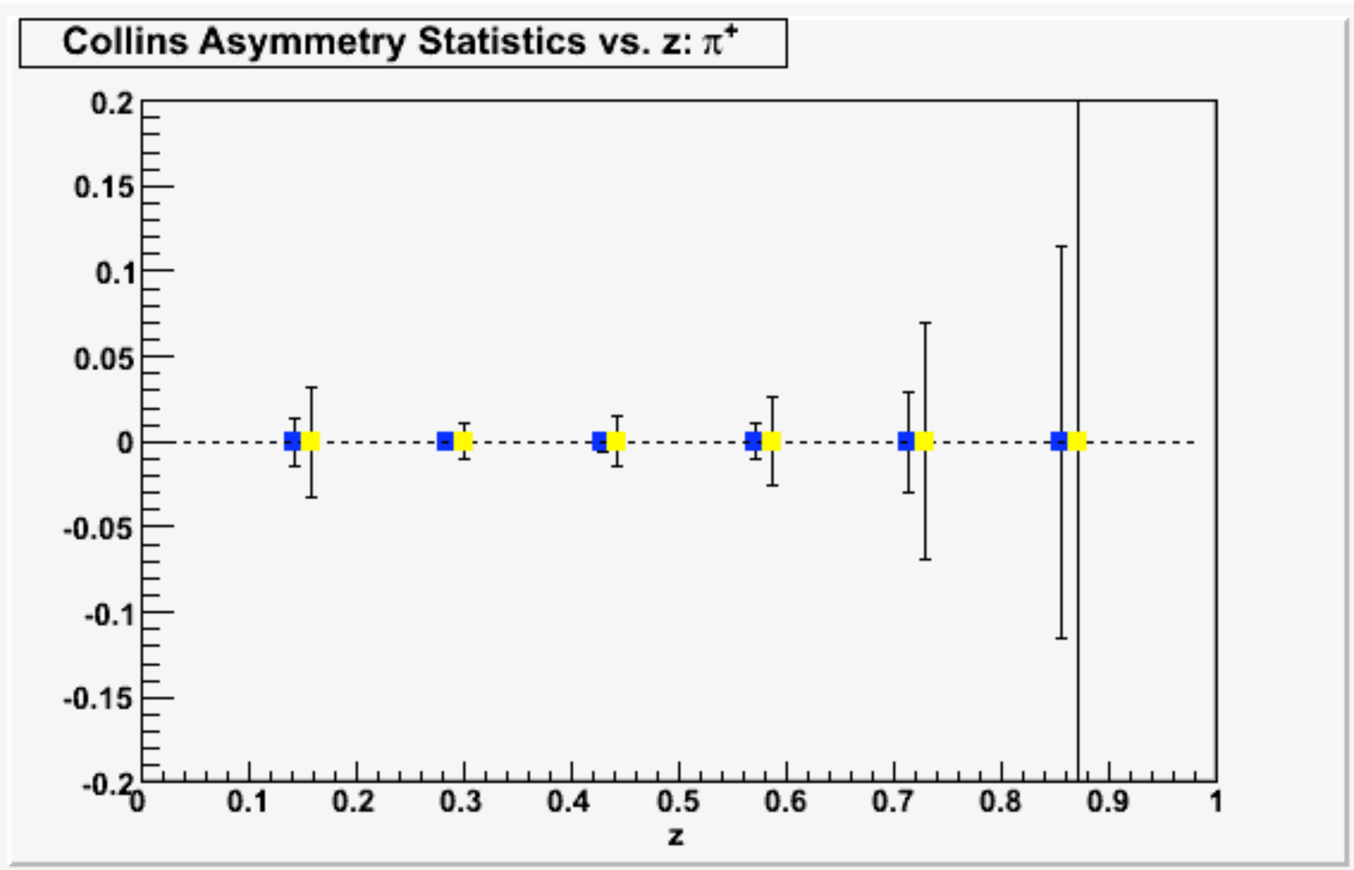
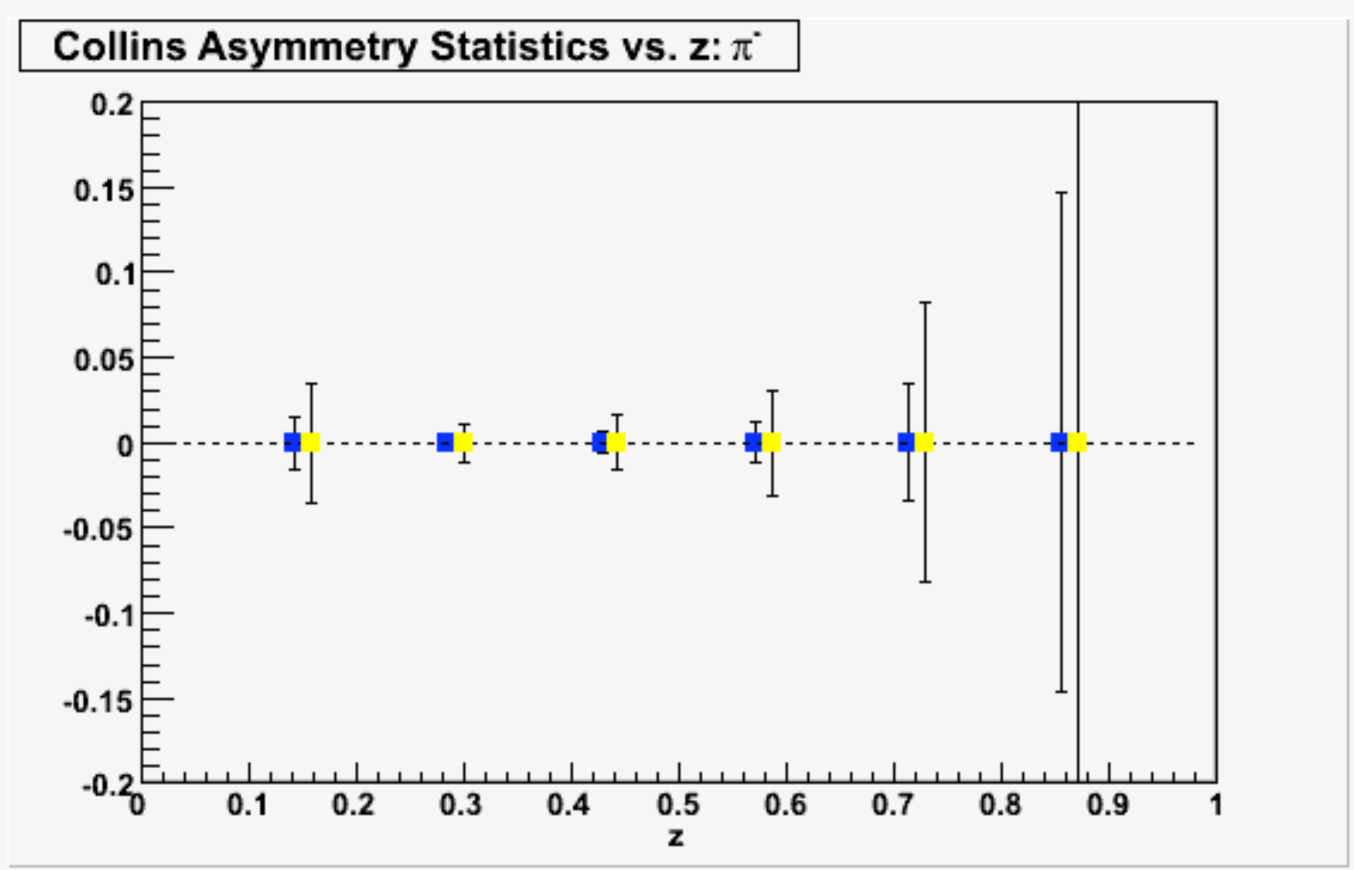
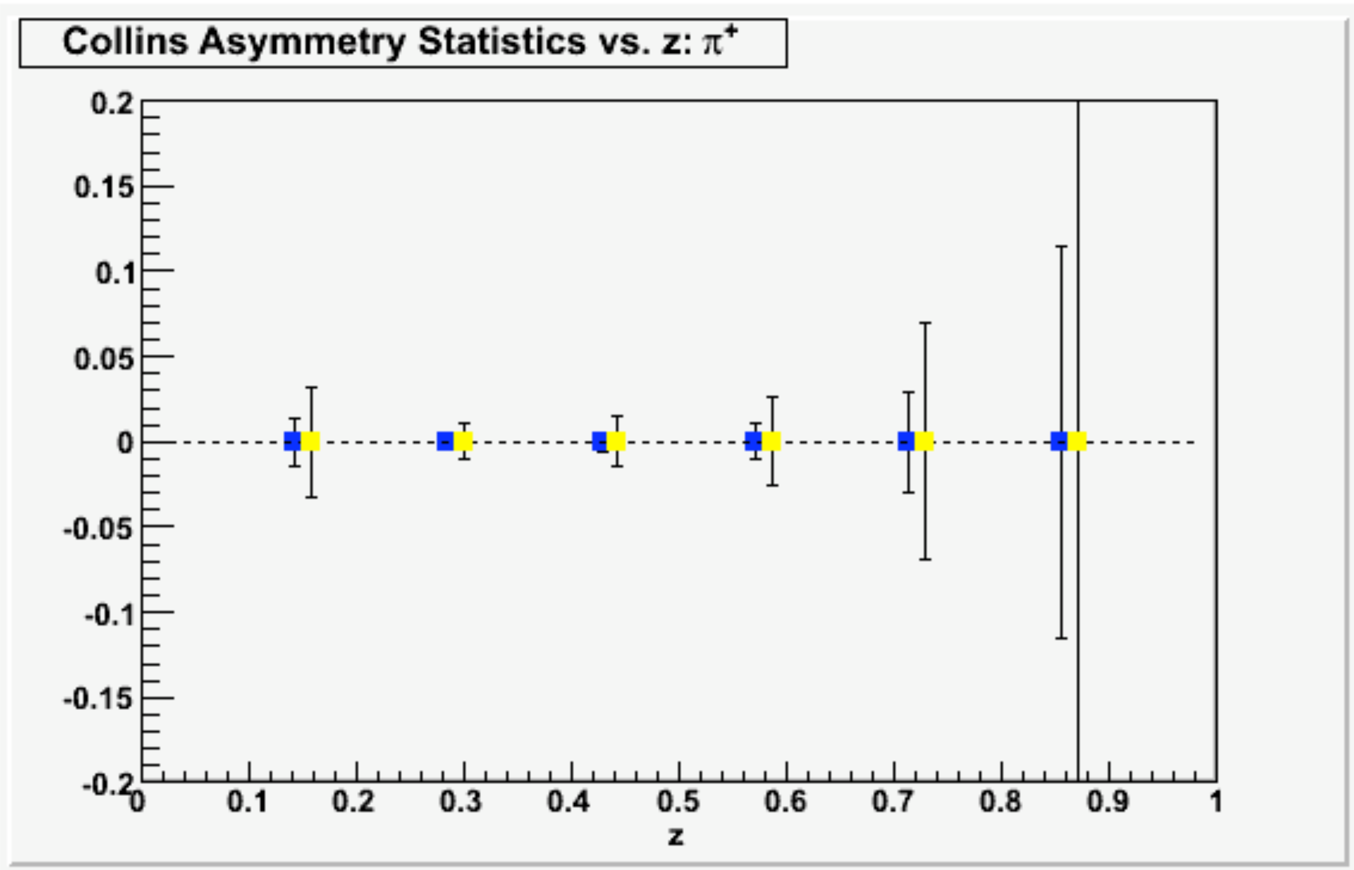
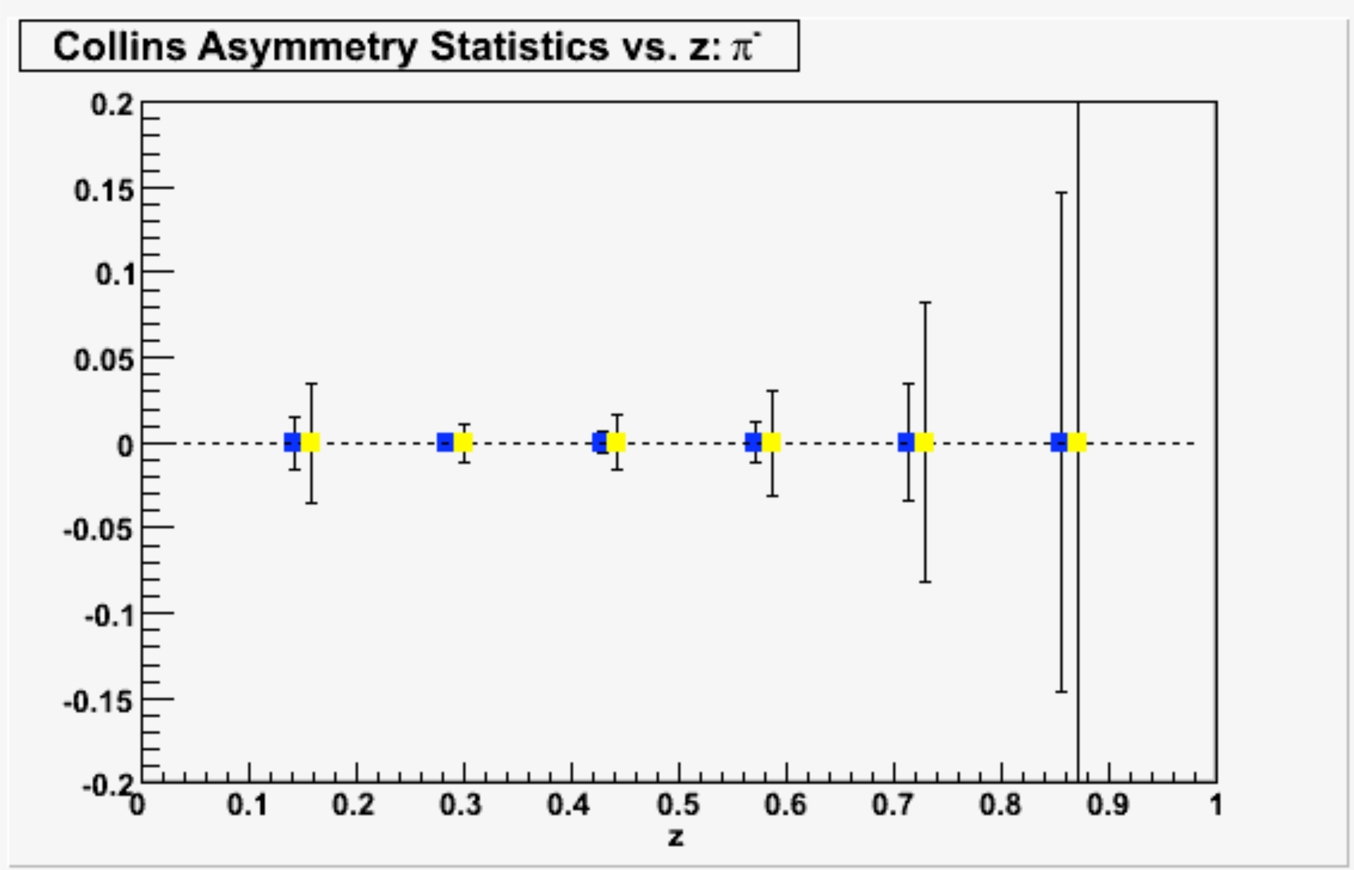




Asymmetry Statistics



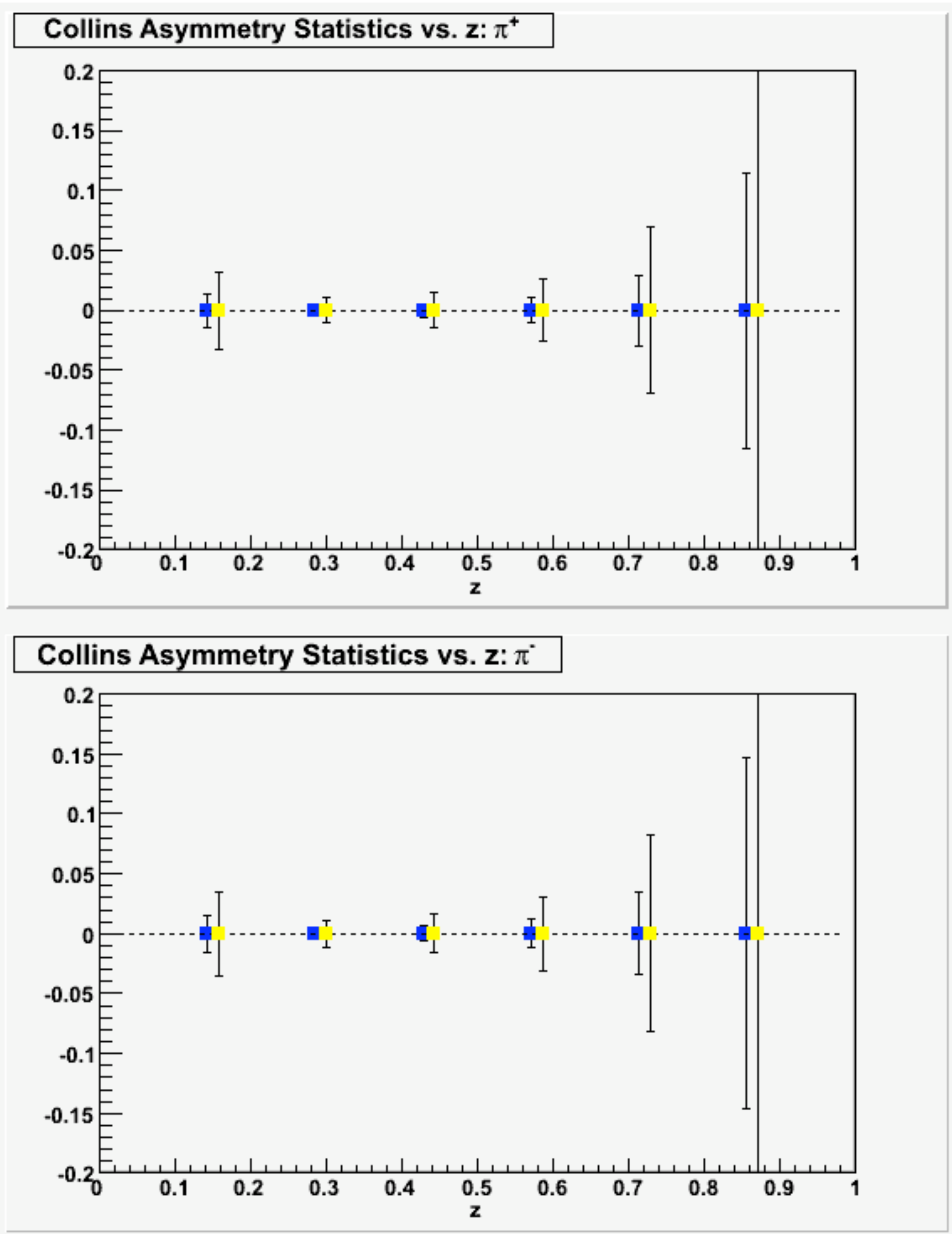


"blue" beam polarized

"yellow" beam polarized

(jets in forward hemisphere of each beam analyzed)

Asymmetry Statistics



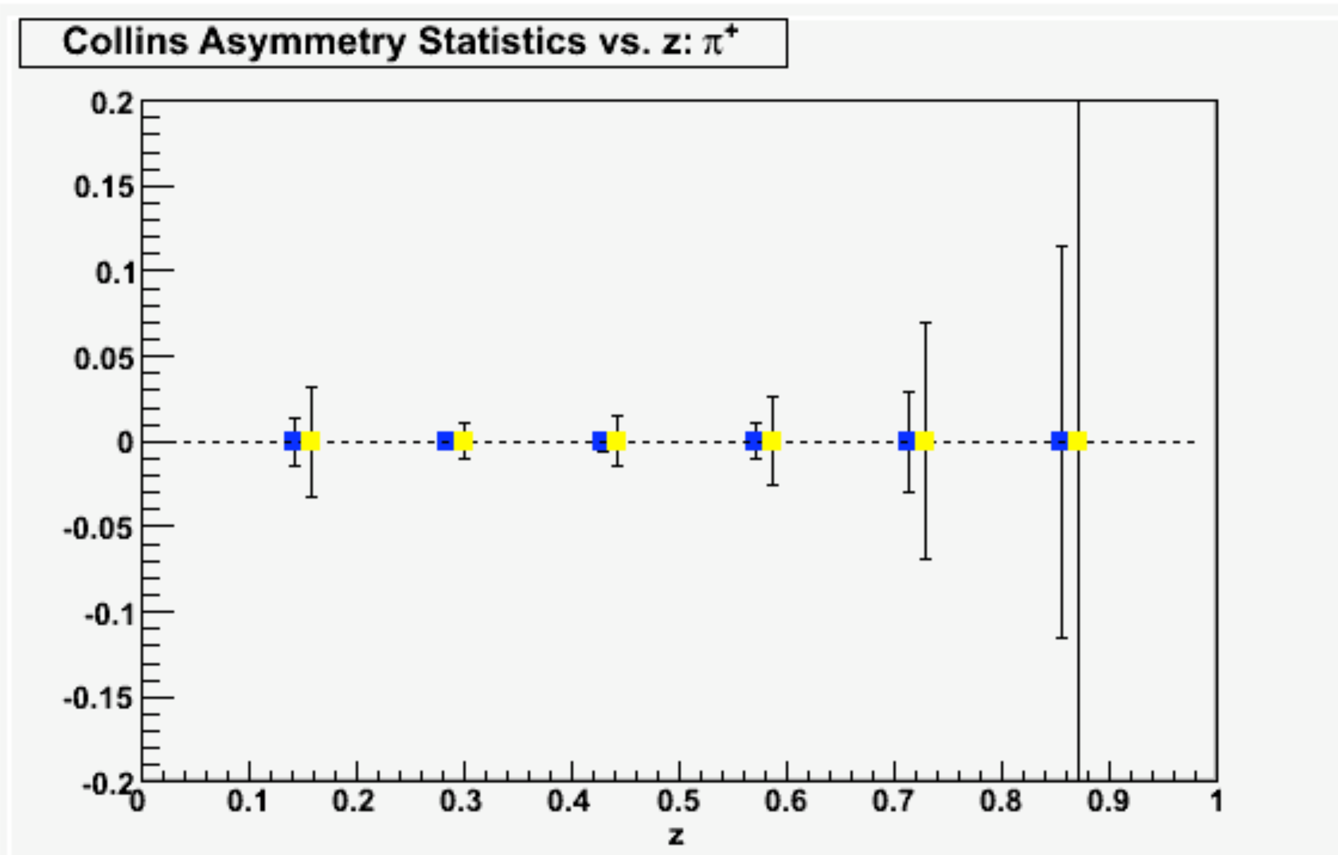
"blue" beam polarized

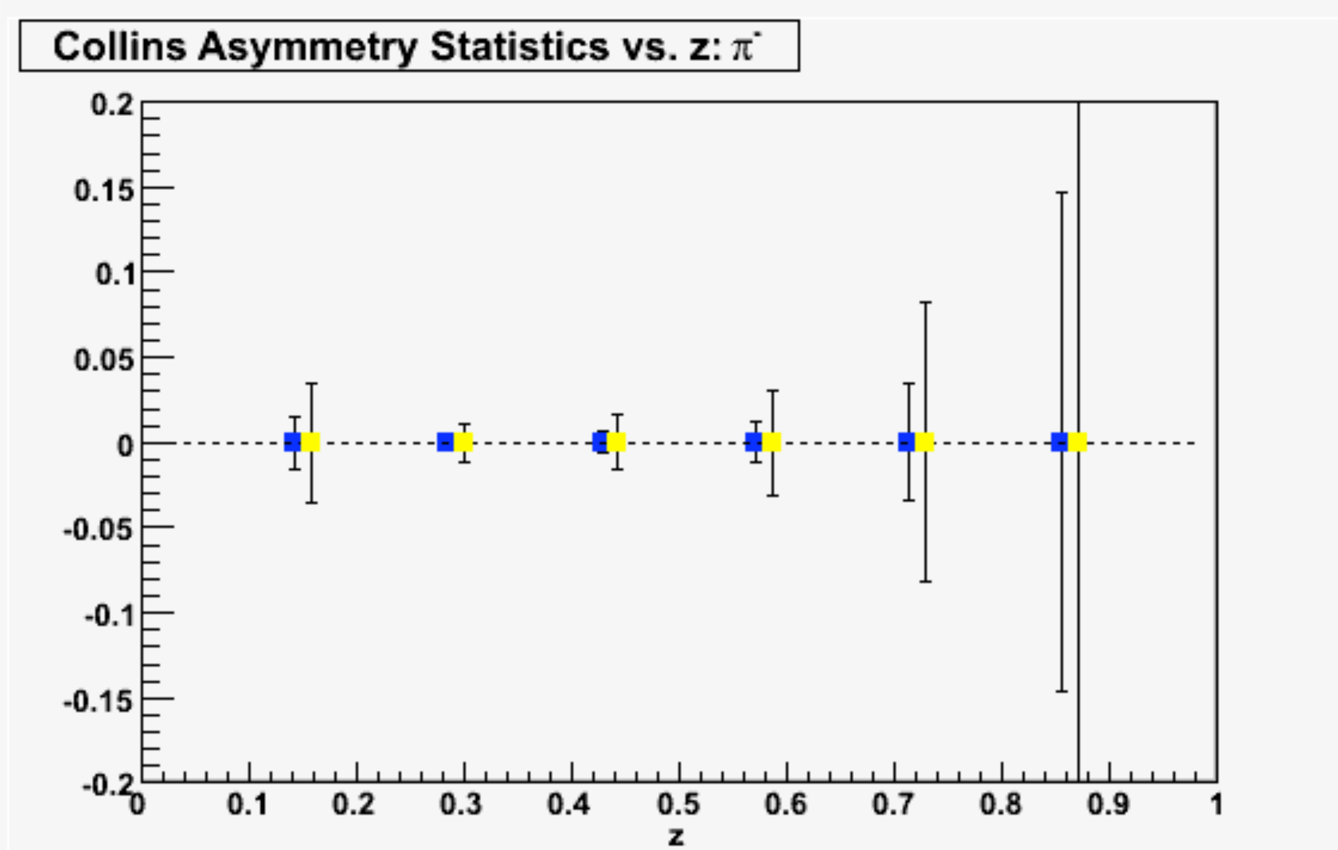
"yellow" beam polarized

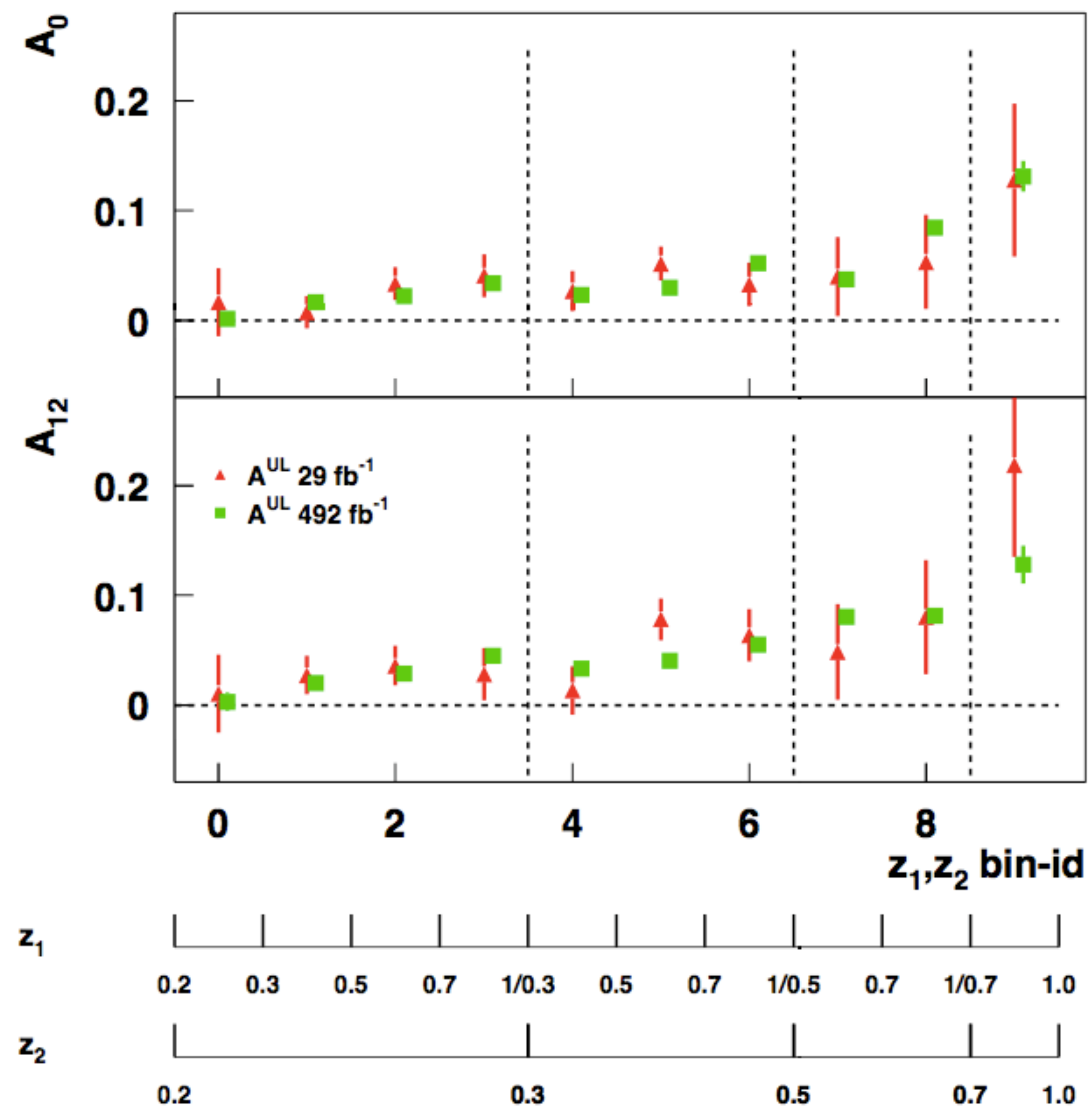
(jets in forward hemisphere of each beam analyzed)

Asymmetry should be opposite in sign for + vs. – pions

Asymmetry Statistics







Published e^+e^- results from Belle

Upcoming: Systematic Errors

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- TRIGGER BIAS ⇒ accurate determination of leading pions; natural $\langle z \rangle$ distribution (need PYTHIA simulation)

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- Track efficiency

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- Track efficiency
- Accuracy of both jet and π kinematics
- Polarization direction and magnitude
- Relative luminosity error

Conclusion and Status of Research

The Collins mechanism yields sensitivity to transvesity in polarized p↑p jet production.

Analysis of 2006 transverse data at mid-rapidity is well under way.

The aforementioned systematic effects are now being studied.

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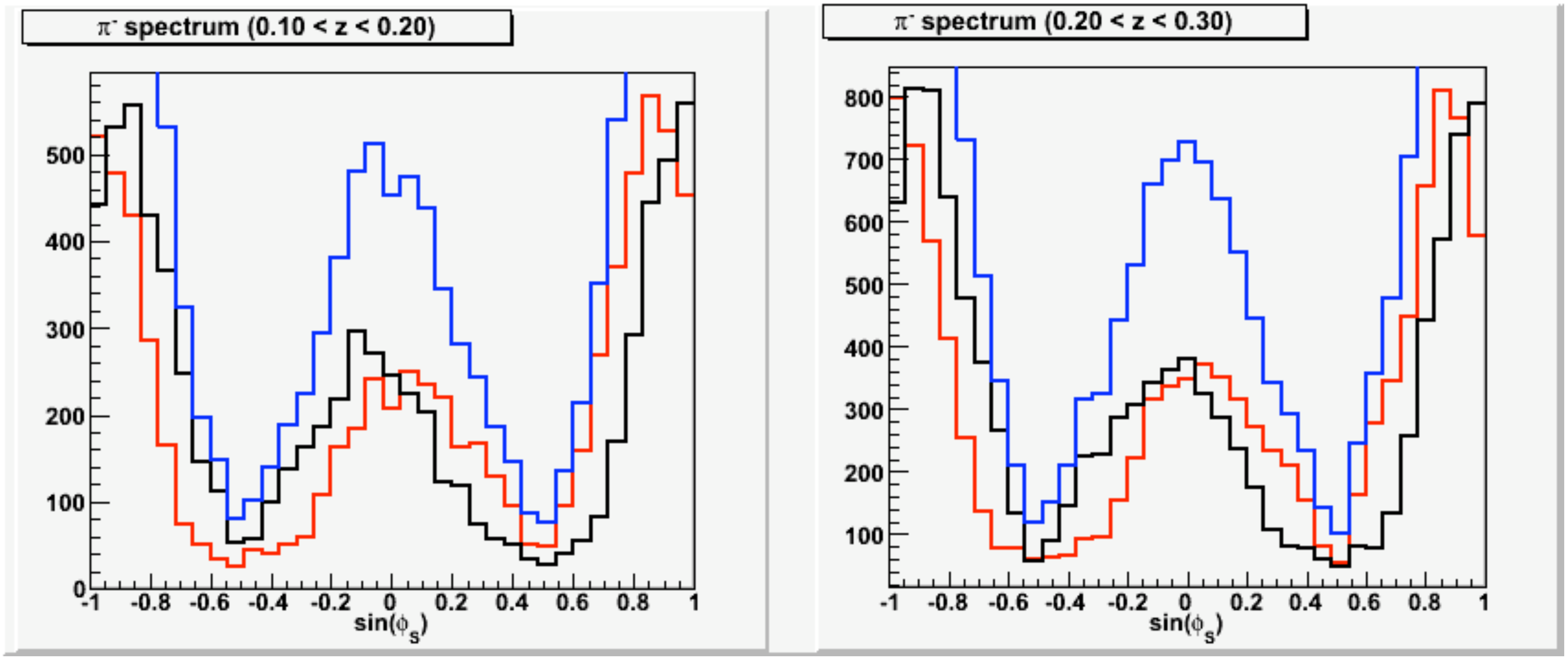
Extra Reference Slides

...after acceptances cancel when ↑ and ↓ polarizations are added



red = up pol., black = down pol., blue = added

Quantifying the Asymmetry

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$$A = \frac{\langle \sin(\Phi_s - \Phi_h) \Delta\sigma^{TU} \rangle}{\langle \sigma^{UU} \rangle}$$

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Quantifying the Asymmetry

$$A = \frac{\langle \sin(\Phi_s - \Phi_h)\Delta\sigma^{TU} \rangle}{\langle \sigma^{UU} \rangle}$$

How do we get the cross-sections from particle counts in the detector?

We sum over both ↑ and ↓ polarizations* and exploit symmetry

*weighted by relative luminosities

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For $0 < \Phi_S - \Phi_h < 180°$:

Azimuthal symmetry requires that

$$N(\Phi_S - \Phi_h)\uparrow = N(\Phi_S - \Phi_h + 180°)\downarrow + \Delta N$$

$$N(\Phi_S - \Phi_h)\downarrow = N(\Phi_S - \Phi_h + 180°)\uparrow + \Delta N$$

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Weighting and summing over opposite detector sides yields

$$A = \frac{N^{+}\uparrow[\sin(\Phi_S - \Phi_h)] + N^{-}\downarrow[\sin(\Phi_S - \Phi_h + 180°)] + N^{+}\downarrow[\sin(\Phi_S - \Phi_h)] + N^{-}\uparrow[\sin(\Phi_S - \Phi_h + 180°)] + 2\Delta N}{\Sigma N}$$

Quantifying the Asymmetry

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$$= \frac{N^{+}\uparrow[\sin(\Phi_S - \Phi_h)] - N^{-}\downarrow[\sin(\Phi_S - \Phi_h)] + N^{+}\downarrow[\sin(\Phi_S - \Phi_h)] - N^{-}\uparrow[\sin(\Phi_S - \Phi_h)] + 2\Delta N}{\Sigma N}$$

Quantifying the Asymmetry

$$A = \frac{\langle \sin(\Phi_s - \Phi_h)\Delta\sigma^{TU} \rangle}{\langle \sigma^{UU} \rangle}$$

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Azimuthal symmetry requires that

$$N^+\uparrow = N^-\downarrow + \Delta N$$

$$N^+\downarrow = N^-\uparrow + \Delta N$$

Weighting and summing over opposite detector sides yields

$$A = \frac{N^+\uparrow[\sin(\Phi_S - \Phi_h)] + N^-\downarrow[\sin(\Phi_S - \Phi_h + 180°)] + N^+\downarrow[\sin(\Phi_S - \Phi_h)] + N^-\uparrow[\sin(\Phi_S - \Phi_h + 180°)] + 2\Delta N}{\Sigma N}$$

$$= \frac{N^+\uparrow[\sin(\Phi_S - \Phi_h)] - N^-\downarrow[\sin(\Phi_S - \Phi_h)] + N^+\downarrow[\sin(\Phi_S - \Phi_h)] - N^-\uparrow[\sin(\Phi_S - \Phi_h)] + 2\Delta N}{\Sigma N}$$

$$= \frac{2\Delta N}{\Sigma N}$$

Quantifying the Asymmetry

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$$N^{+}\downarrow = N^{-}\uparrow + \Delta N$$

Weighting and summing over opposite detector sides yields

$$A = \frac{N^{+}\uparrow[\sin(\Phi_S - \Phi_h)] + N^{-}\downarrow[\sin(\Phi_S - \Phi_h + 180°)] + N^{+}\downarrow[\sin(\Phi_S - \Phi_h)] + N^{-}\uparrow[\sin(\Phi_S - \Phi_h + 180°)] + 2\Delta N}{\Sigma N}$$

$$= \frac{N^{+}\uparrow[\sin(\Phi_S - \Phi_h)] - N^{-}\downarrow[\sin(\Phi_S - \Phi_h)] + N^{+}\downarrow[\sin(\Phi_S - \Phi_h)] - N^{-}\uparrow[\sin(\Phi_S - \Phi_h)] + 2\Delta N}{\Sigma N}$$

$$= \frac{2\Delta N}{\Sigma N}$$

Acceptances cancel if opposing polarizations summed

Quantifying the Asymmetry

$$A = \frac{N_{\sin(\Phi s - \Phi h)}^{\uparrow} + N_{\sin(\Phi s - \Phi h)}^{\downarrow}}{N^{\uparrow} + N^{\downarrow}}$$

How do we get the cross-sections from particle counts in the detector?

We sum over both ↑ and ↓ polarizations*

and exploit symmetry

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$$= \frac{2\Delta N}{\Sigma N}$$

Acceptances cancel if opposing polarizations summed

Quantifying the Asymmetry

$$A = \frac{N_{\sin(\Phi_S - \Phi_h)}{}^{\uparrow}(z, j_T) + N_{\sin(\Phi_S - \Phi_h)}{}^{\downarrow}(z, j_T)}{N^{\uparrow}(z, j_T) + N^{\downarrow}(z, j_T)}$$

How do we get the cross-sections from particle counts in the detector?

We sum over both ↑ and ↓ polarizations* and exploit symmetry

*weighted by relative luminosities

For $0 < \Phi_S - \Phi_h < 180°$:

Azimuthal symmetry requires that

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$$N^{+}\downarrow = N^{-}\uparrow + \Delta N$$

Weighting and summing over opposite detector sides yields

$$A = \frac{N^{+}\uparrow[\sin(\Phi_S - \Phi_h)] + N^{-}\downarrow[\sin(\Phi_S - \Phi_h + 180°)] + N^{+}\downarrow[\sin(\Phi_S - \Phi_h)] + N^{-}\uparrow[\sin(\Phi_S - \Phi_h + 180°)] + 2\Delta N}{\Sigma N}$$

$$= \frac{N^{+}\uparrow[\sin(\Phi_S - \Phi_h)] - N^{-}\downarrow[\sin(\Phi_S - \Phi_h)] + N^{+}\downarrow[\sin(\Phi_S - \Phi_h)] - N^{-}\uparrow[\sin(\Phi_S - \Phi_h)] + 2\Delta N}{\Sigma N}$$

$$= \frac{2\Delta N}{\Sigma N}$$

Acceptances cancel if opposing polarizations summed

Extraction of δq

F. Yuan, arXiv:0804.3047 [hep-ph] (2008)

$$\frac{d\sigma}{dy_1 dy_2 dp_T^2 dz d^2 j_T} \equiv \frac{d\sigma}{d\mathbf{P.S.}} = \frac{d\sigma_{UU}}{d\mathbf{P.S.}} + |S_\perp| \frac{|j_T|}{m_\pi} \sin(\phi_\pi - \phi_S) \frac{d\sigma_{TU}}{d\mathbf{P.S.}}$$

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phase space

Extraction of δq

F. Yuan, arXiv:0804.3047 [hep-ph] (2008)

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phase space

polarization

Extraction of δq

F. Yuan, arXiv:0804.3047 [hep-ph] (2008)

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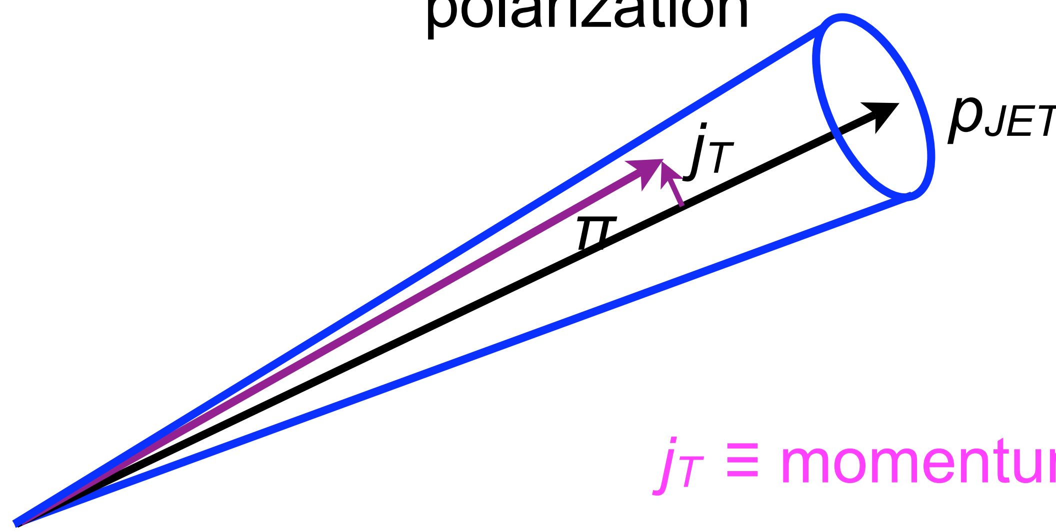
phase space

polarization



$j_T \equiv$ momentum of π transverse to jet

Extraction of δq

F. Yuan, arXiv:0804.3047 [hep-ph] (2008)

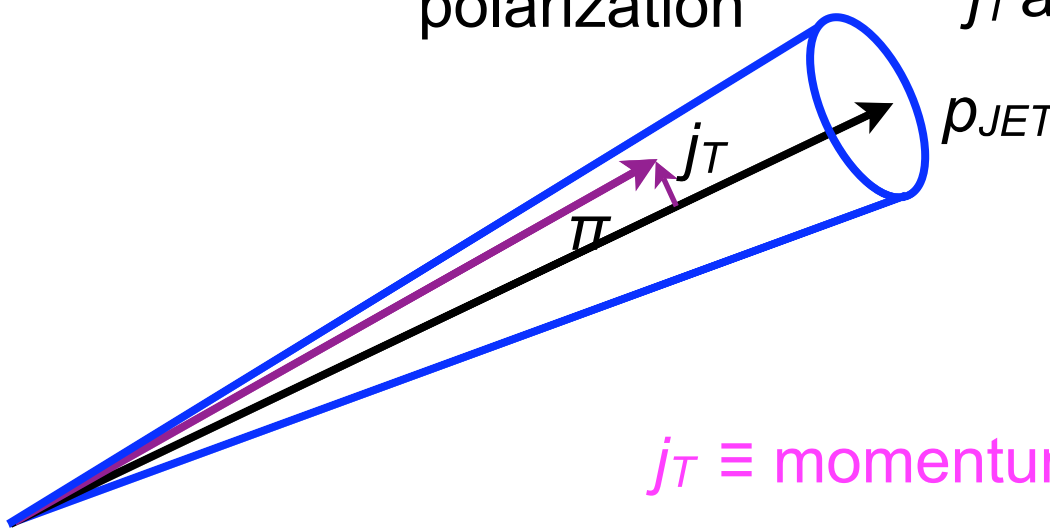
$$\frac{d\sigma}{dy_1 dy_2 dp_T^2 dz d^2 j_T} \equiv \frac{d\sigma}{d\mathbf{P.S.}} = \frac{d\sigma_{UU}}{d\mathbf{P.S.}} + |S_\perp| \frac{|j_T|}{m_\pi} \sin(\phi_\pi - \phi_S) \frac{d\sigma_{TU}}{d\mathbf{P.S.}}$$

phase space

polarization

j_T angle

pol. angle



$j_T \equiv$ momentum of π transverse to jet

Extraction of δq

F. Yuan, arXiv:0804.3047 [hep-ph] (2008)

unpolarized, polarized cross-sections

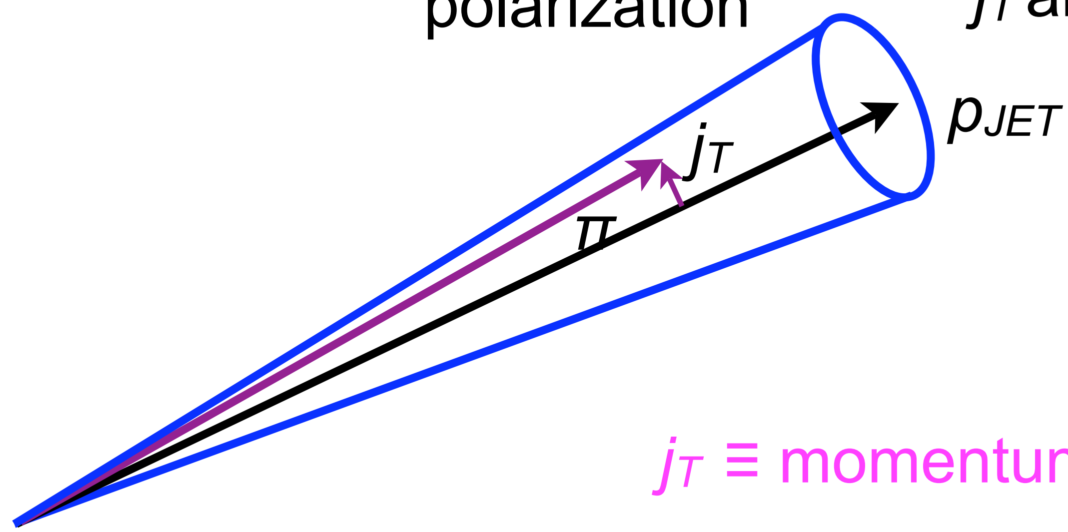
$$\frac{d\sigma}{dy_1 dy_2 dp_T^2 dz d^2 j_T} \equiv \frac{d\sigma}{d\mathbf{P.S.}} = \frac{d\sigma_{UU}}{d\mathbf{P.S.}} + |S_\perp| \frac{|j_T|}{m_\pi} \sin(\phi_\pi - \phi_S) \frac{d\sigma_{TU}}{d\mathbf{P.S.}}$$

phase space

polarization

j_T angle

pol. angle



j_T ≡ momentum of π transverse to jet

$$\frac{d\sigma_{UU}}{d\mathbf{P.S.}} = \sum_{a,b,c} x' f_b(x') x f_a(x) D_c^h(z, j_T) H_{ab\to cd}$$

$$\frac{d\sigma_{TU}}{d\mathbf{P.S.}} = \sum_{b,q} x' f_b(x') x \delta q(x) \Delta^N D_q(z, j_T) H_{qb\to qb}^{\text{Collins}}$$

Extraction of δq

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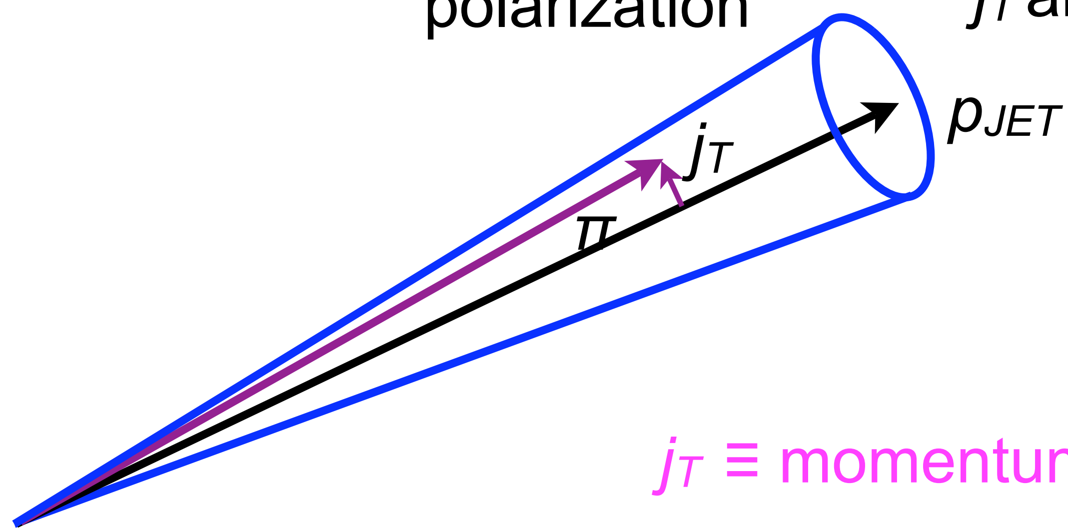
phase space

polarization

j_T angle

pol. angle



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(Unpolarized) quark distributions at x ≈ 0.2

Extraction of δq

F. Yuan, arXiv:0804.3047 [hep-ph] (2008)

unpolarized, polarized cross-sections

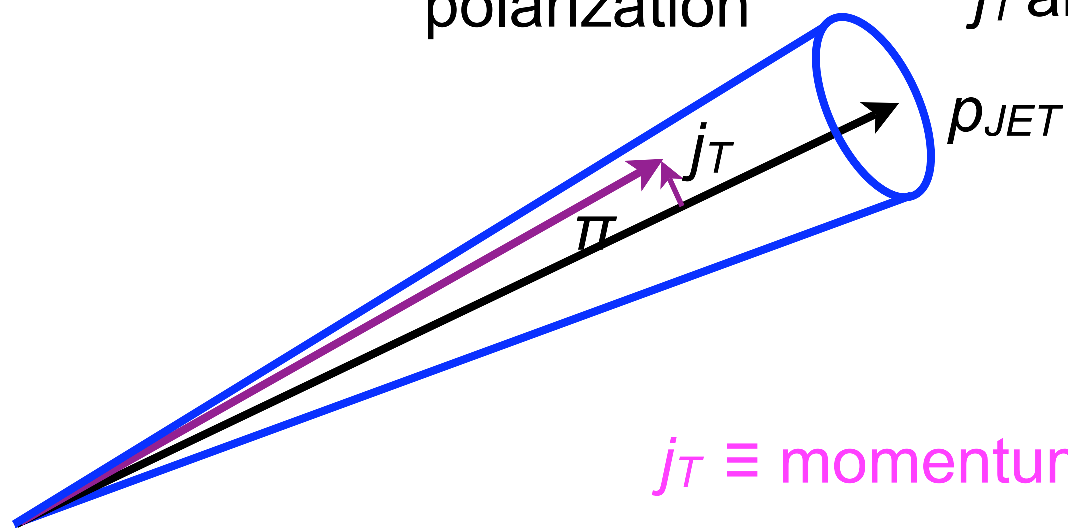
$$\frac{d\sigma}{dy_1 dy_2 dp_T^2 dz d^2 j_T} \equiv \frac{d\sigma}{d\mathbf{P.S.}} = \frac{d\sigma_{UU}}{d\mathbf{P.S.}} + |S_\perp| \frac{|j_T|}{m_\pi} \sin(\phi_\pi - \phi_S) \frac{d\sigma_{TU}}{d\mathbf{P.S.}}$$

phase space

polarization

j_T angle

pol. angle



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(Unpolarized) quark distributions at $x \approx 0.2$

Fragmentation functions (Collins, Sivers)

Extraction of δq

F. Yuan, arXiv:0804.3047 [hep-ph] (2008)

unpolarized, polarized cross-sections

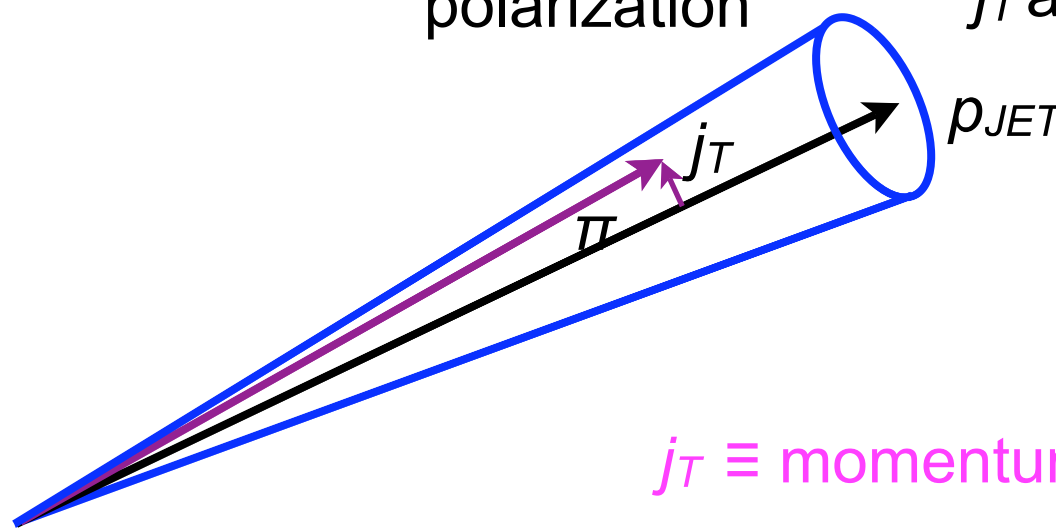
$$\frac{d\sigma}{dy_1 dy_2 dp_T^2 dz d^2 j_T} \equiv \frac{d\sigma}{d\mathbf{P.S.}} = \frac{d\sigma_{UU}}{d\mathbf{P.S.}} + |S_\perp| \frac{|j_T|}{m_\pi} \sin(\phi_\pi - \phi_S) \frac{d\sigma_{TU}}{d\mathbf{P.S.}}$$

phase space

polarization

j_T angle

pol. angle



$j_T \equiv$ momentum of π transverse to jet

Extraction of Collins fragmentation function from fit to SIDIS data (HERMES, COMPASS) and Belle Collab. data (KEK)
(Anselmino, *et al.*, 2008)

$$\frac{d\sigma_{UU}}{d\mathbf{P.S.}} = \sum_{a,b,c} x' f_b(x') x f_a(x) D_c^h(z, j_T) H_{ab\to cd}$$

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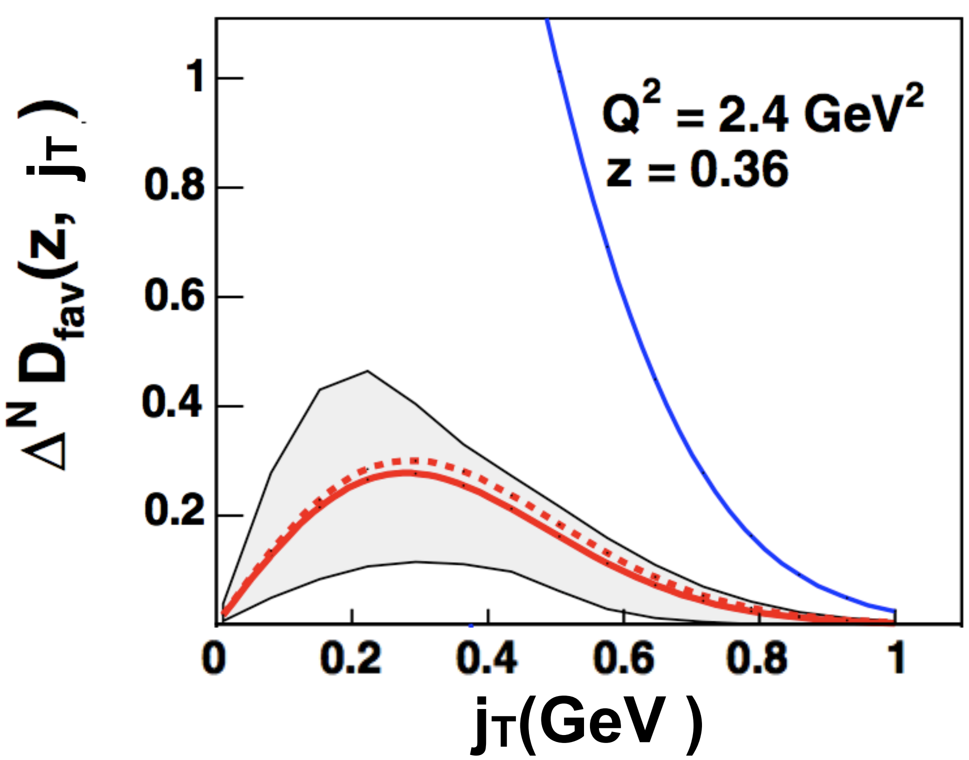
(Unpolarized) quark distributions at x ≈ 0.2

Fragmentation functions (Collins, Sivers)



Isospin-favored Collins frag. function

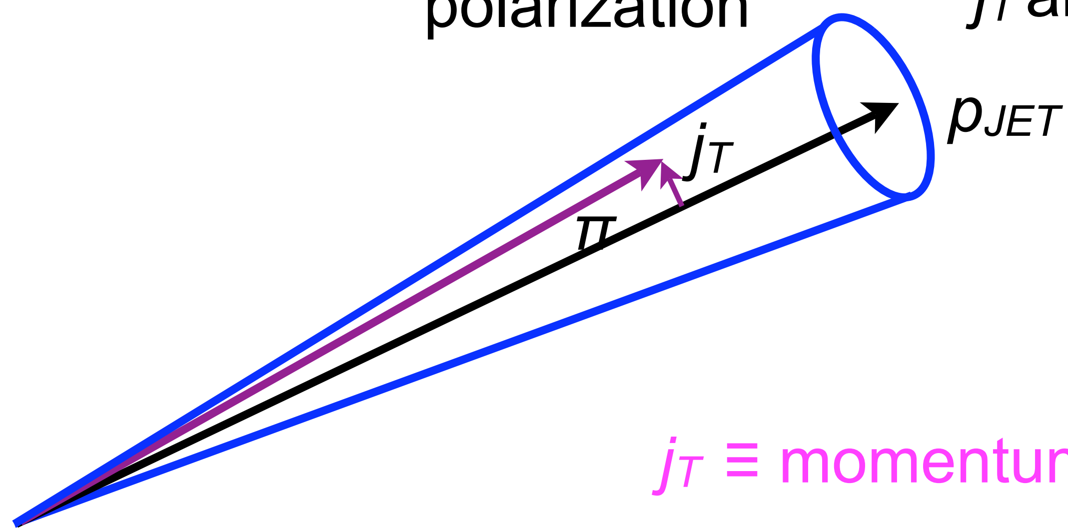
Extraction of δq

F. Yuan, arXiv:0804.3047 [hep-ph] (2008)

unpolarized, polarized cross-sections

$$\frac{d\sigma}{dy_1 dy_2 dp_T^2 dz d^2 j_T} \equiv \frac{d\sigma}{d\mathbf{P.S.}} = \frac{d\sigma_{UU}}{d\mathbf{P.S.}} + |S_\perp| \frac{|j_T|}{m_\pi} \sin(\phi_\pi - \phi_S) \frac{d\sigma_{TU}}{d\mathbf{P.S.}}$$

phase space — polarization — j_T angle — pol. angle



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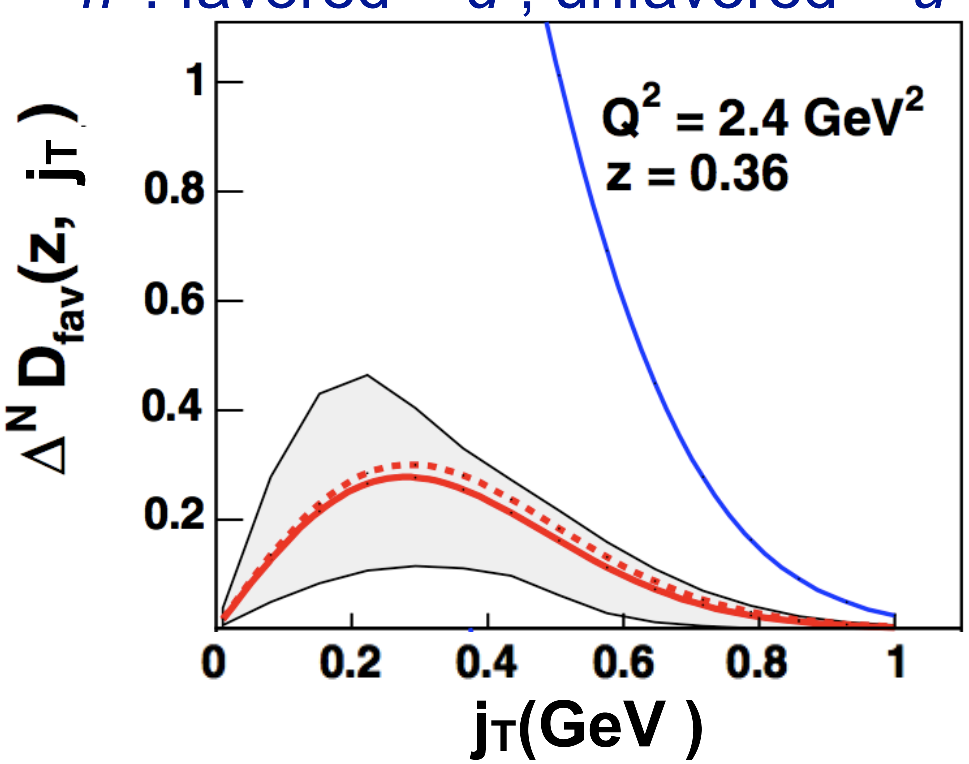
π^+: favored = u , unfavored = d

π^-: favored = d , unfavored = u



$$\frac{d\sigma_{UU}}{d\mathbf{P.S.}} = \sum_{a,b,c} x' f_b(x') x f_a(x) D_c^h(z, j_T) H_{ab\to cd}$$

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(Unpolarized) quark distributions at x ≈ 0.2

Fragmentation functions (Collins, Sivers)

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Extraction of δq

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unpolarized, polarized cross-sections

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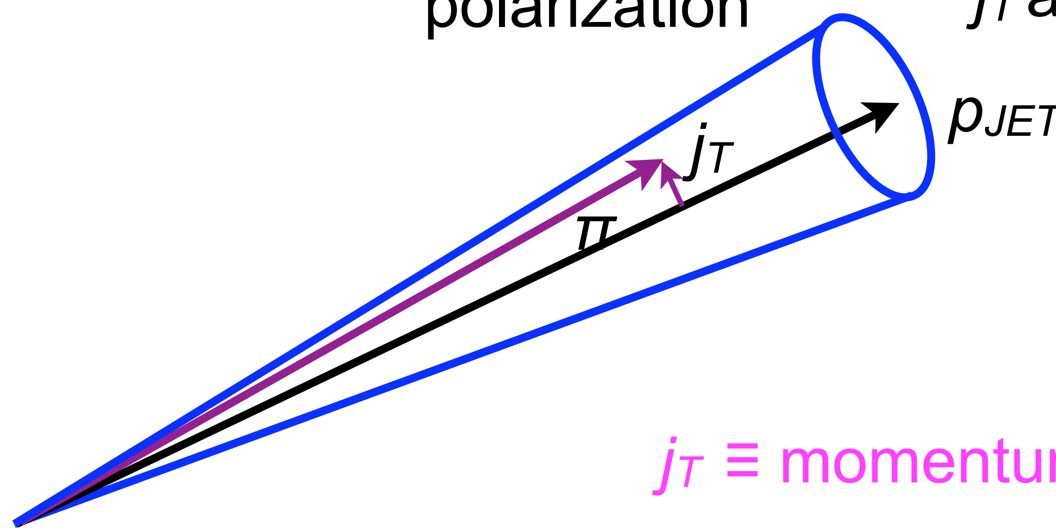
phase space

polarization

j_T angle

pol. angle



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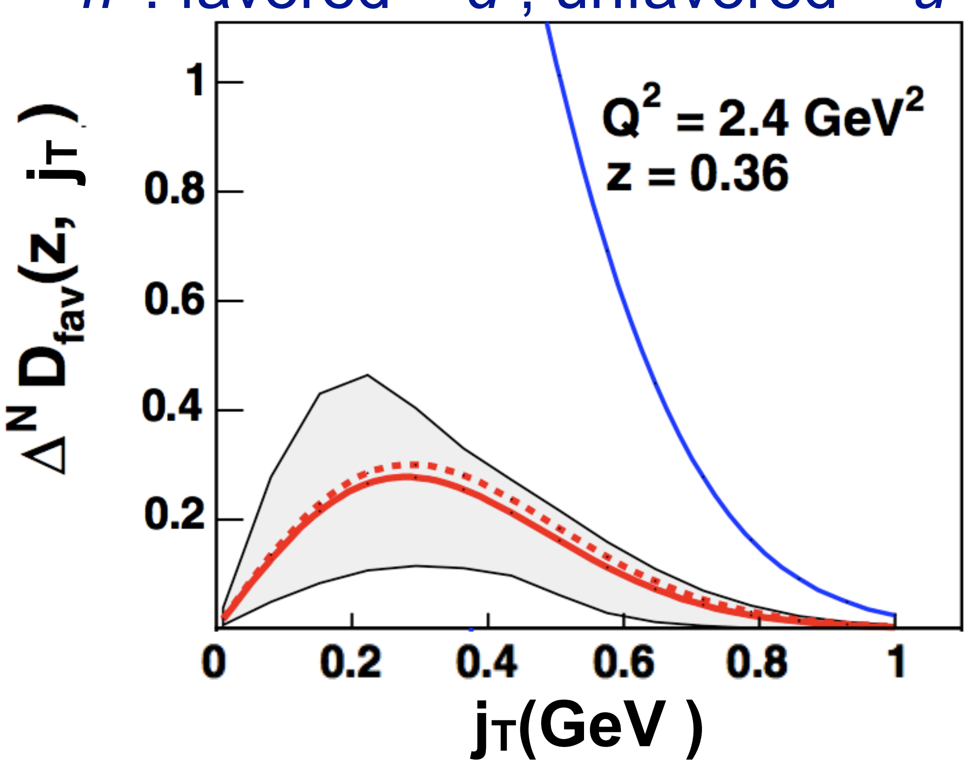


(Unpolarized) quark distributions at x ≈ 0.2

Fragmentation functions (Collins, Sivers)

Isospin-favored Collins frag. function

Hard scattering term ~0.4-0.5

Extraction of δq

F. Yuan, arXiv:0804.3047 [hep-ph] (2008)

unpolarized, polarized cross-sections

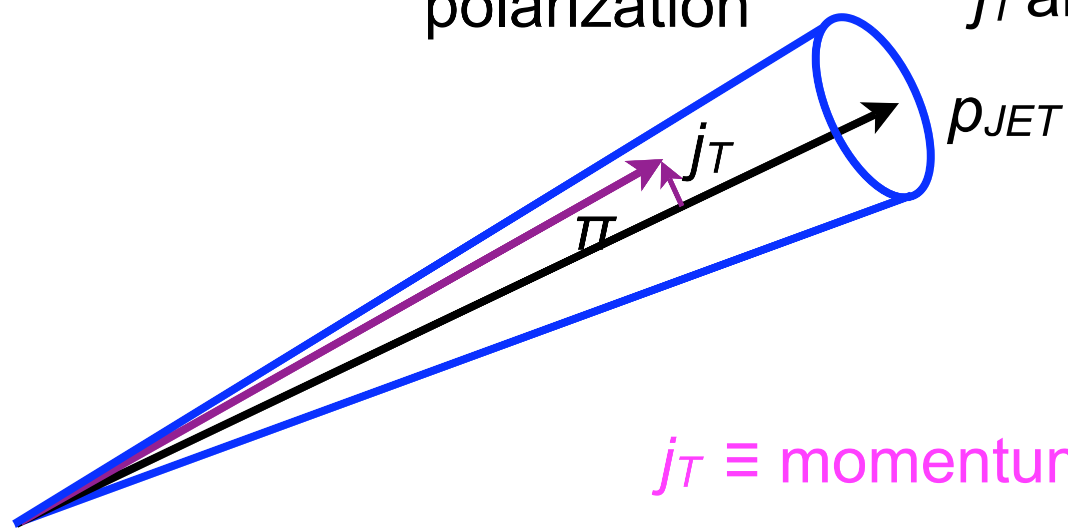
$$\frac{d\sigma}{dy_1 dy_2 dp_T^2 dz d^2 j_T} \equiv \frac{d\sigma}{d\mathbf{P.S.}} = \frac{d\sigma_{UU}}{d\mathbf{P.S.}} + |S_\perp| \frac{|j_T|}{m_\pi} \sin(\phi_\pi - \phi_S) \frac{d\sigma_{TU}}{d\mathbf{P.S.}}$$

phase space

polarization

j_T angle

pol. angle



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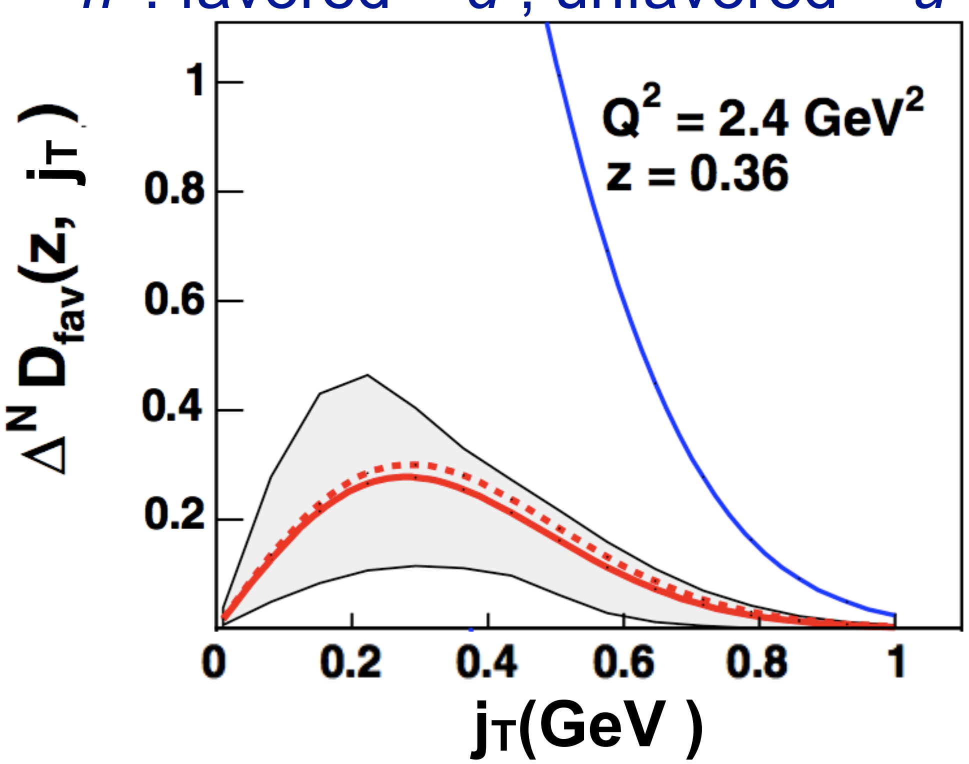

Isospin-favored Collins frag. function

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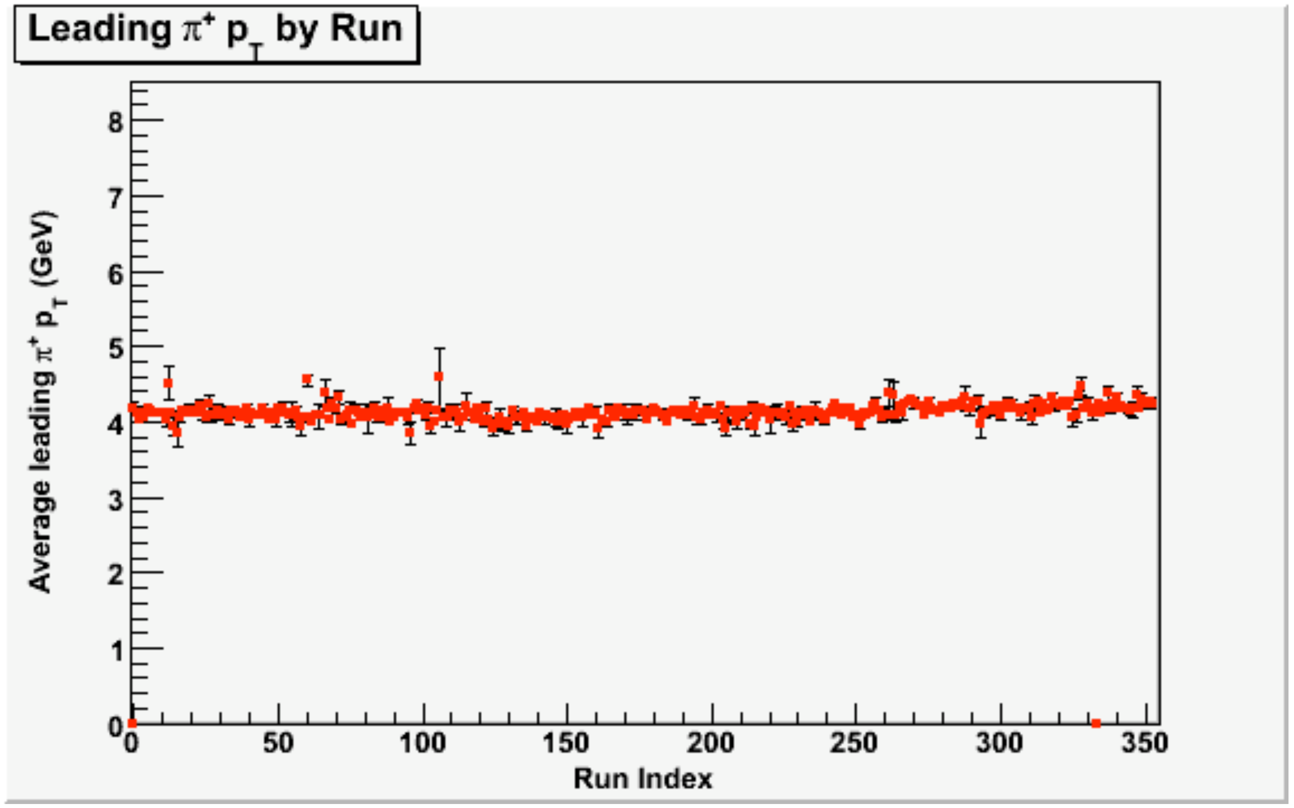
(Unpolarized) quark distributions at x ≈ 0.2

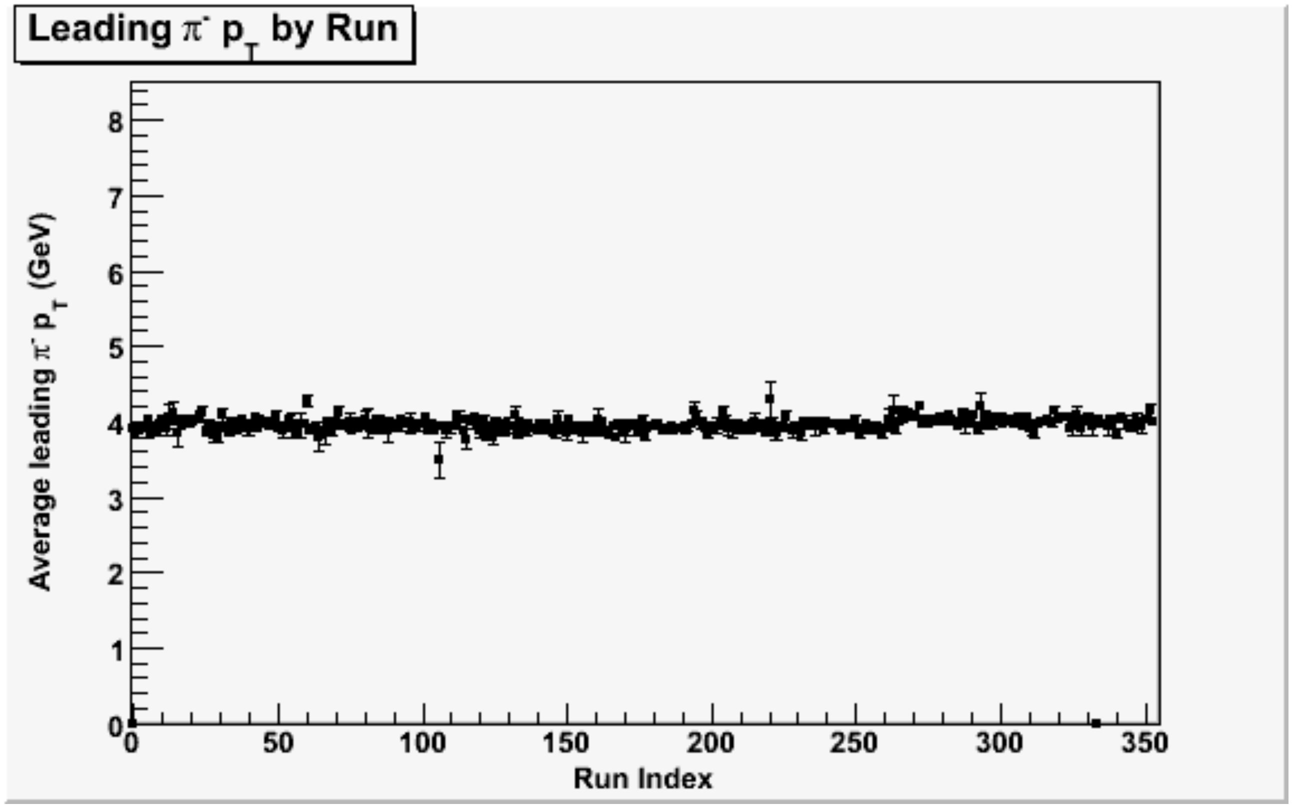
Fragmentation functions (Collins, Sivers)

Hard scattering term ~0.4-0.5

Quark transversity

Quality Assessment:





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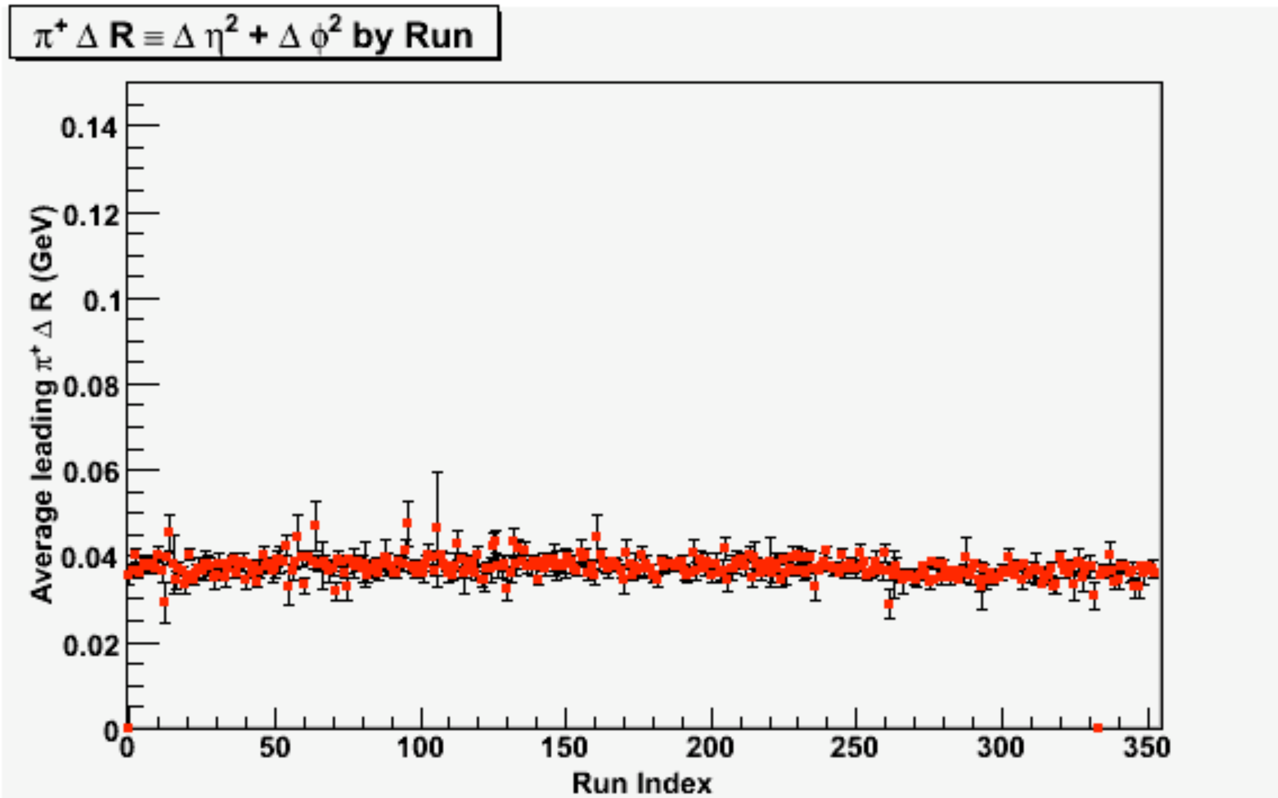

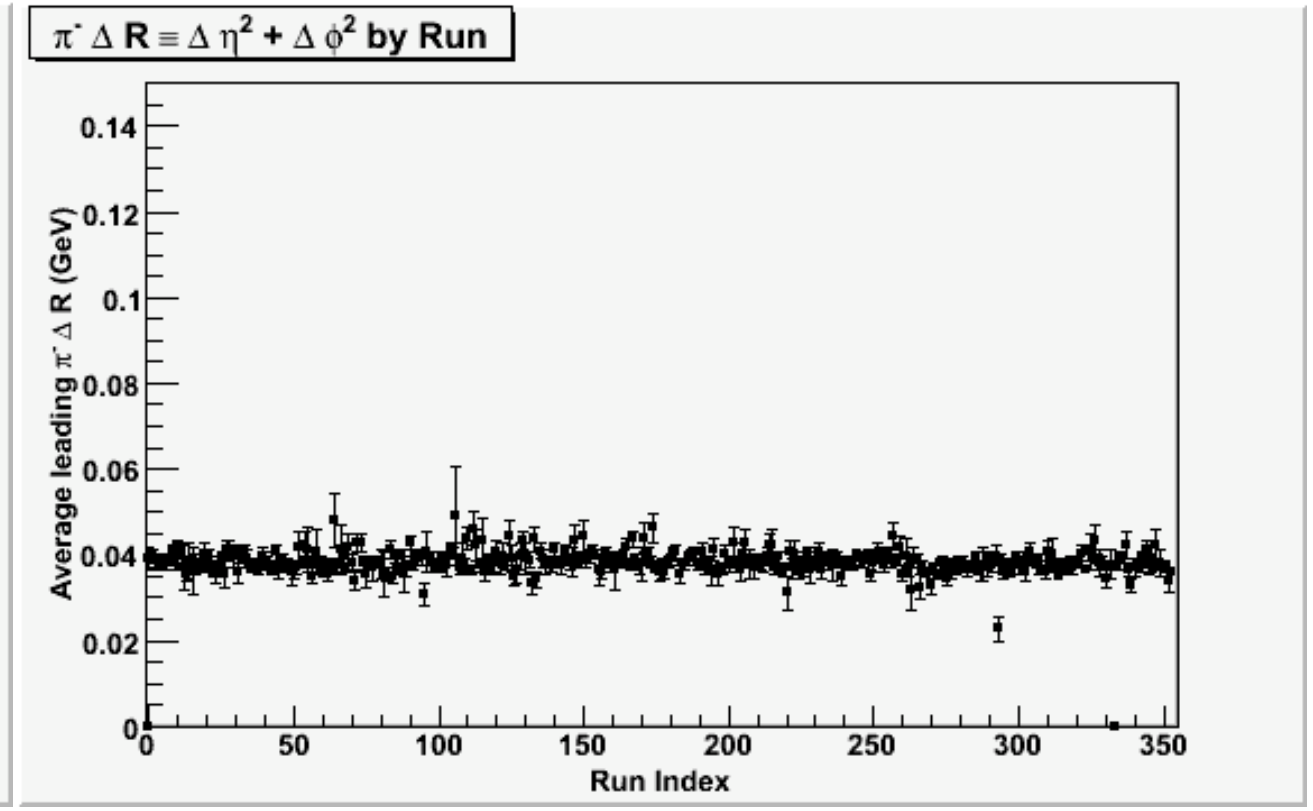

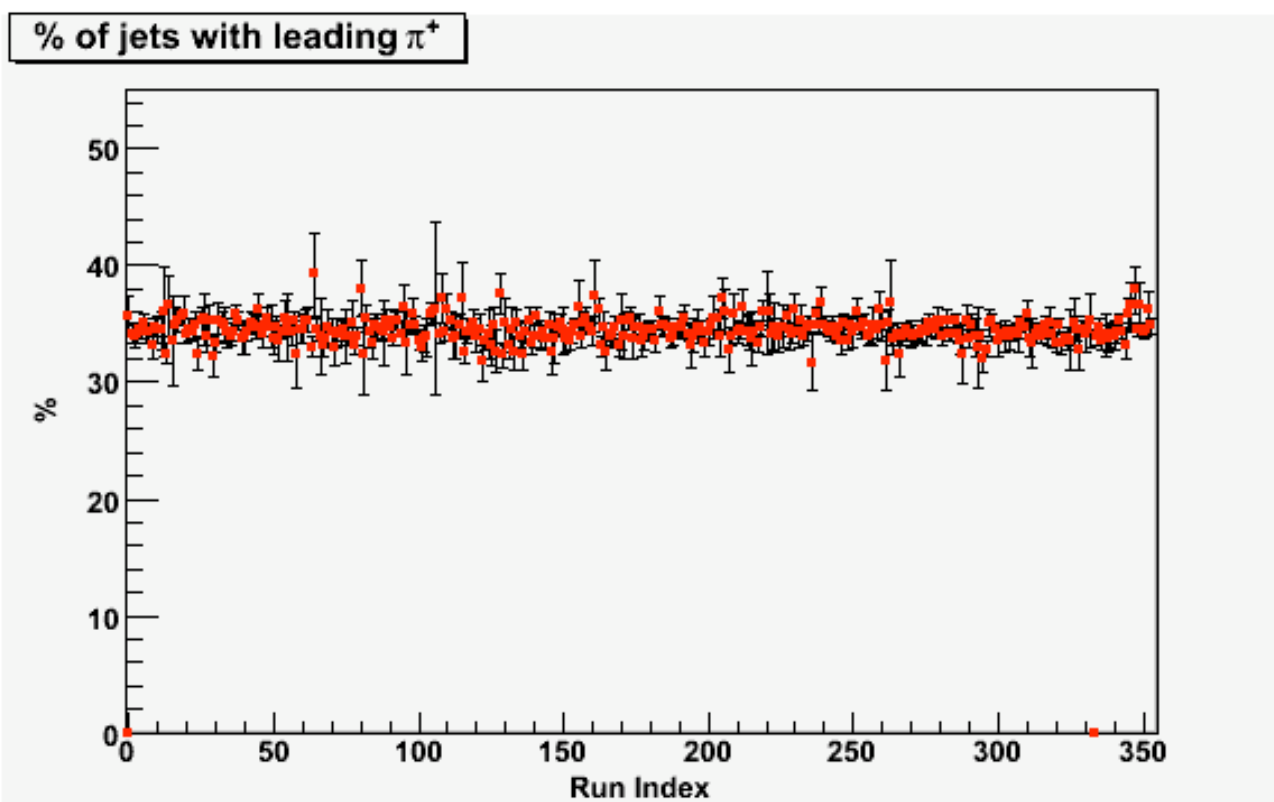

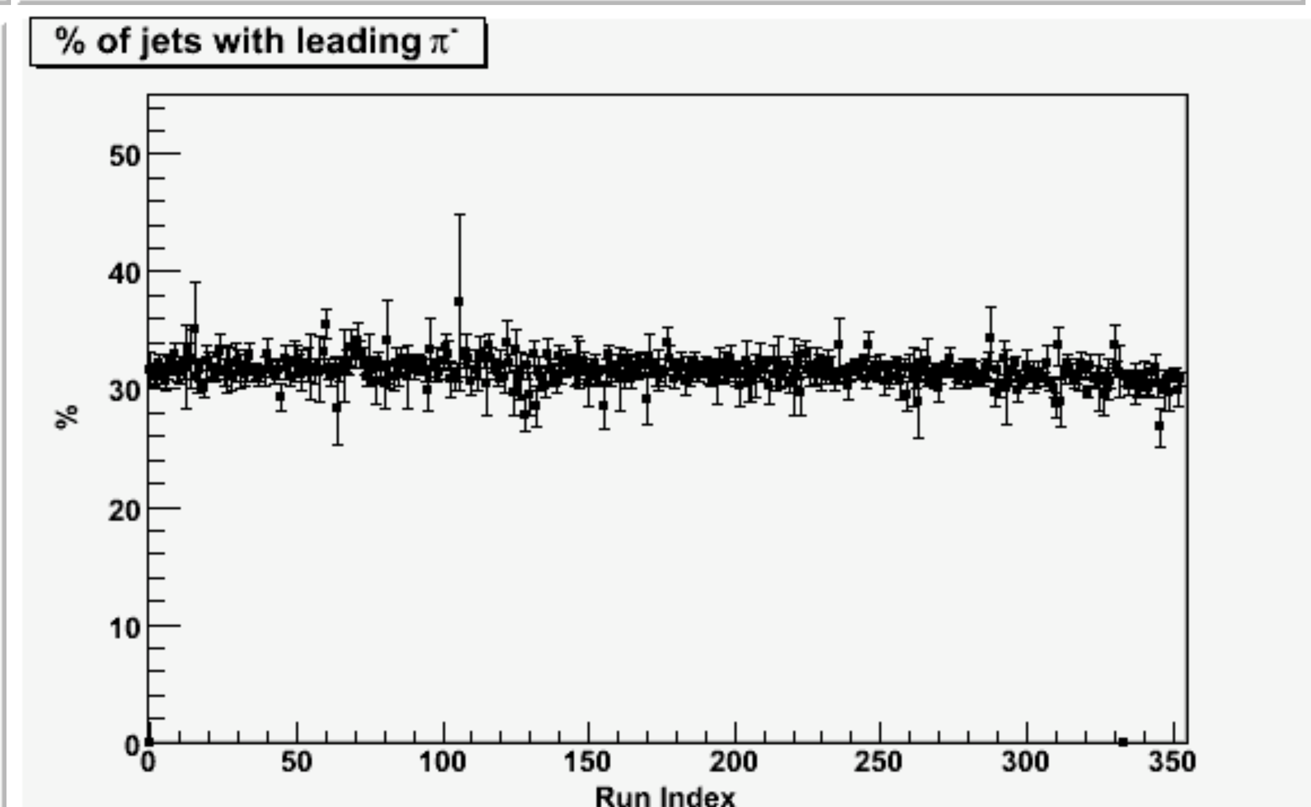

Effect on z due to triggering on neutral particles