Measurement of Quark Transversity through the Collins Mechanism in Mid-Rapidity Jets in p↑p Collisions at STAR

Robert Fersch
University of Kentucky
for the STAR Collaboration

Talk for the 2009 April Meeting of the American Physical Society

Motivation: Understanding the Parton Content of the Nucleon

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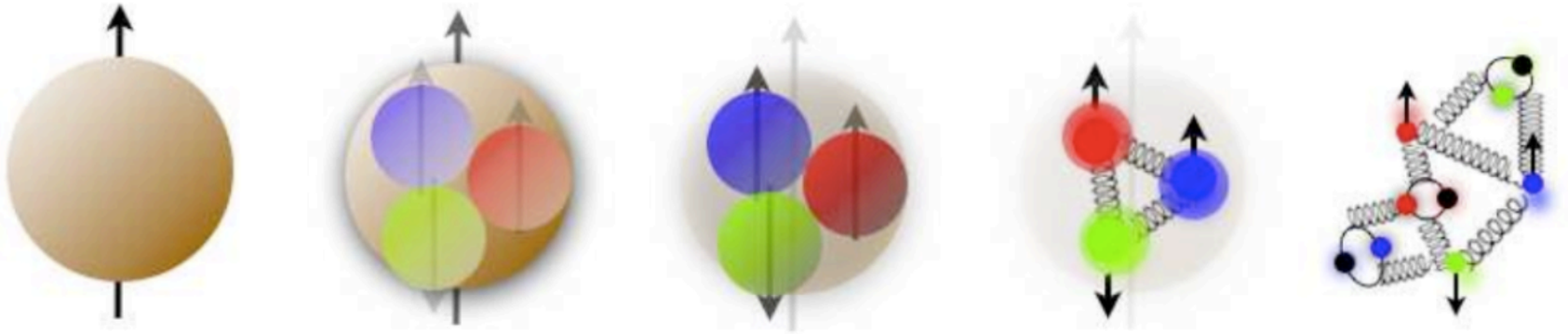

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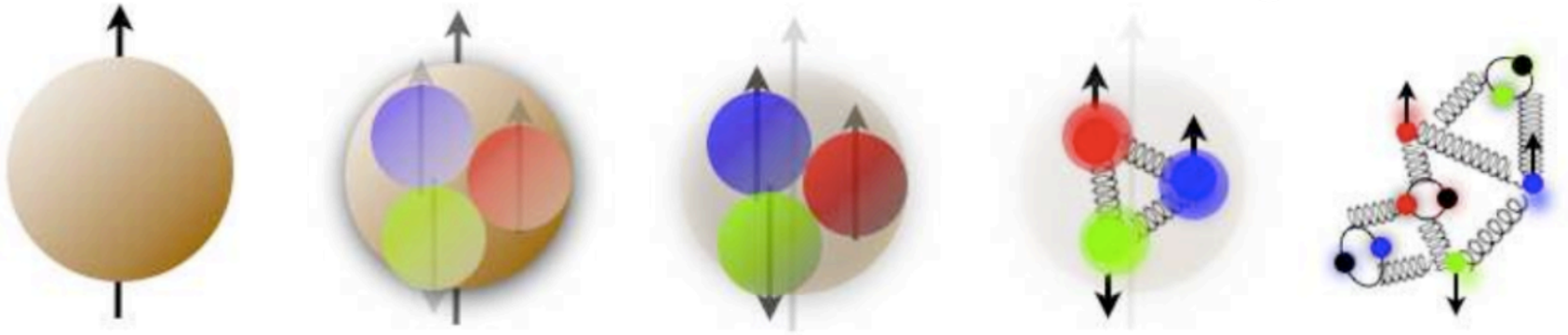
low energy ⟶ high energy



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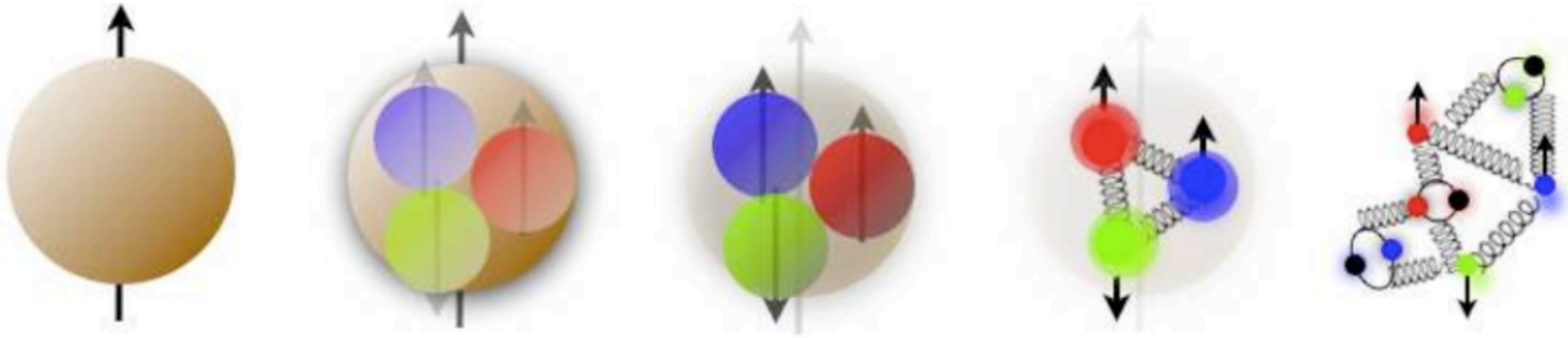

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Pieces of the puzzle:

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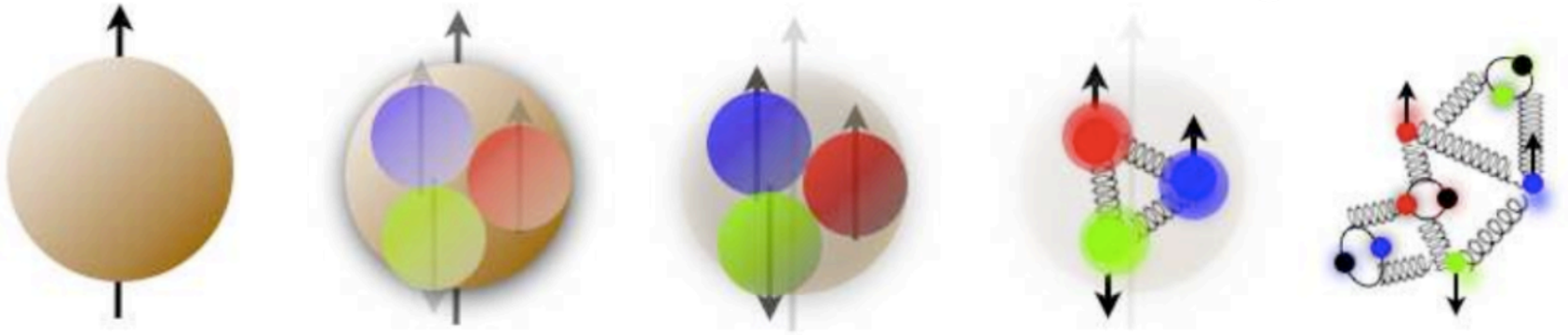

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Pieces of the puzzle:

(unpolarized scattering experiments) ⟶

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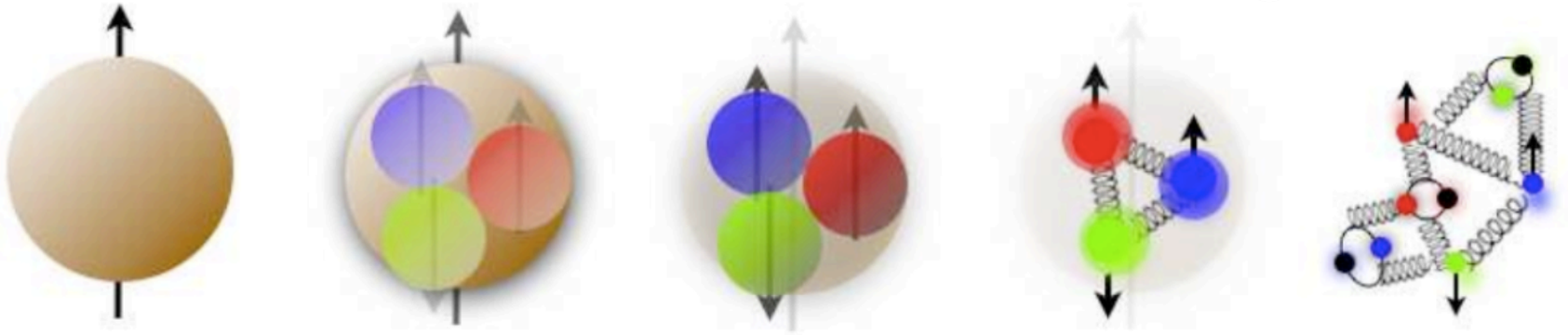

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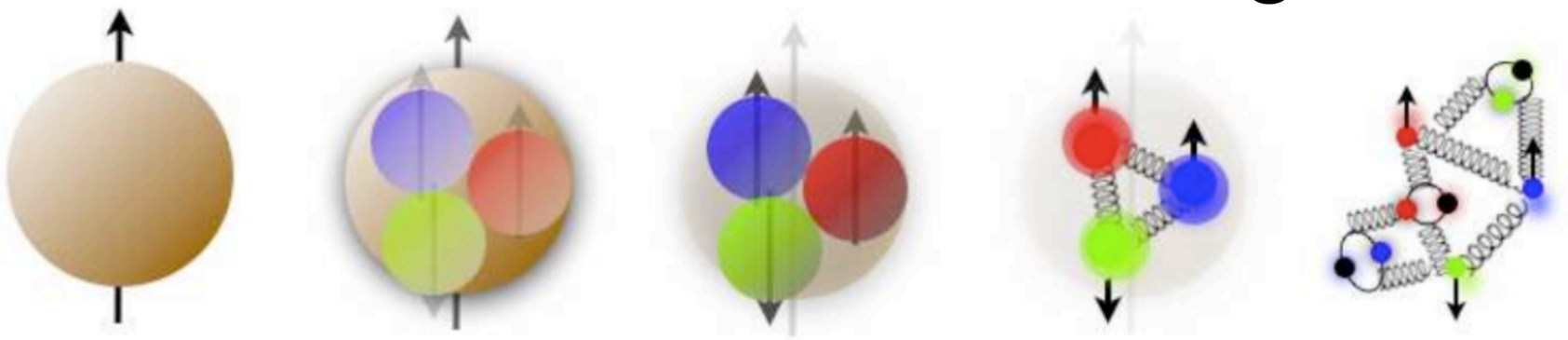

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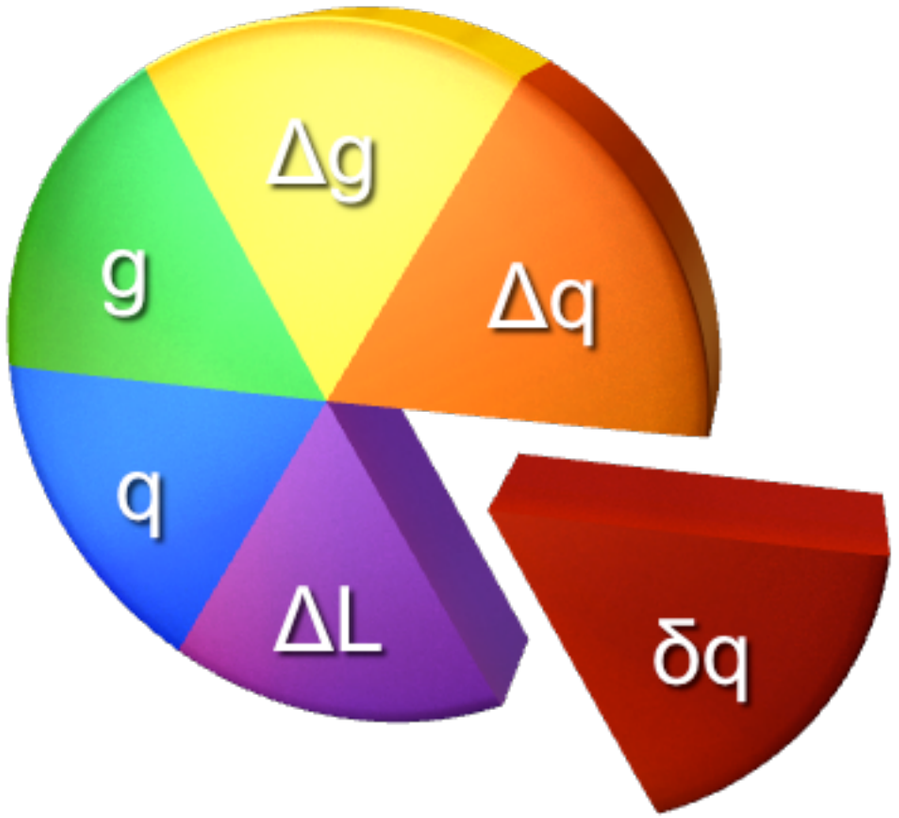

(polarized scattering experiments)

Quark "transversity": spin perpendicular to the proton momentum direction

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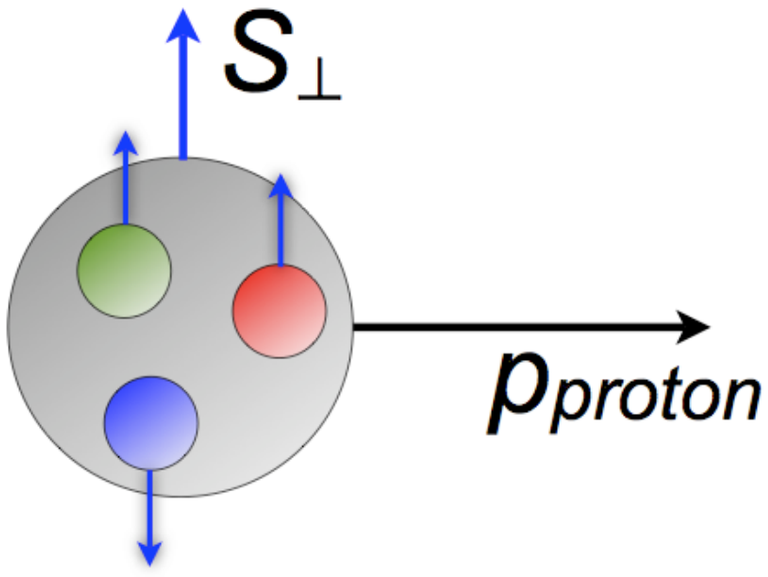

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$$\delta q \equiv q^{\uparrow} - q^{\downarrow}$$

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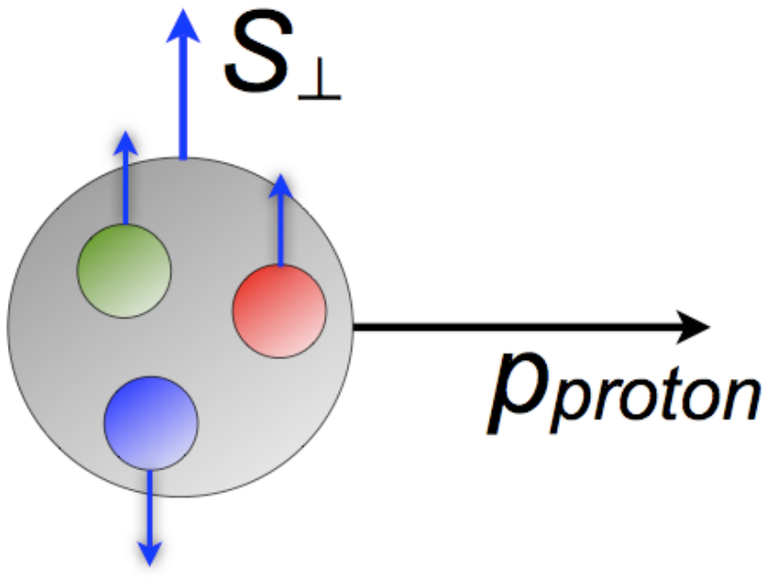

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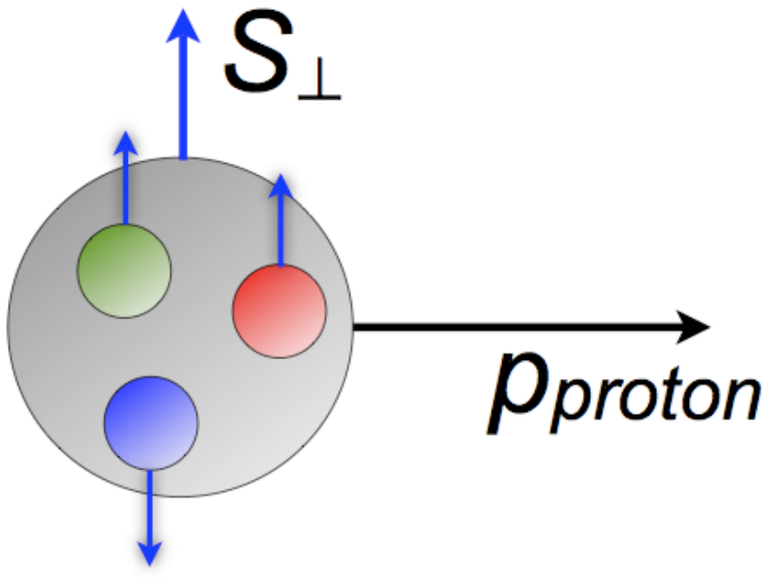

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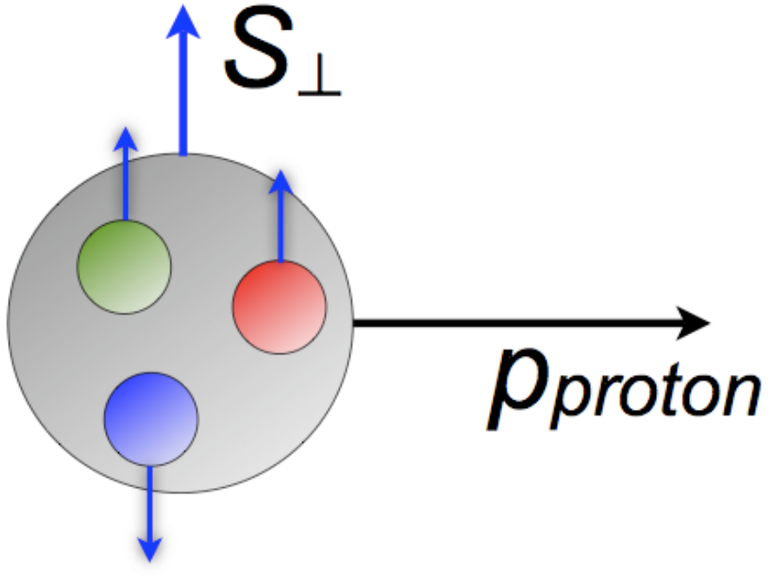

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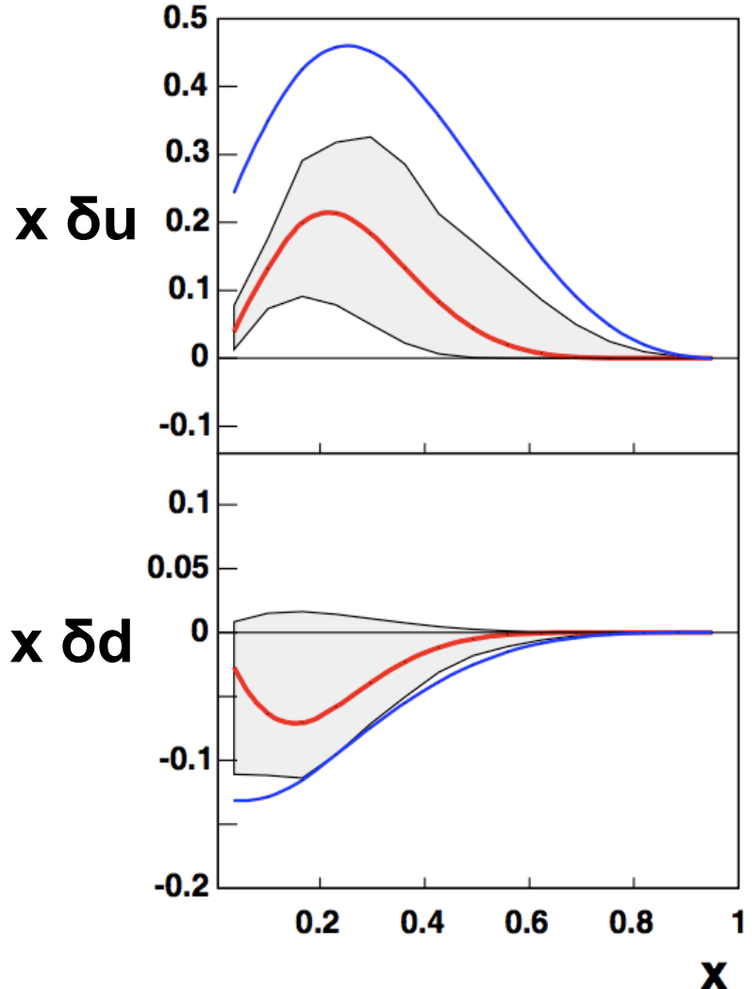

PRD **75,** 054032 (2006) Anselmino, *et al.*

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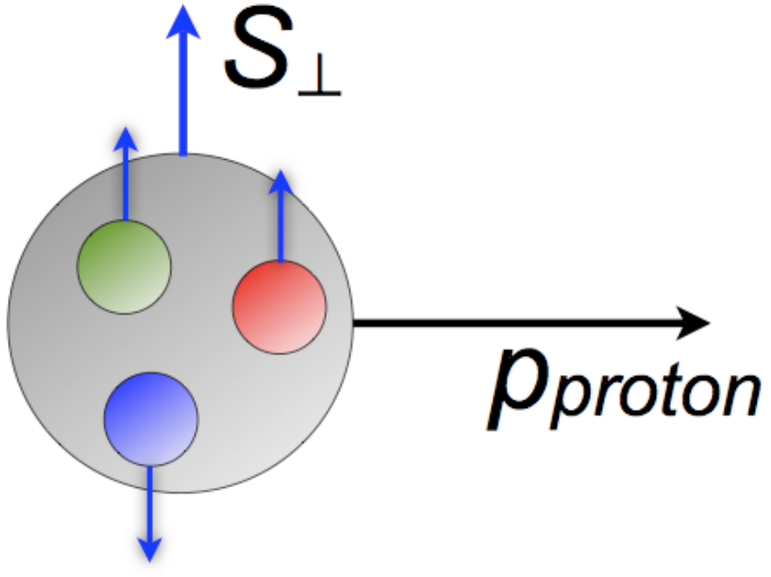

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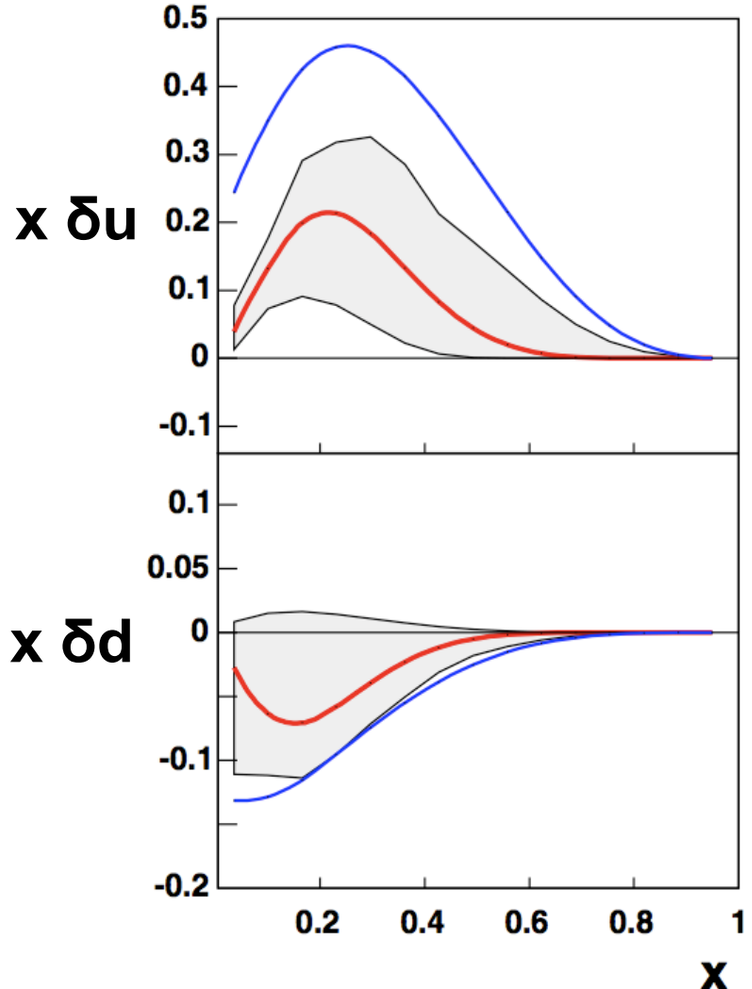

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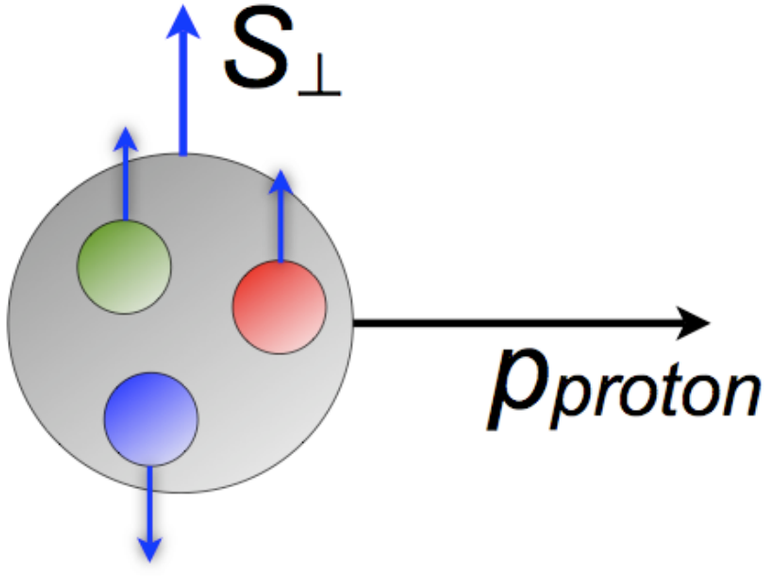

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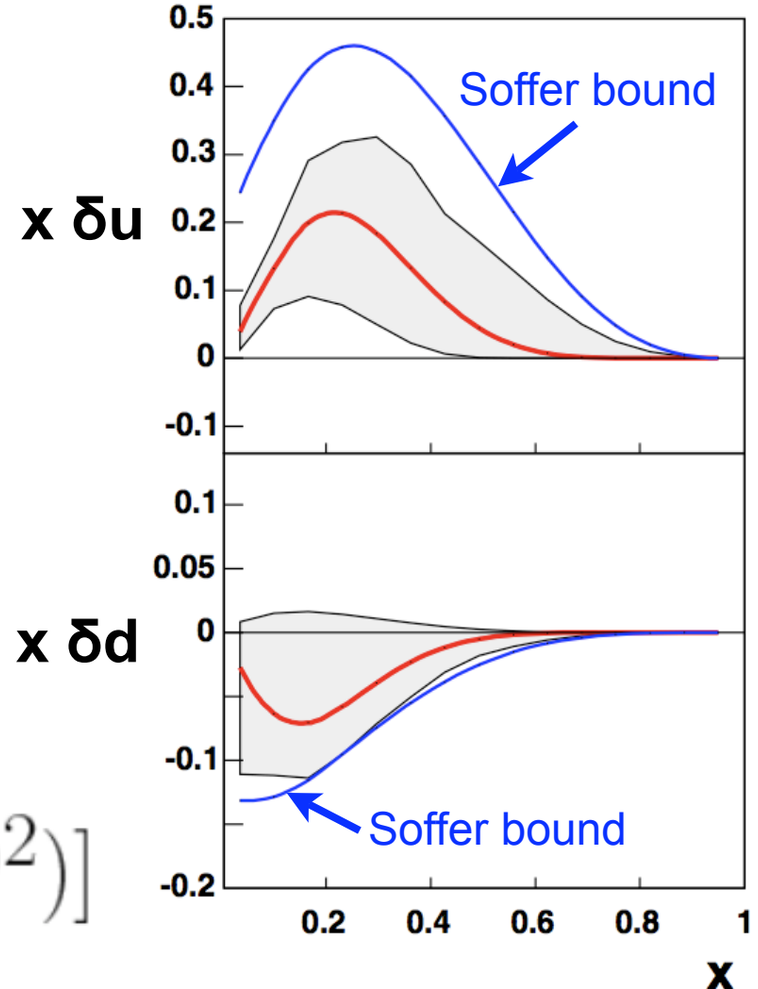
- Constrained by *Soffer bound*:

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



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Experimental access to δq

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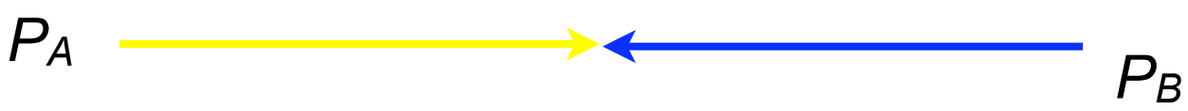
proton-proton scattering:

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



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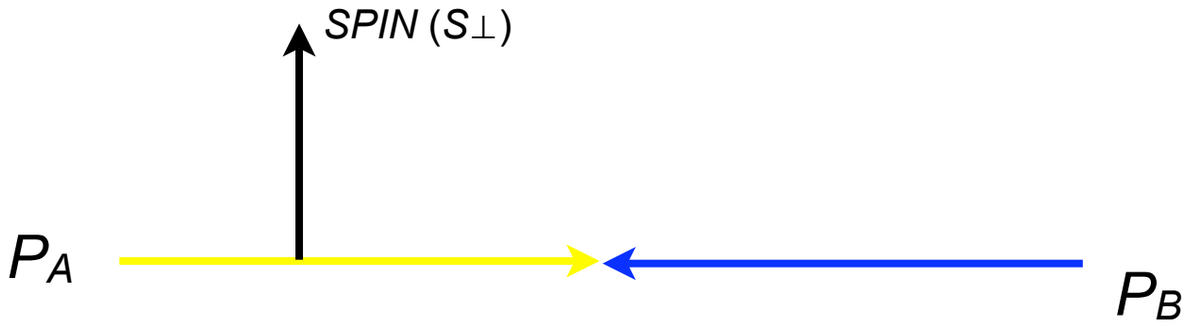

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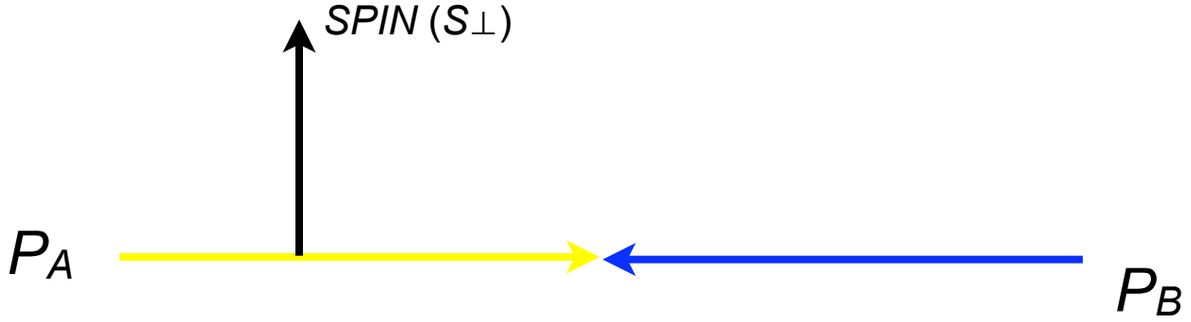

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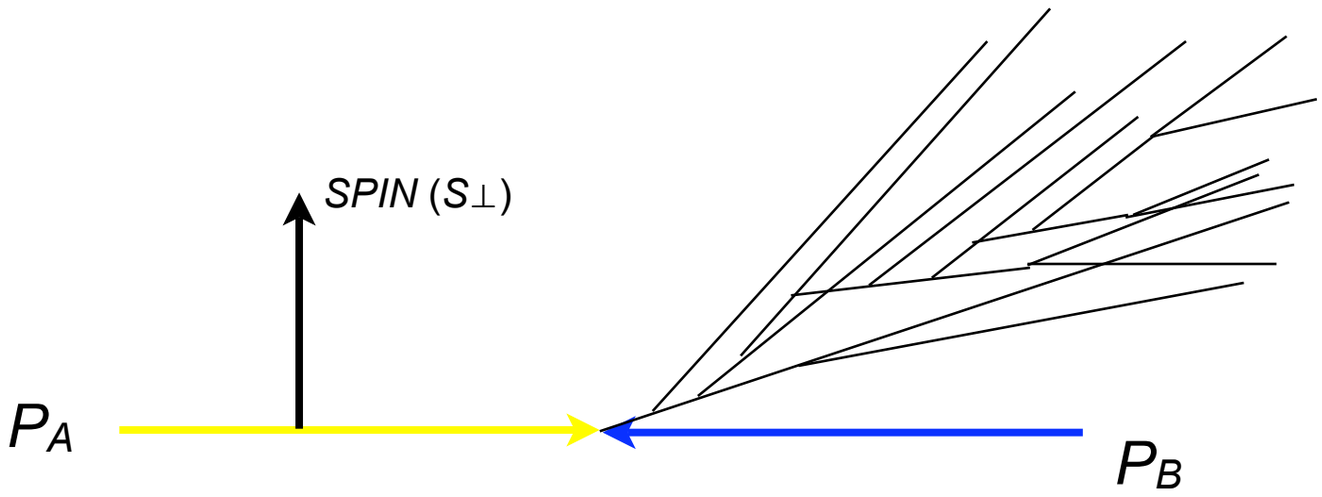

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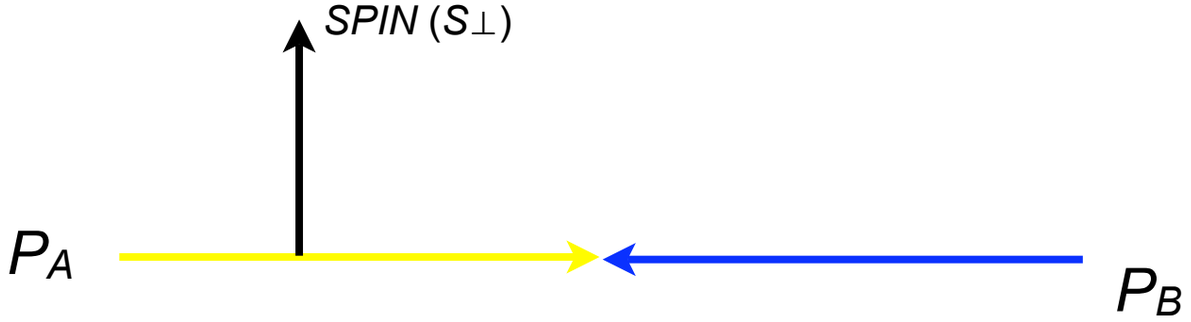

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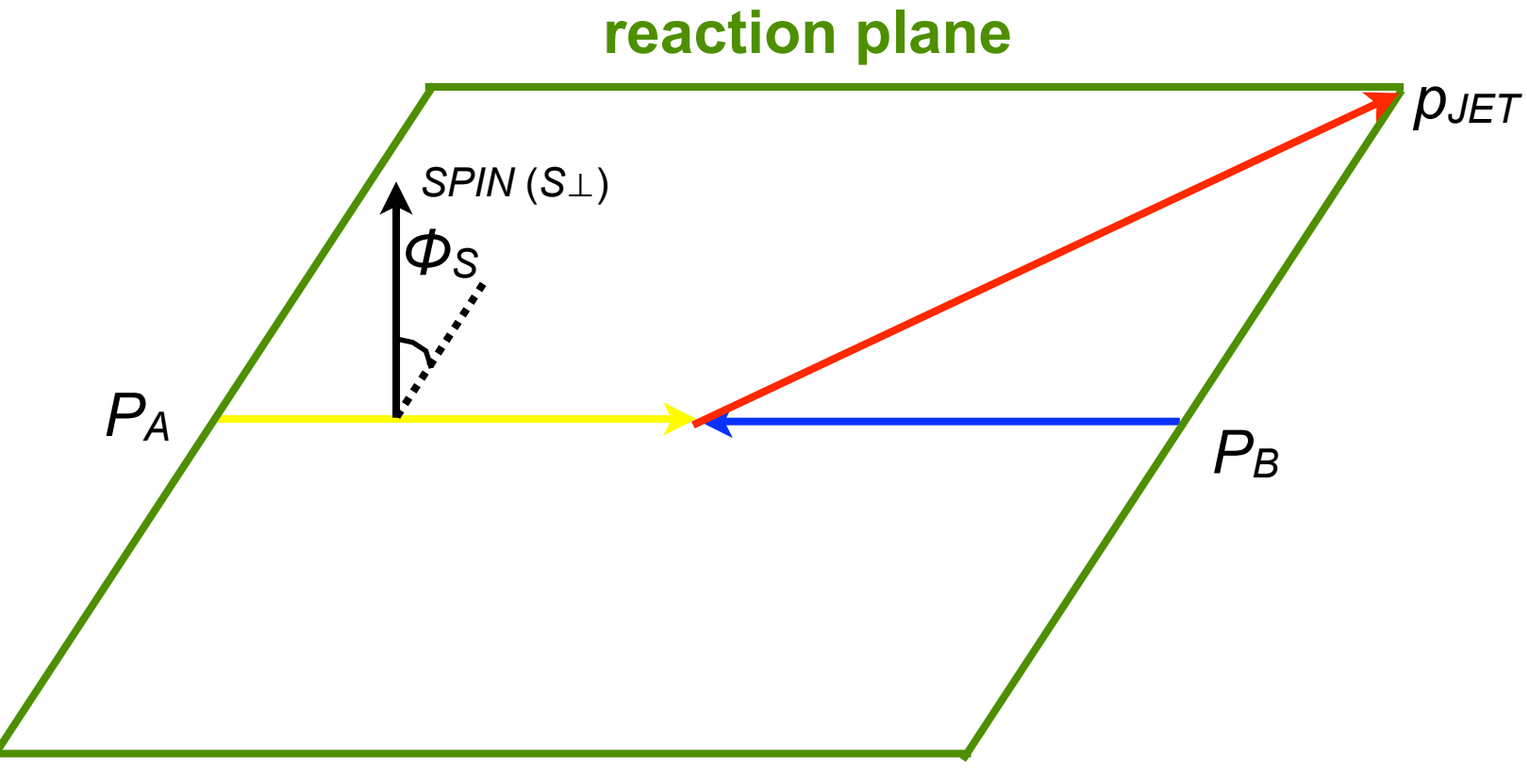

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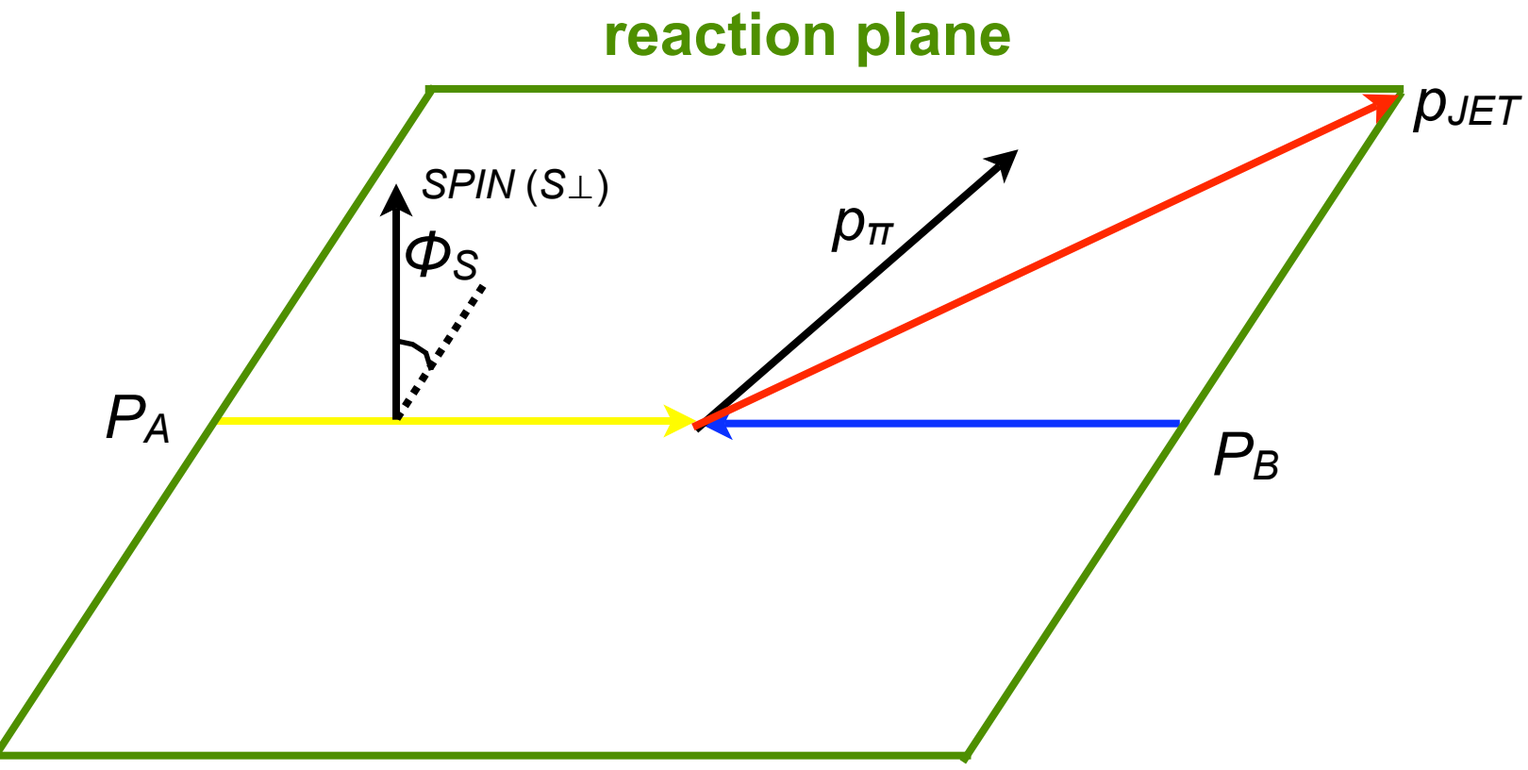

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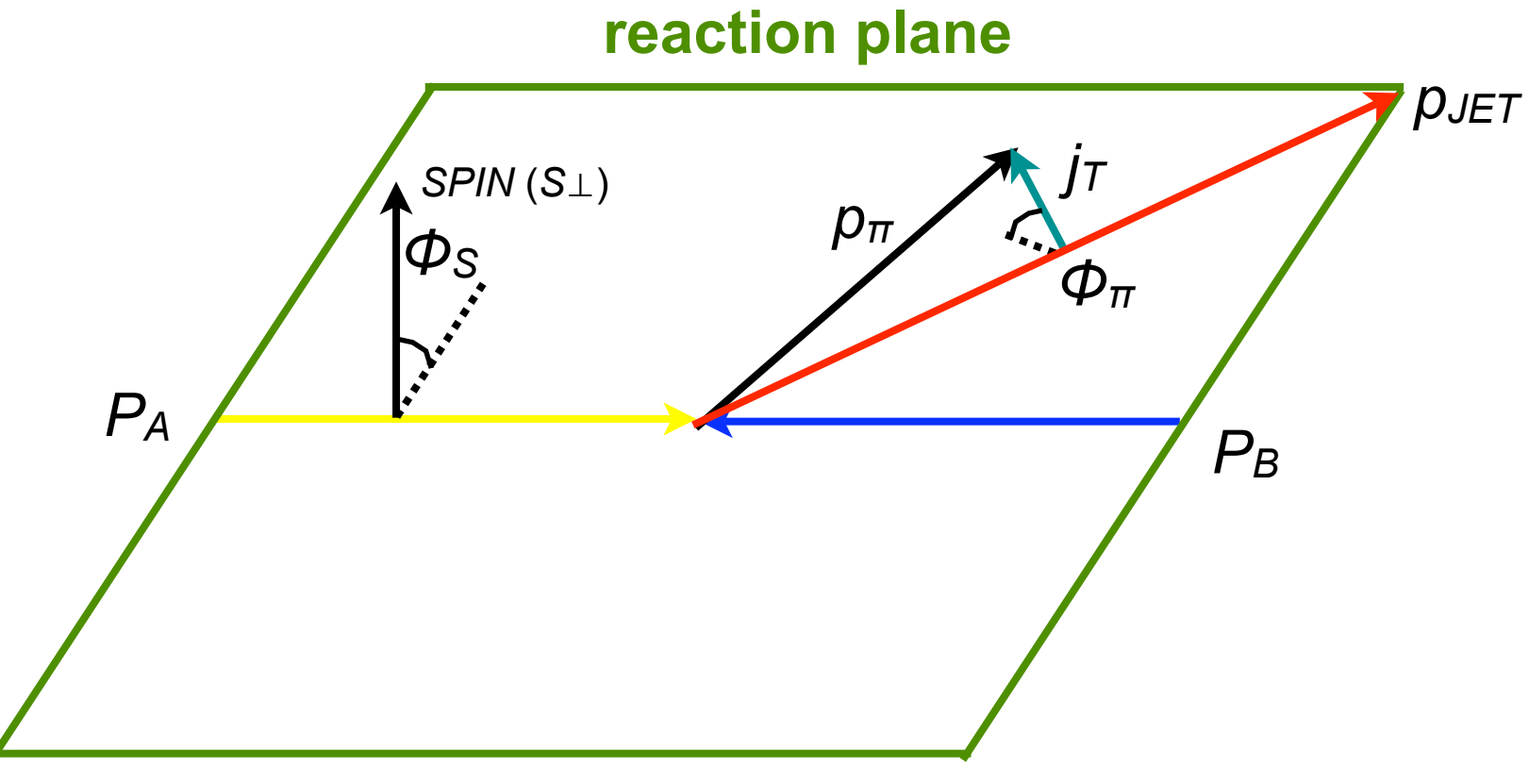

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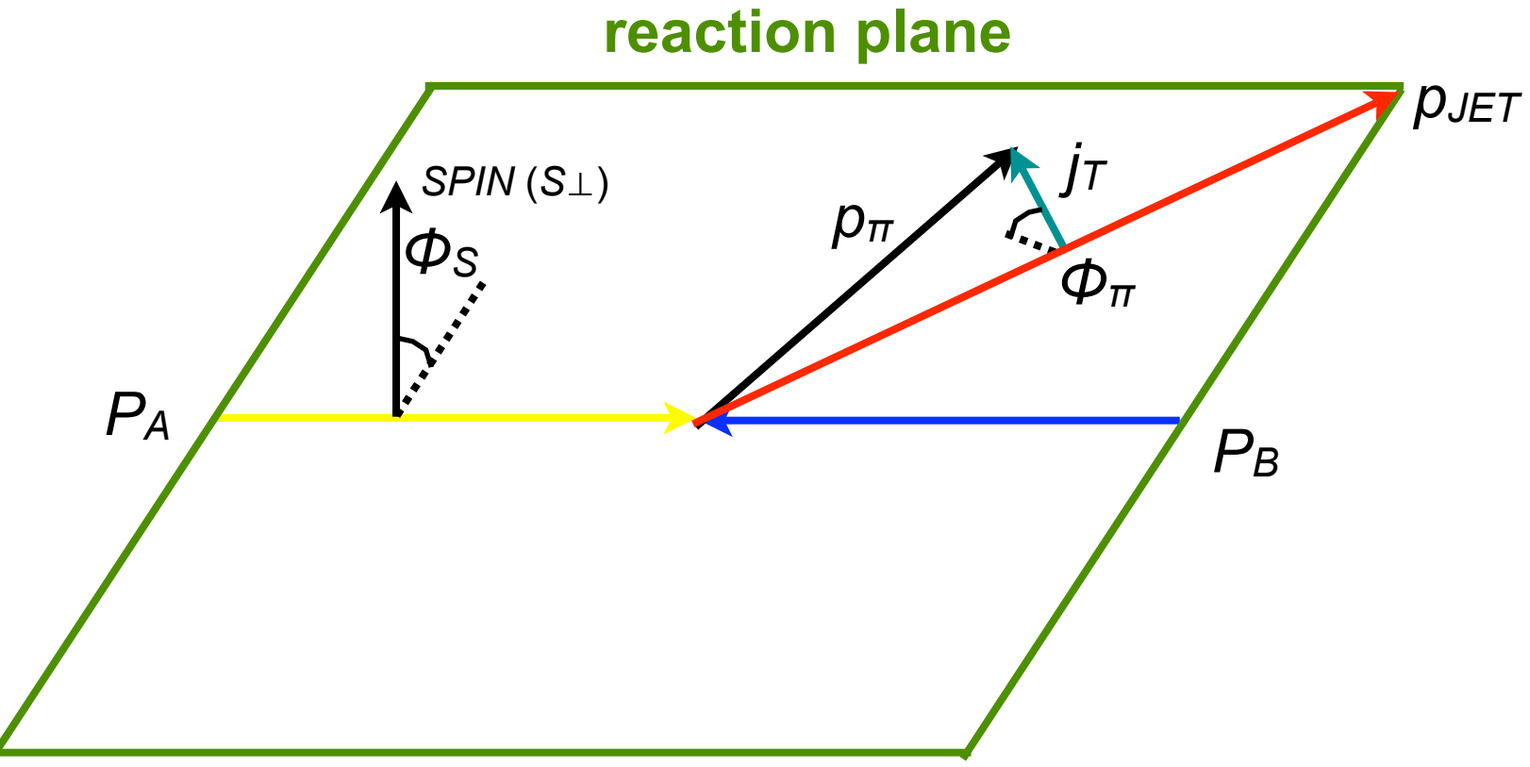

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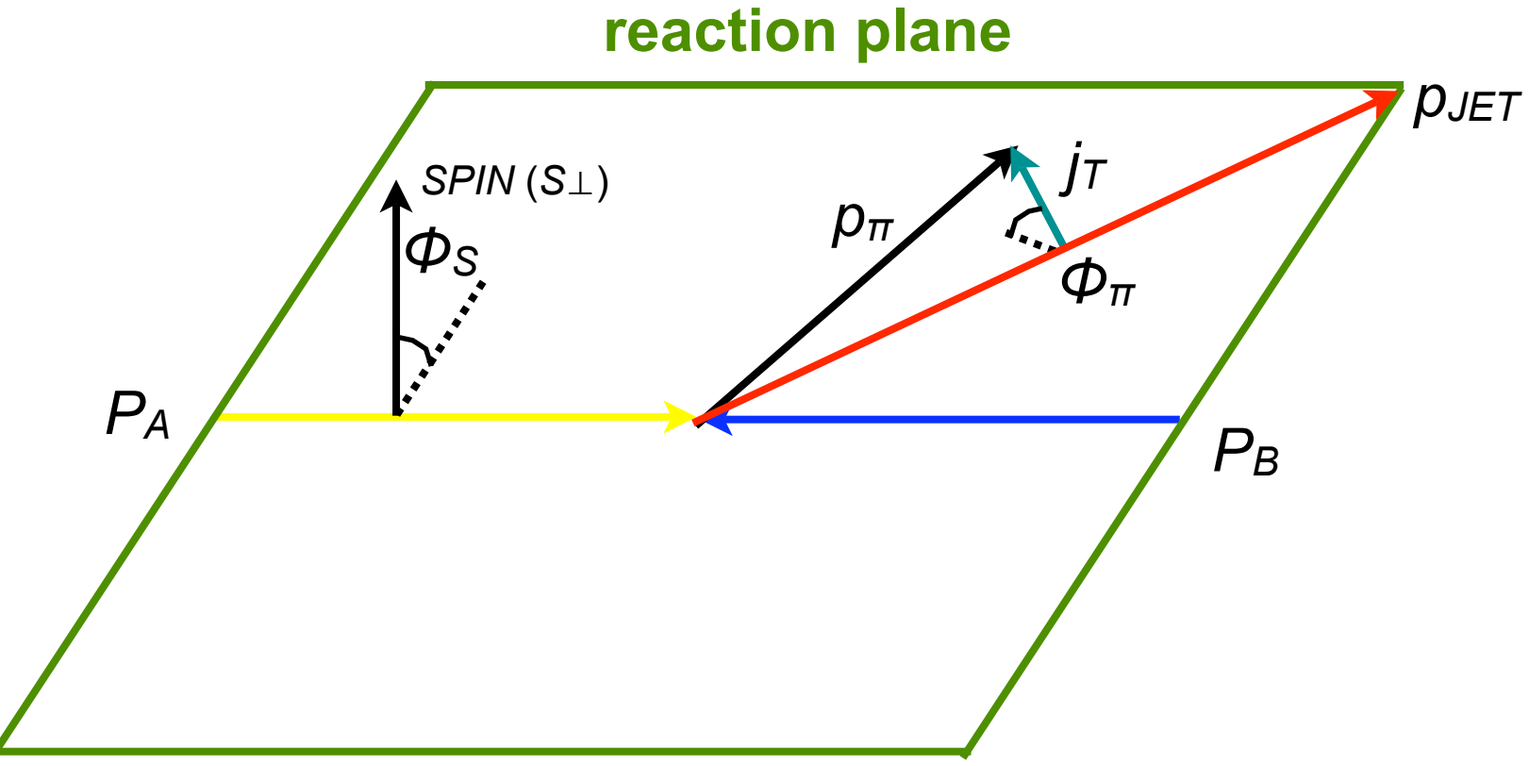

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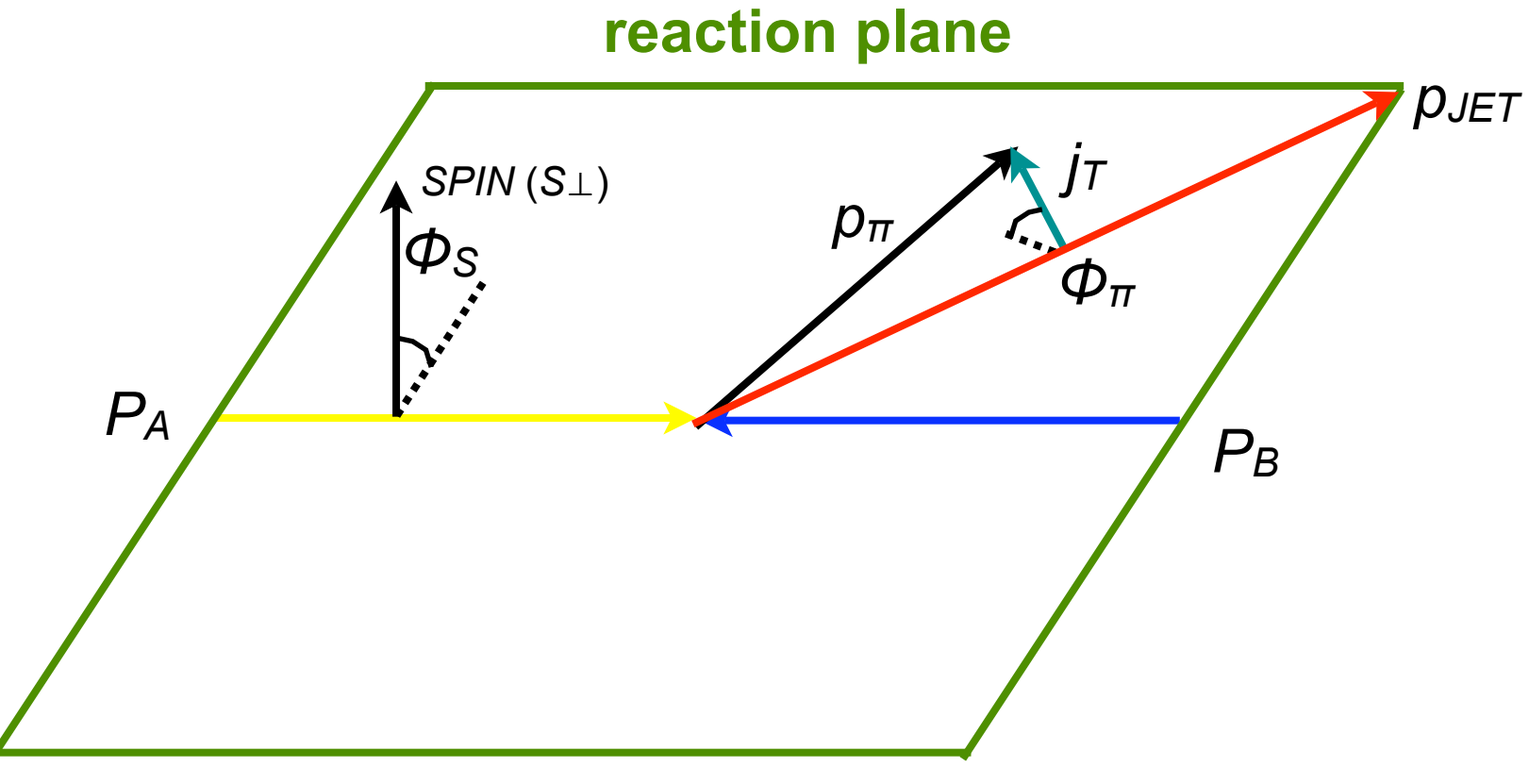

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$$A_N = \frac{\langle 2\sin(\phi_S - \phi_\pi) d\Delta\sigma^{TU} \rangle}{\langle d\sigma^{UU} \rangle}$$

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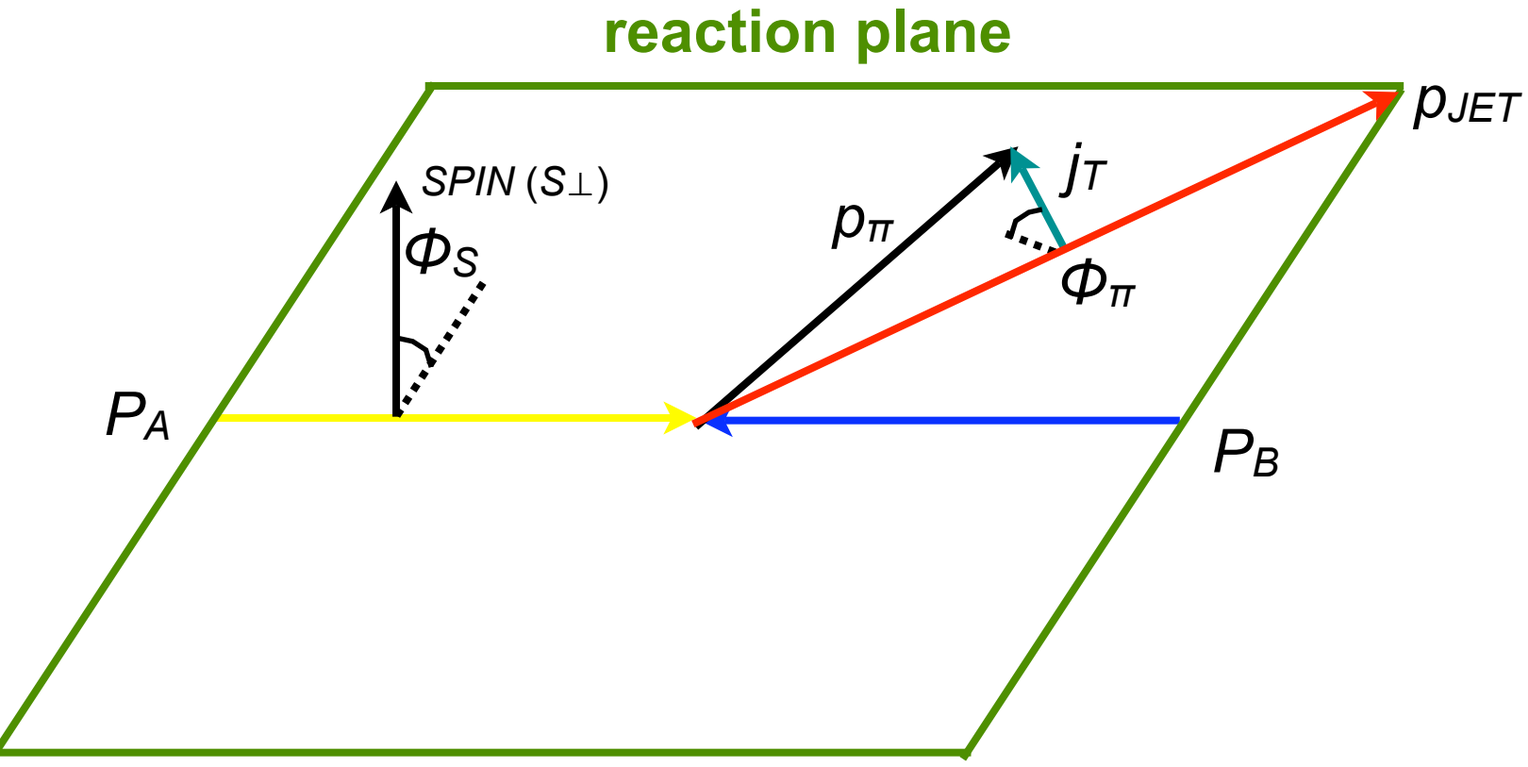

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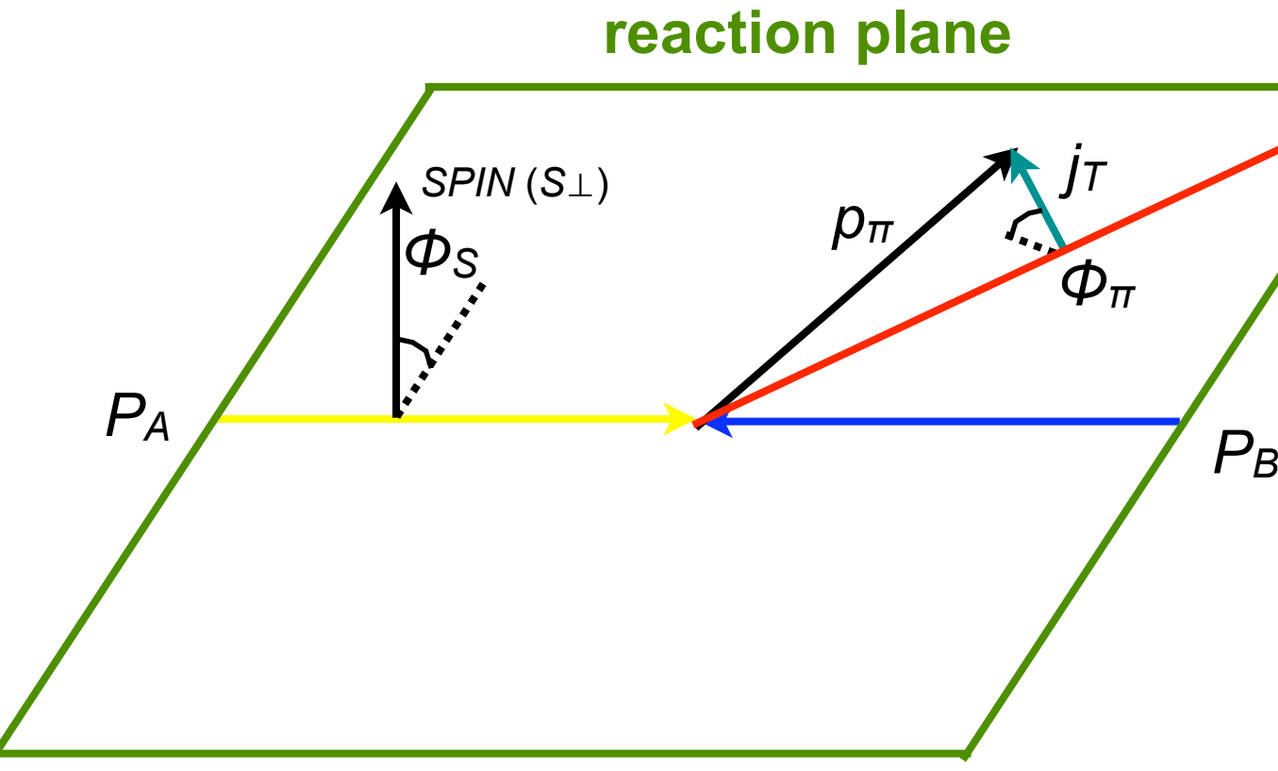

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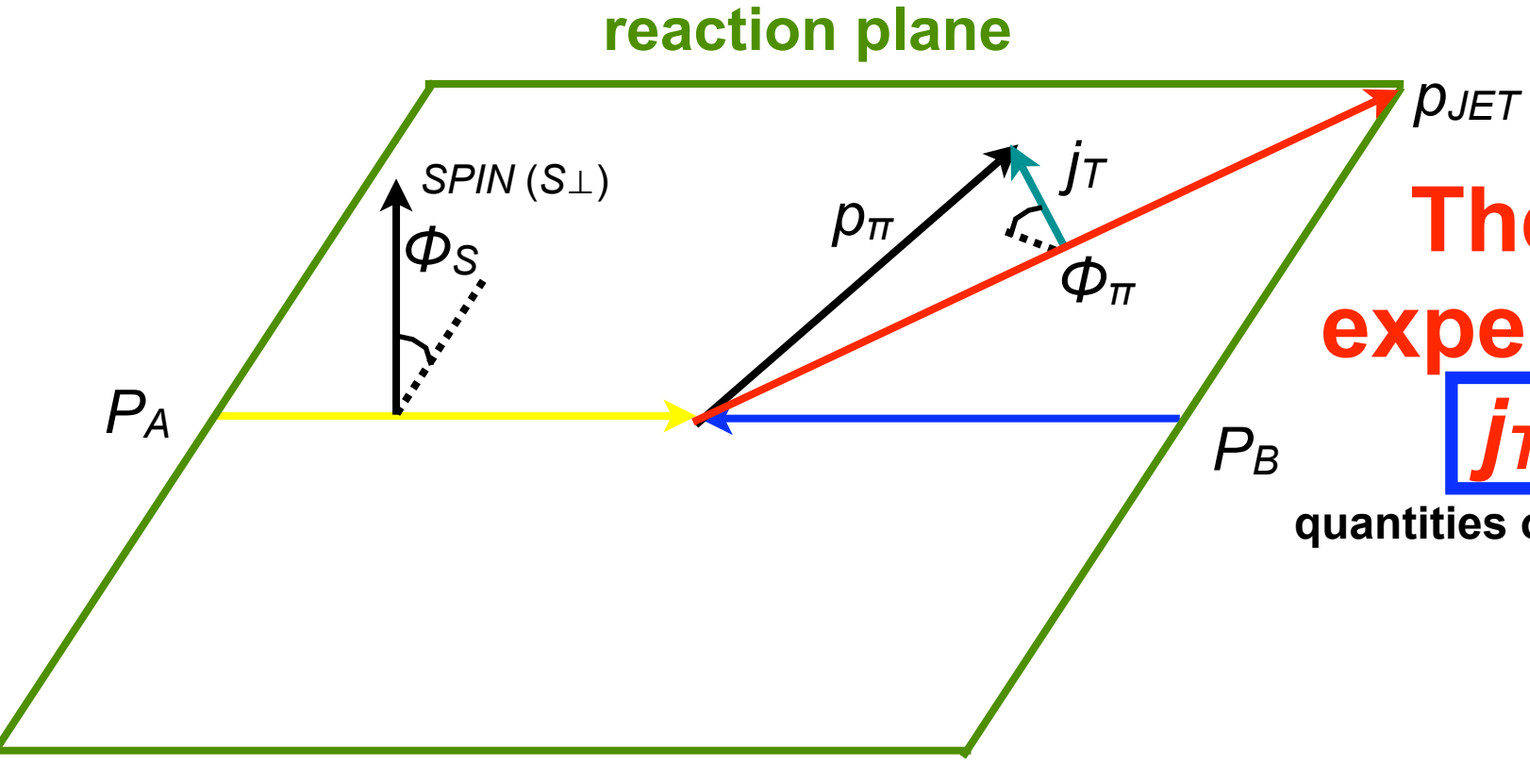

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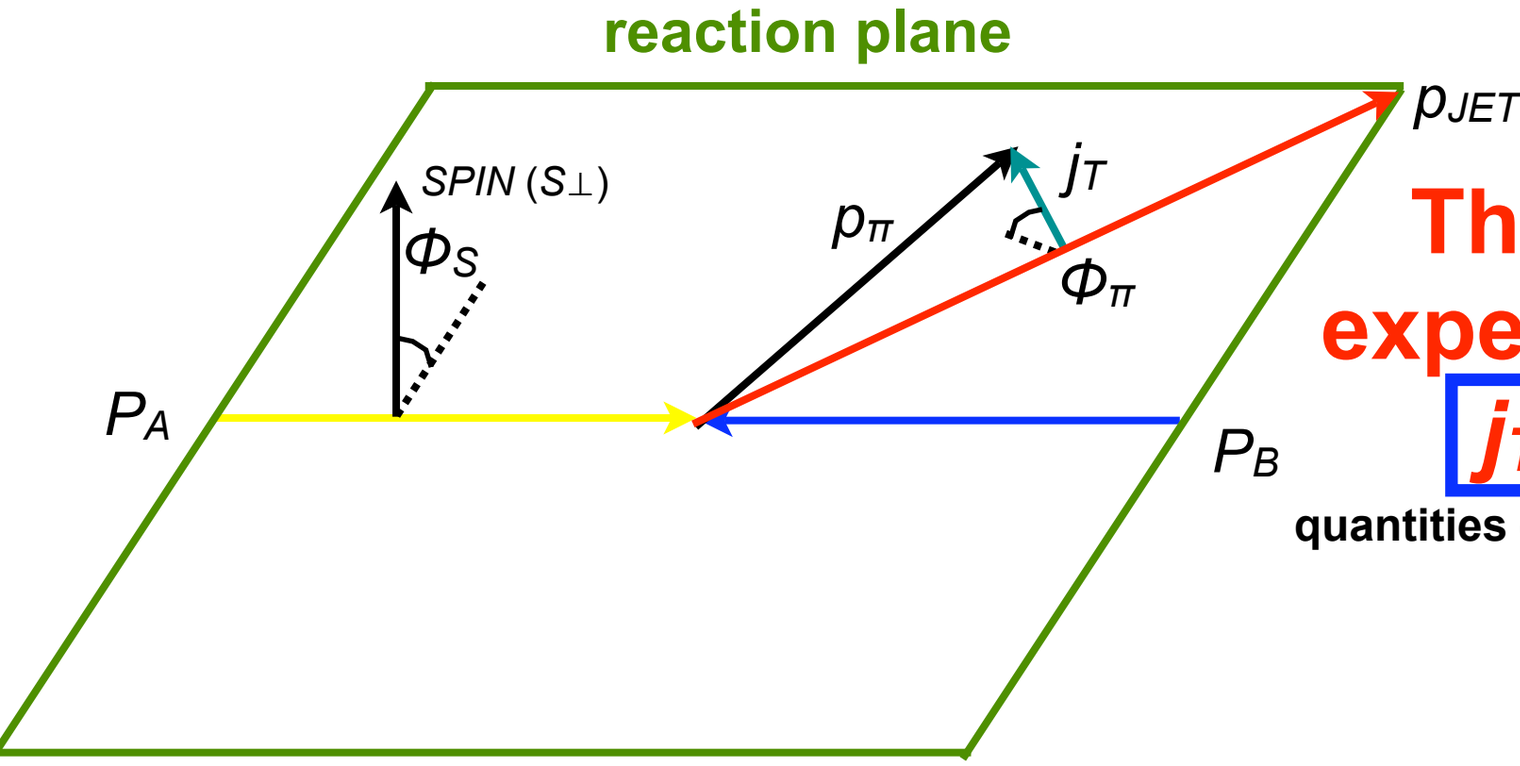

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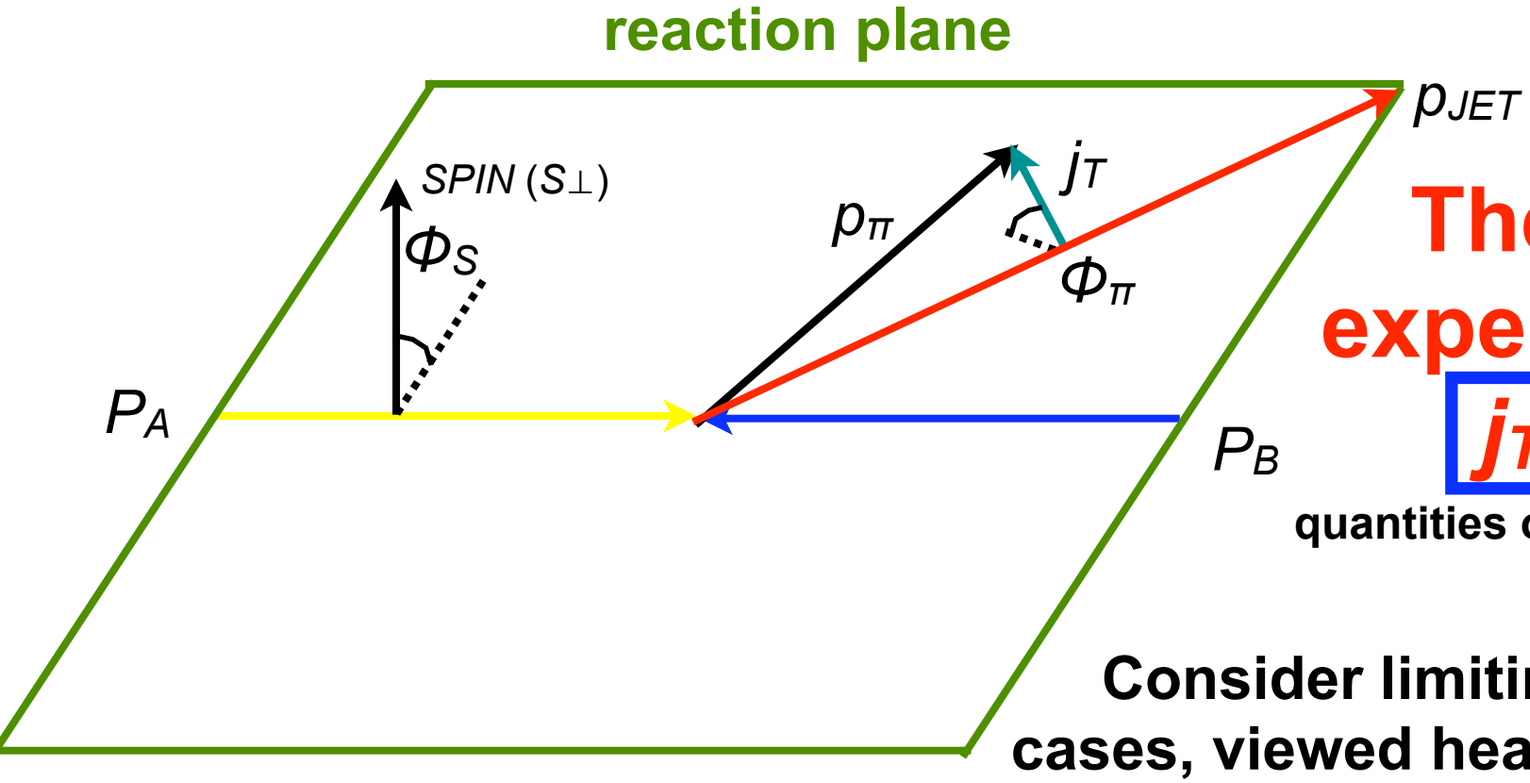

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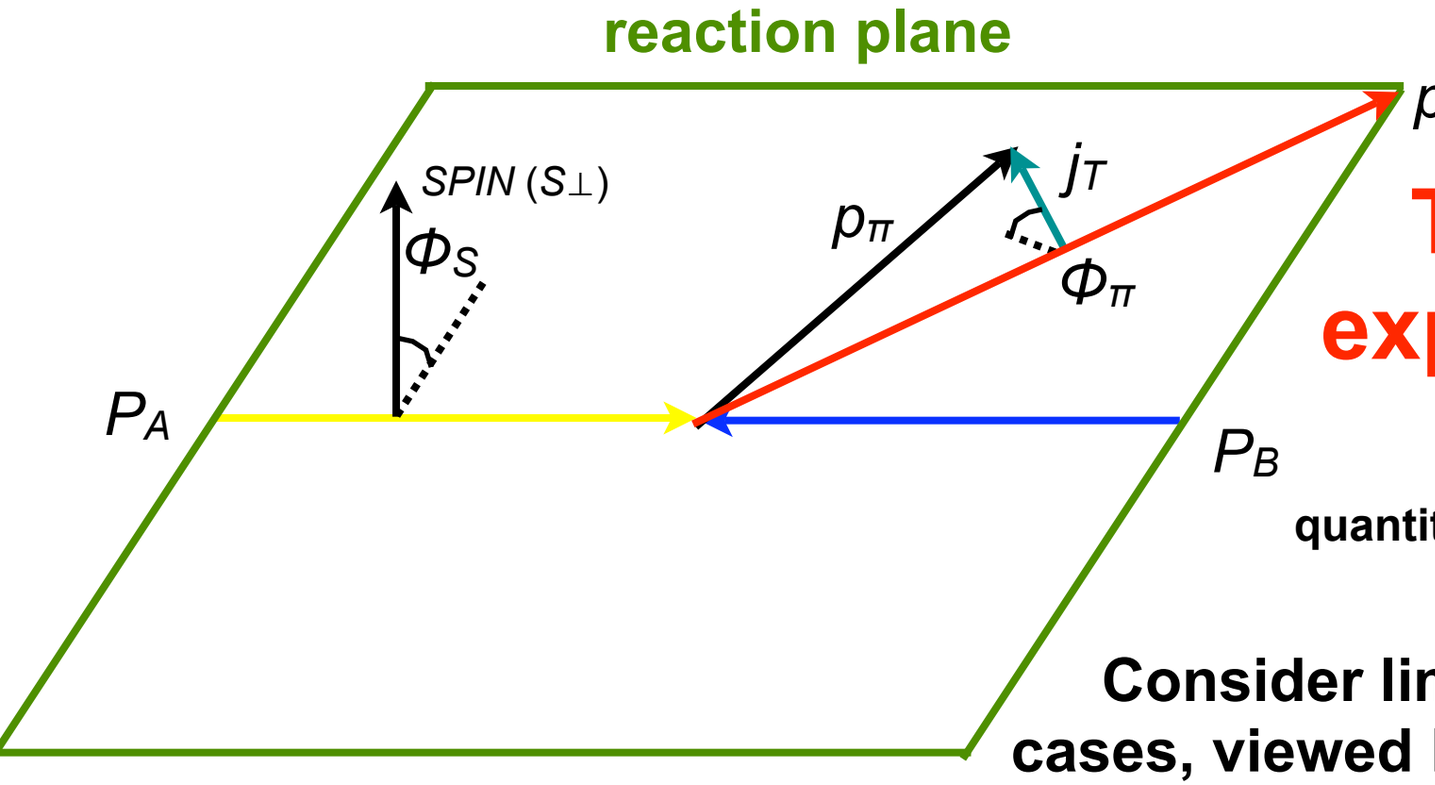

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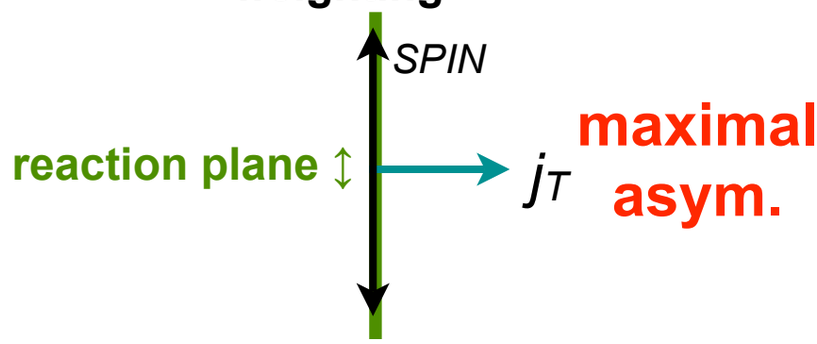

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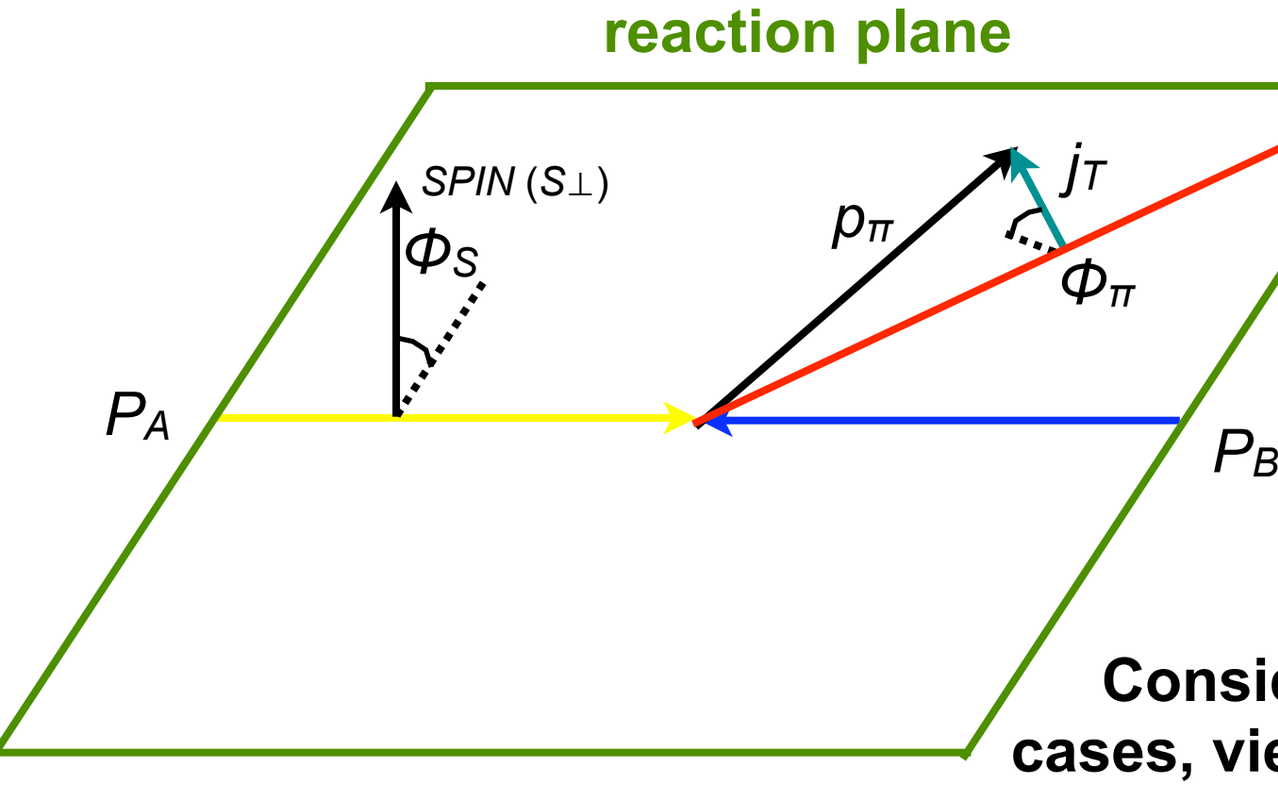
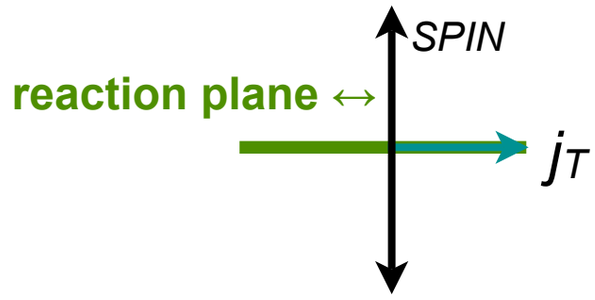


The $\pi^{\pm}$ asymmetries are expected to vary in terms of j_T, z and $\sin(\phi_S - \phi_\pi)$.

quantities of interest **weighting**

Consider limiting cases, viewed head-on:



maximal asym.

Collins Mechanism:

polarized quark → jet ⇒

Φ-dependence of cross-section on $S_\perp^{\pm}$

Measured asymmetry

$$A_N = \frac{\langle 2\sin(\phi_S - \phi_\pi) d\Delta\sigma^{TU} \rangle}{\langle d\sigma^{UU} \rangle}$$

$\Delta\sigma^{TU}$, σ^{UU} depend on z, j_T

$z \equiv p_\pi / p_{JET}$

Experimental access to δq

proton-proton scattering:

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

leading only (highest mom.)

one proton polarized

inclusive (all jets)

all other scattering products

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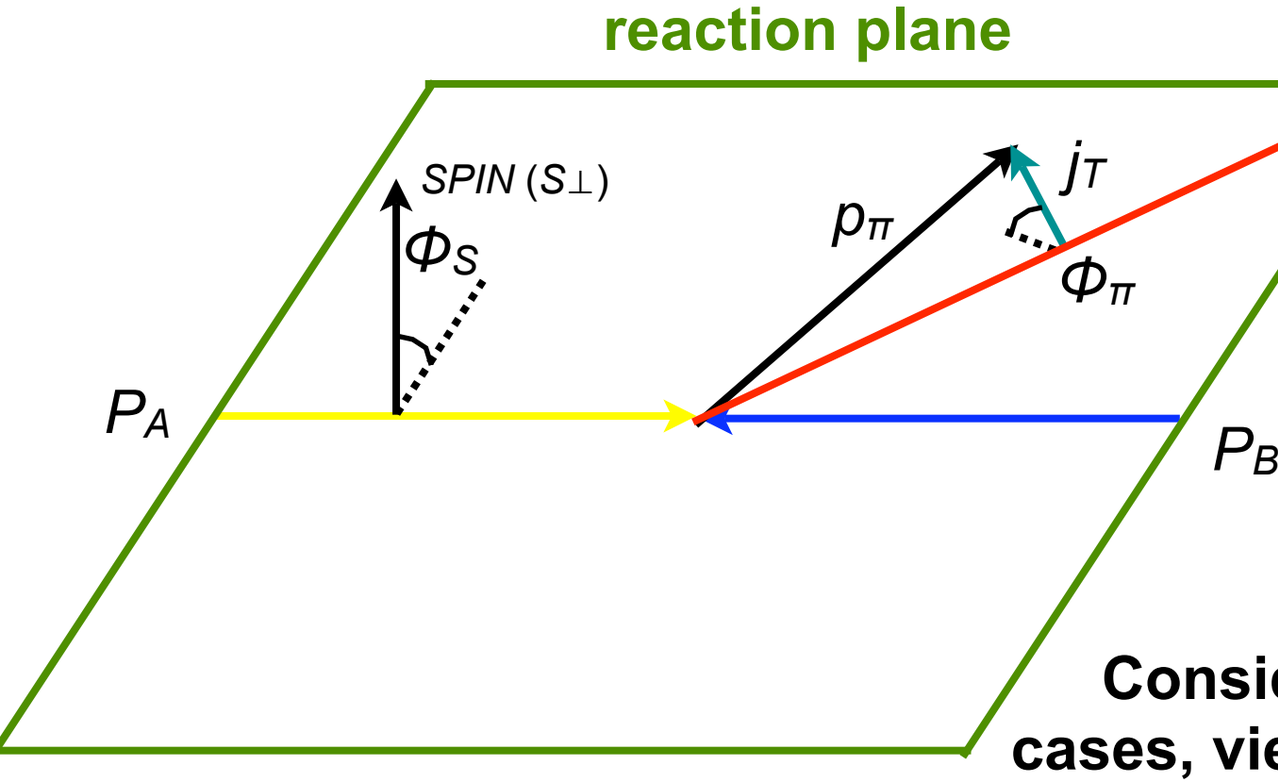

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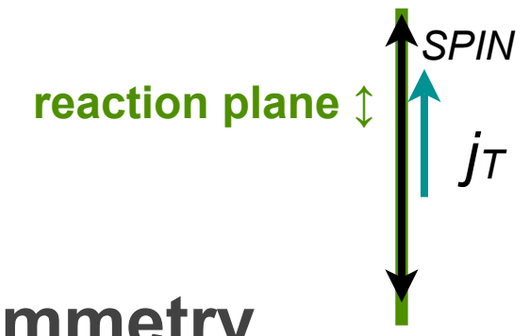

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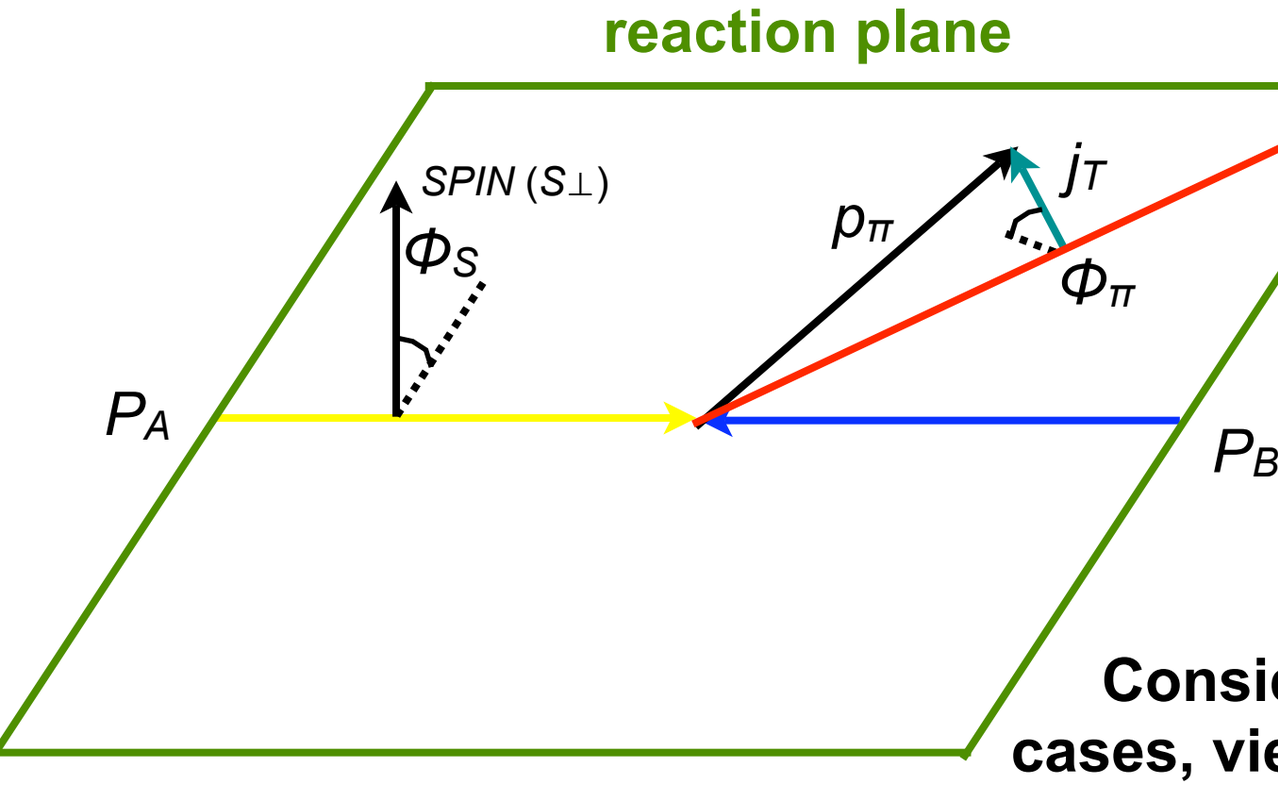

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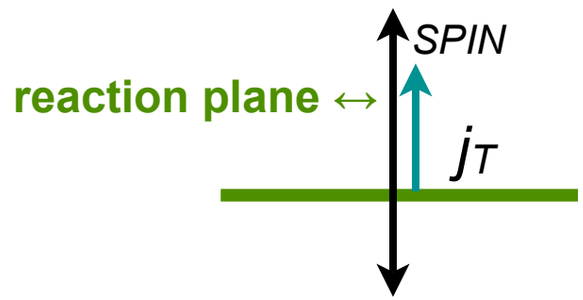

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F. Yuan, arXiv:0804.3047 [hep-ph] (2008)

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phase space

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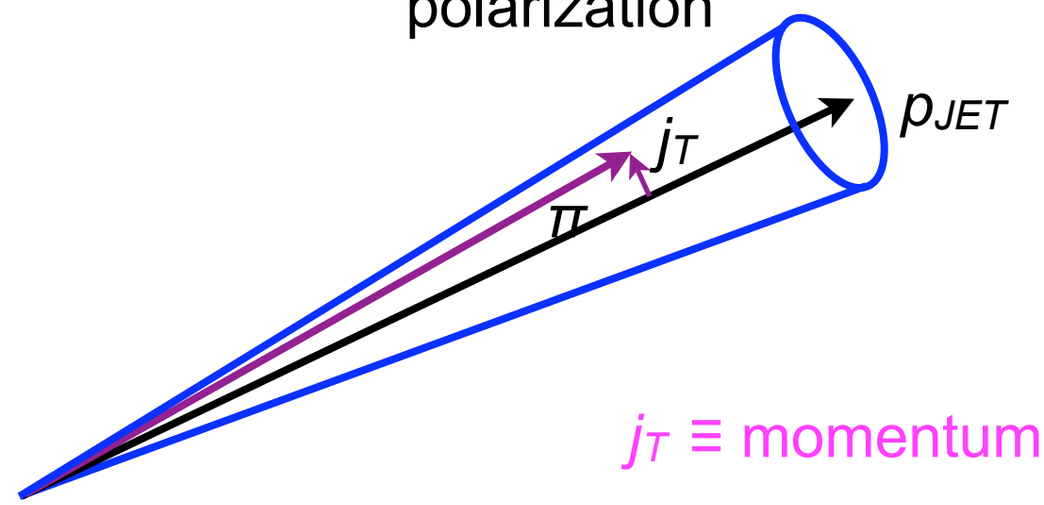

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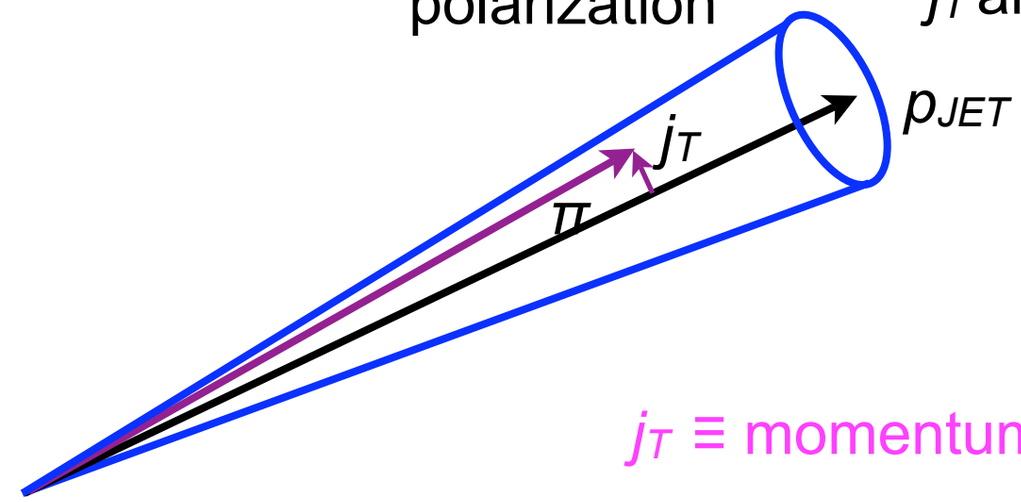
phase space

polarization

j_T angle

pol. angle



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phase space

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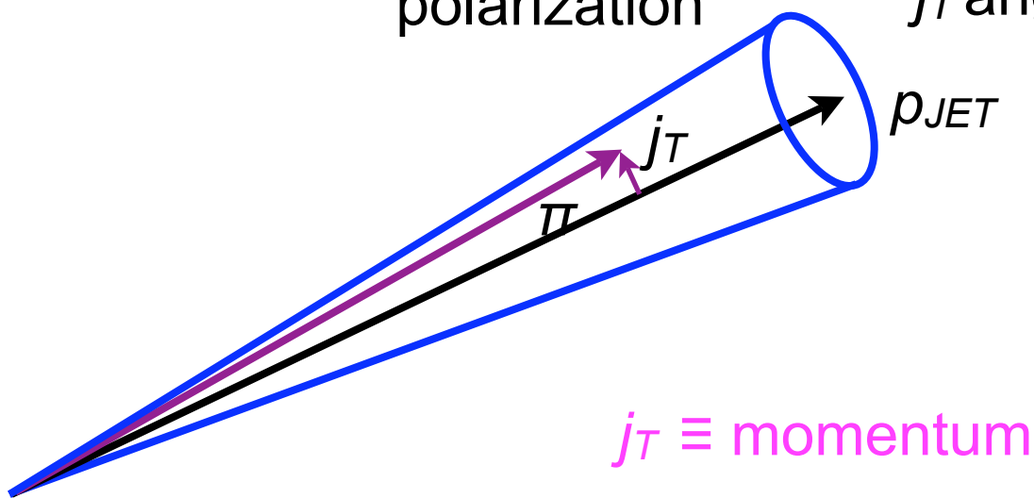

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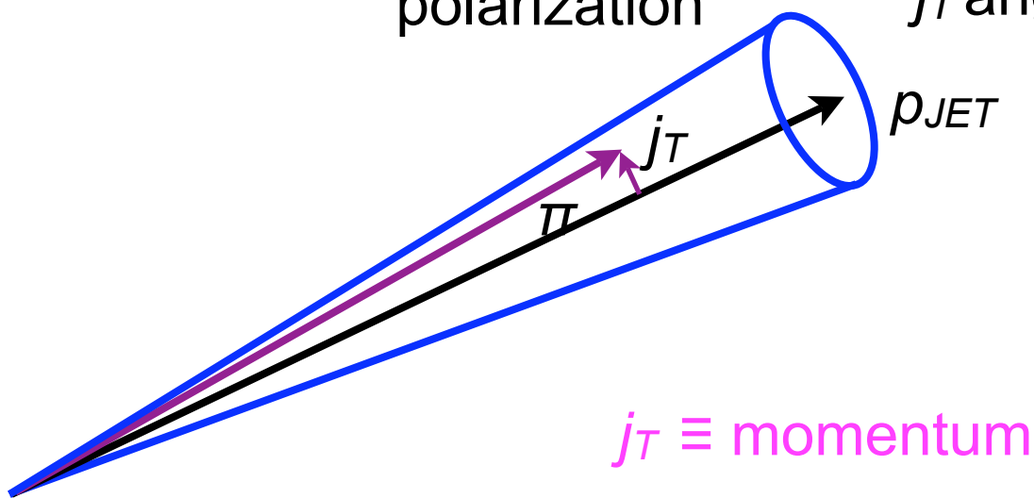

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phase space

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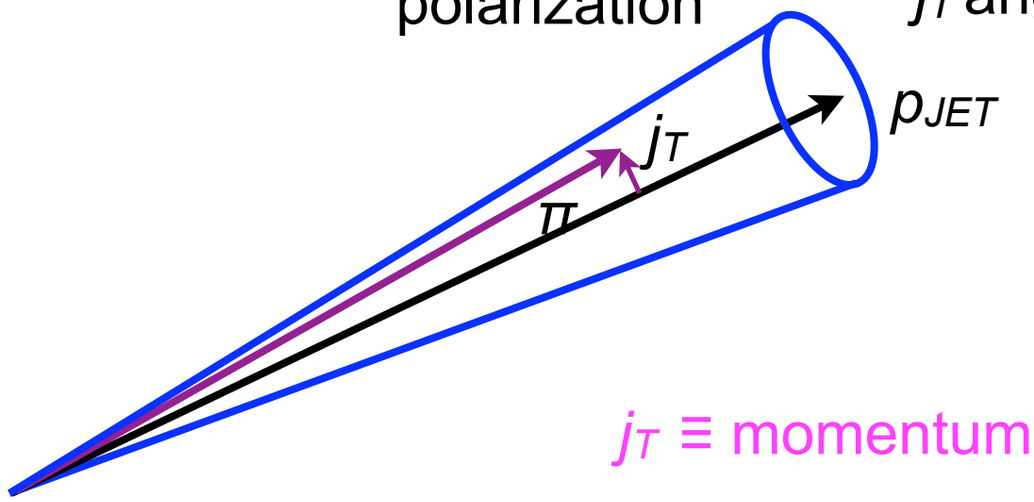

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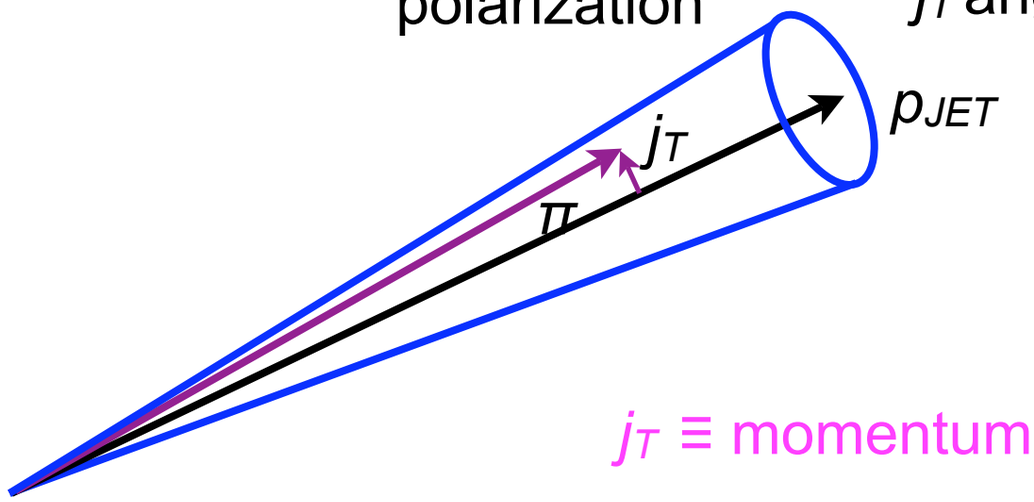

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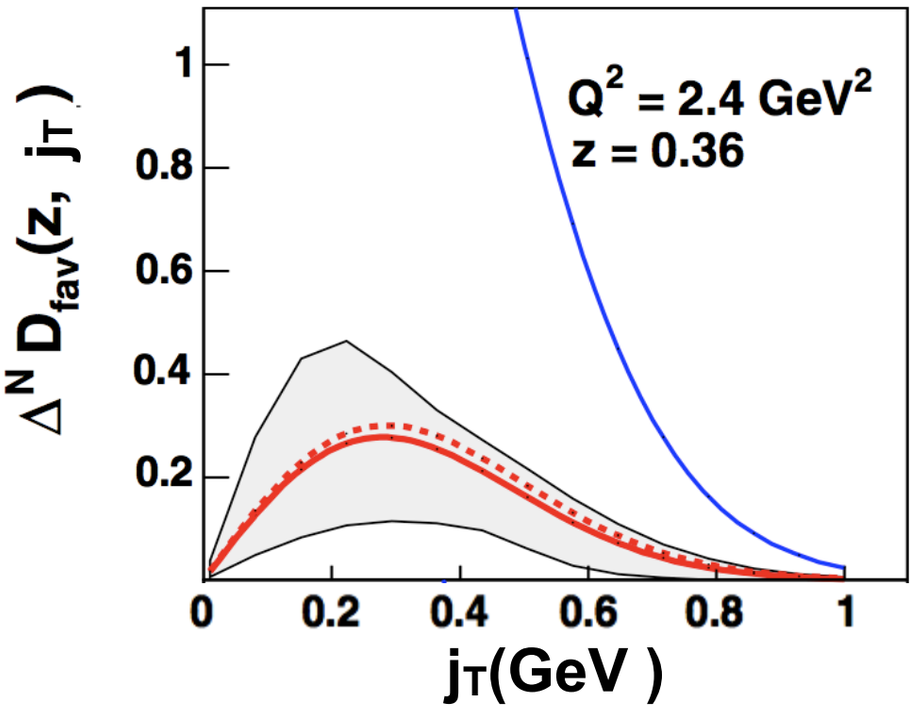

Isospin-favored Collins frag. function

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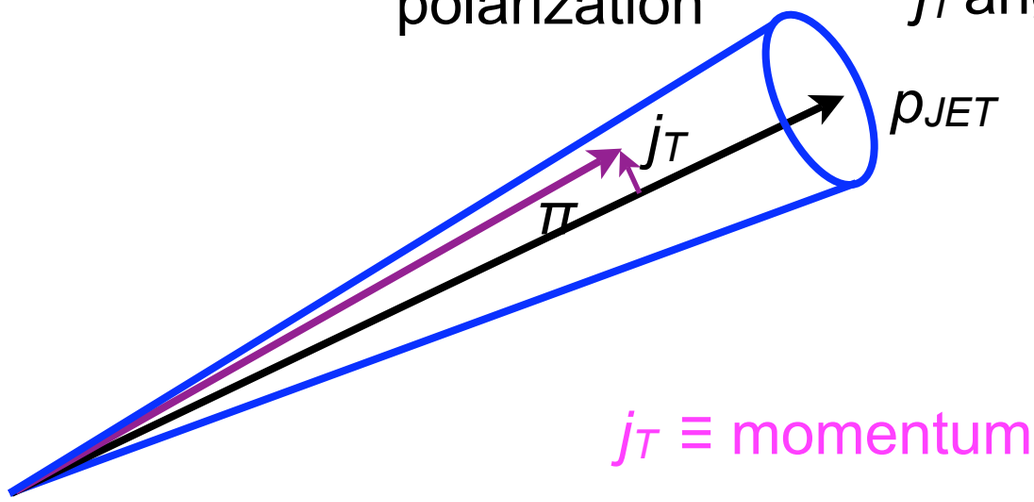

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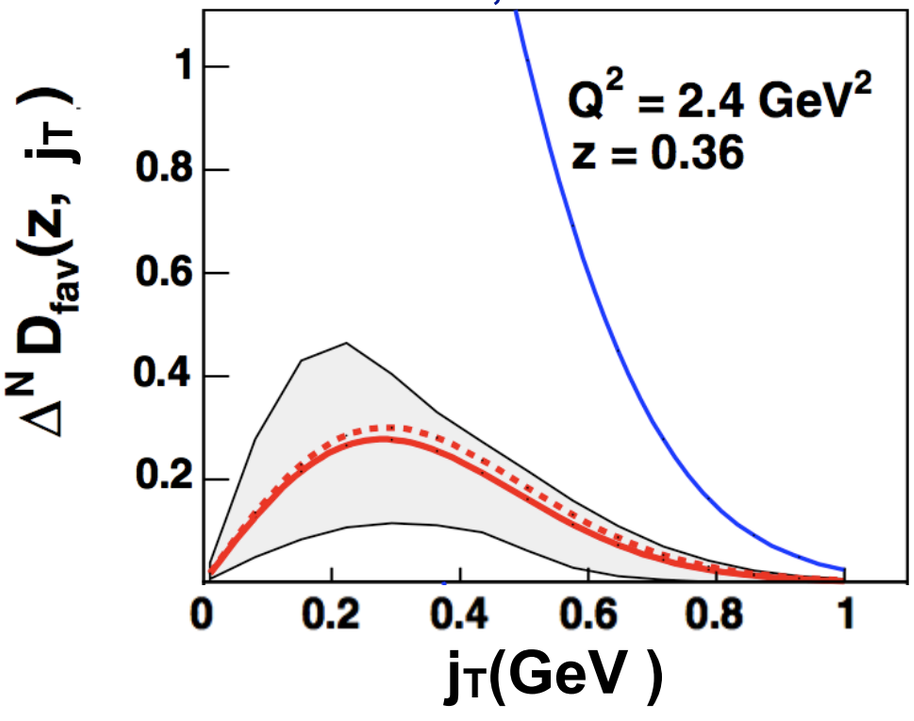

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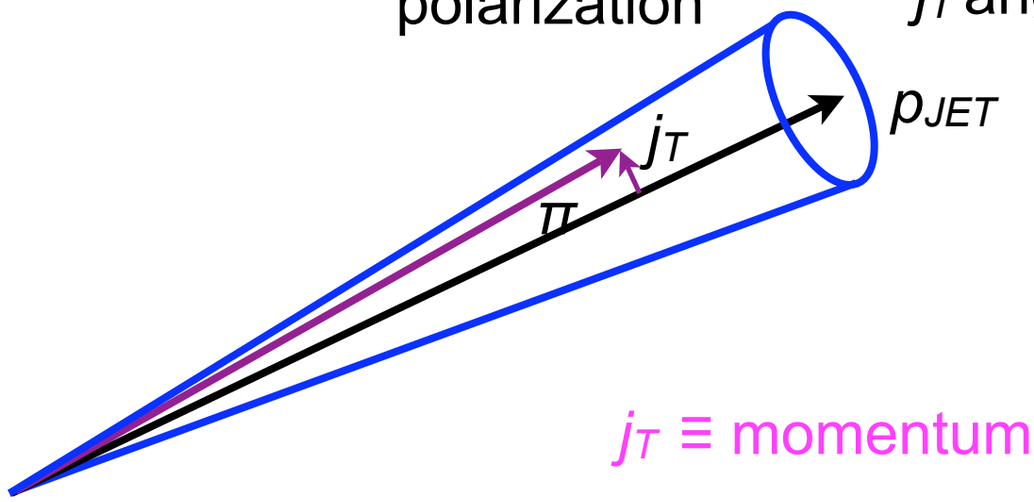
j_T angle

pol. angle



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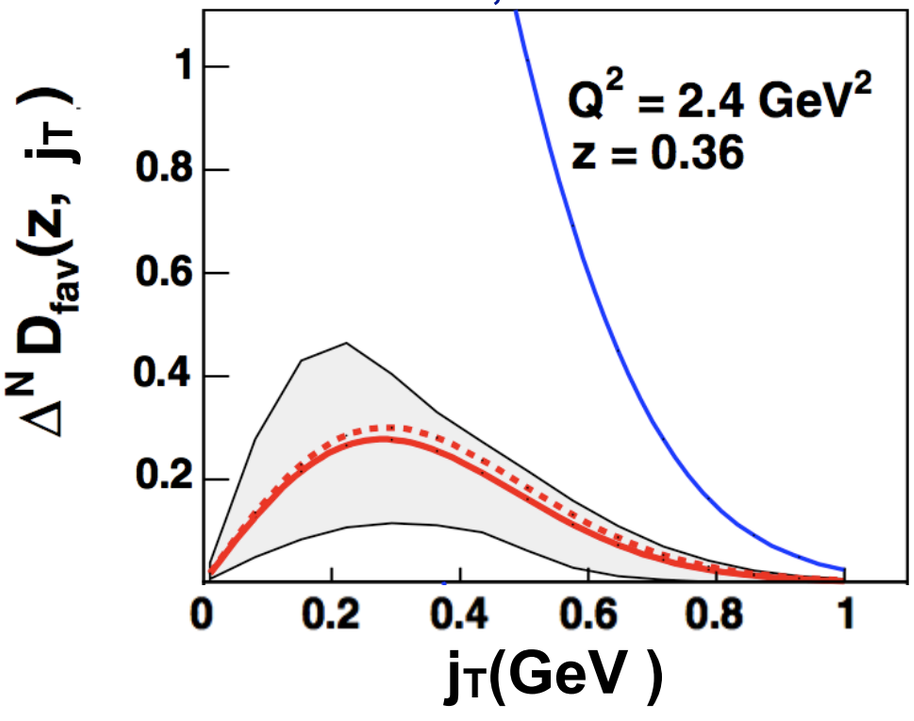

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j_T angle

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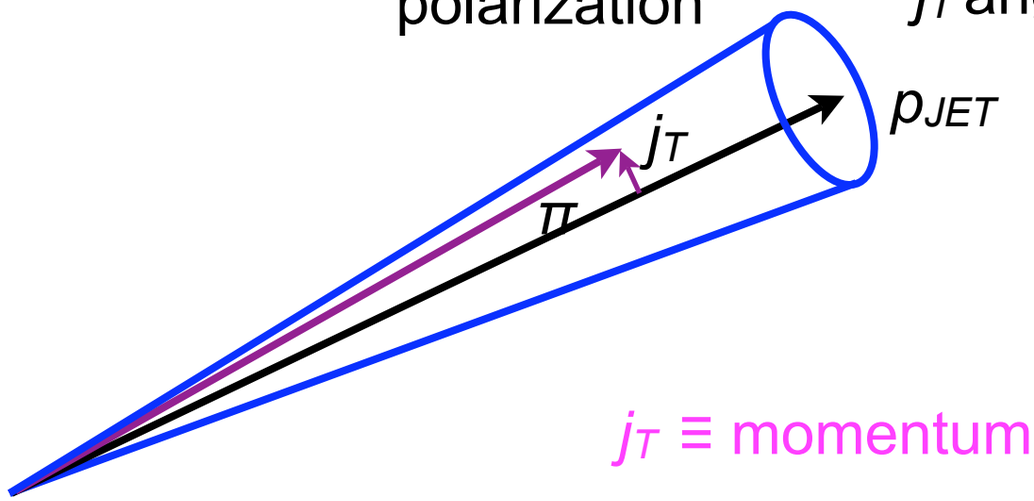

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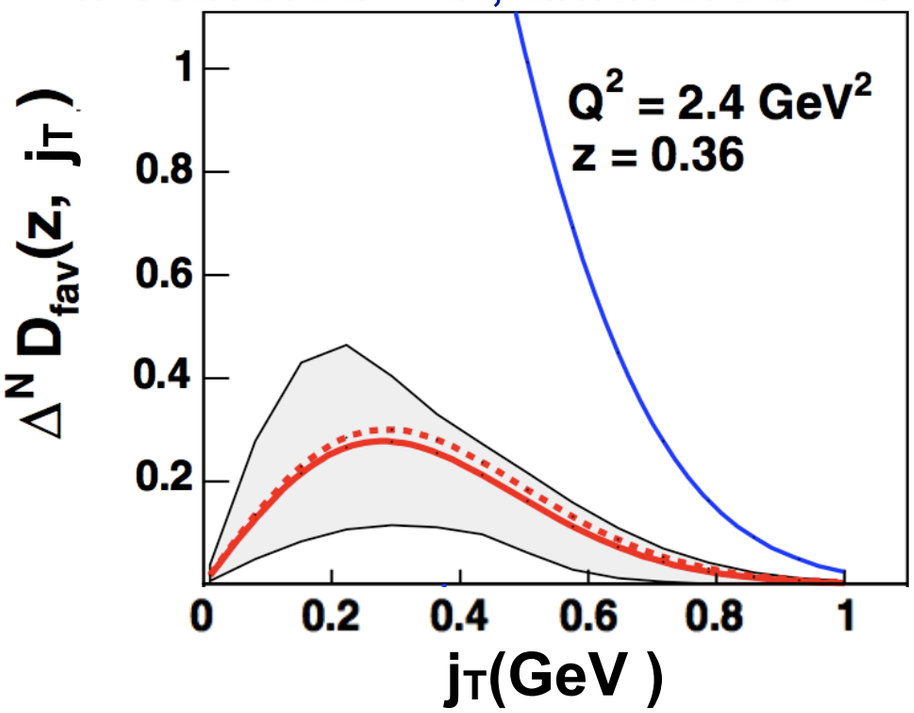

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Quark transversity

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Spin transfer & parton kinematics (x, x´) calculated using STAR simulation package (GEANT + PYTHIA) including full jet reconstruction & trigger effects

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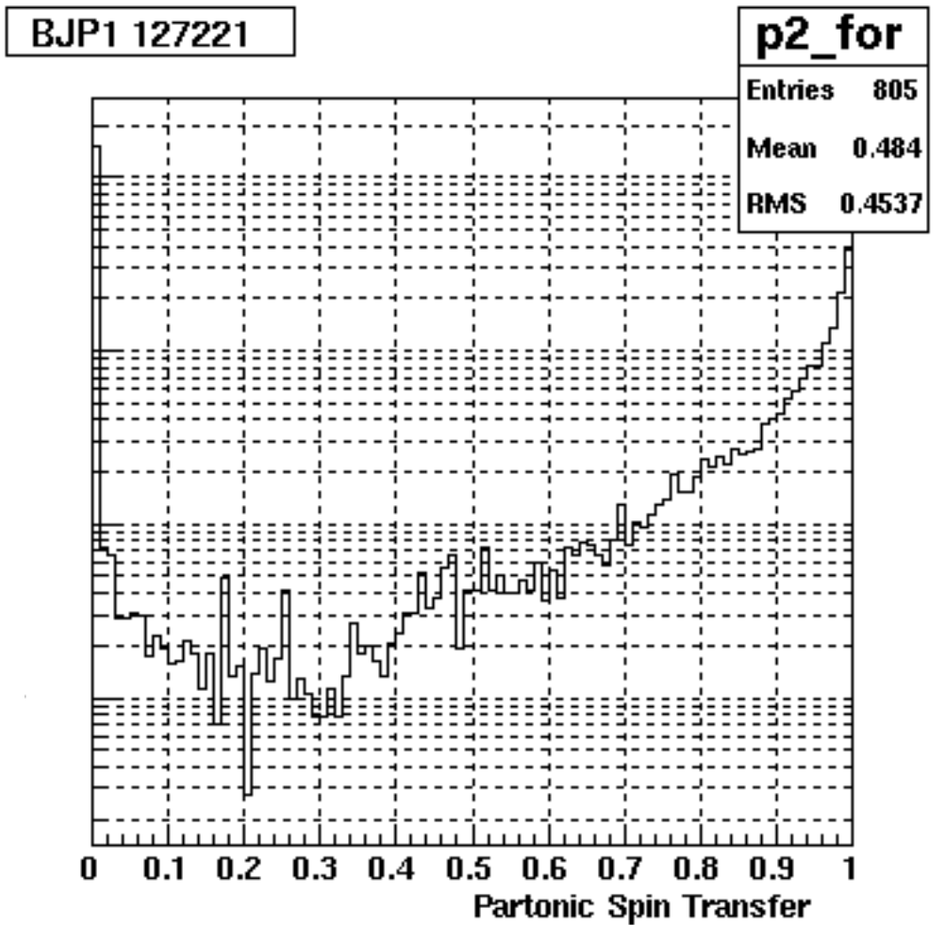

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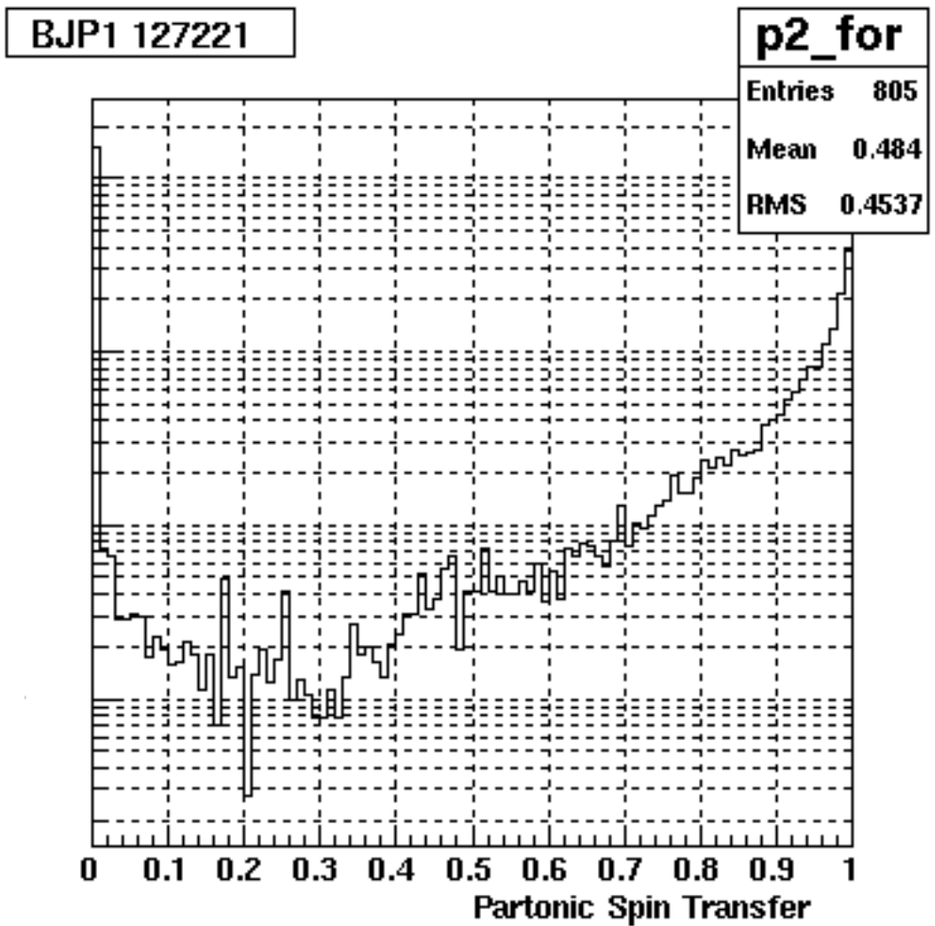

Prediction (estimate): $A_N(\pi^\pm) \approx \pm 0.03$

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Measured asymmetry

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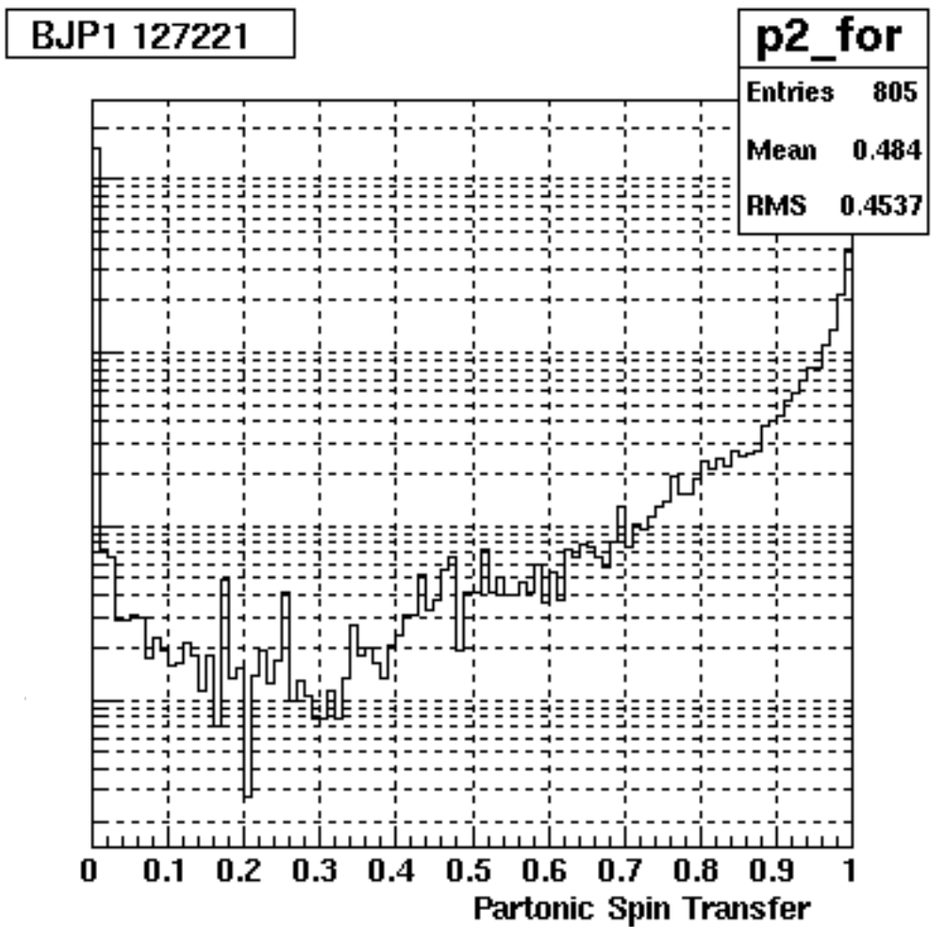
$$A_N \approx \left[\frac{\delta q(x)}{f_q(x)} \frac{\Delta^N D_q(z,j_T)}{D_q^h(z,j_T)} \frac{H_{qb\to qb}^{\text{Collins}}}{H_{qb\to cd}}\right]_{\text{favored } q} + \left[\frac{\delta q(x)}{f_q(x)} \frac{\Delta^N D_q(z,j_T)}{D_q^h(z,j_T)} \frac{H_{qb\to qb}^{\text{Collins}}}{H_{qb\to cd}}\right]_{\text{unfavored } q}$$

Spin transfer coefficient

Spin transfer & parton kinematics (x, x´) calculated using STAR simulation package (GEANT + PYTHIA) including full jet reconstruction & trigger effects



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

Statistical error (estimate):

Integrated luminosity ≈ 1 pb^{-1}

Use inclusive jet A_{TT} measurement from same data

Measurement of A_N

Measured asymmetry

$$A_N = \frac{\langle 2\sin(\phi_S - \phi_\pi) d\Delta\sigma^{TU} \rangle}{\langle d\sigma^{UU} \rangle}$$

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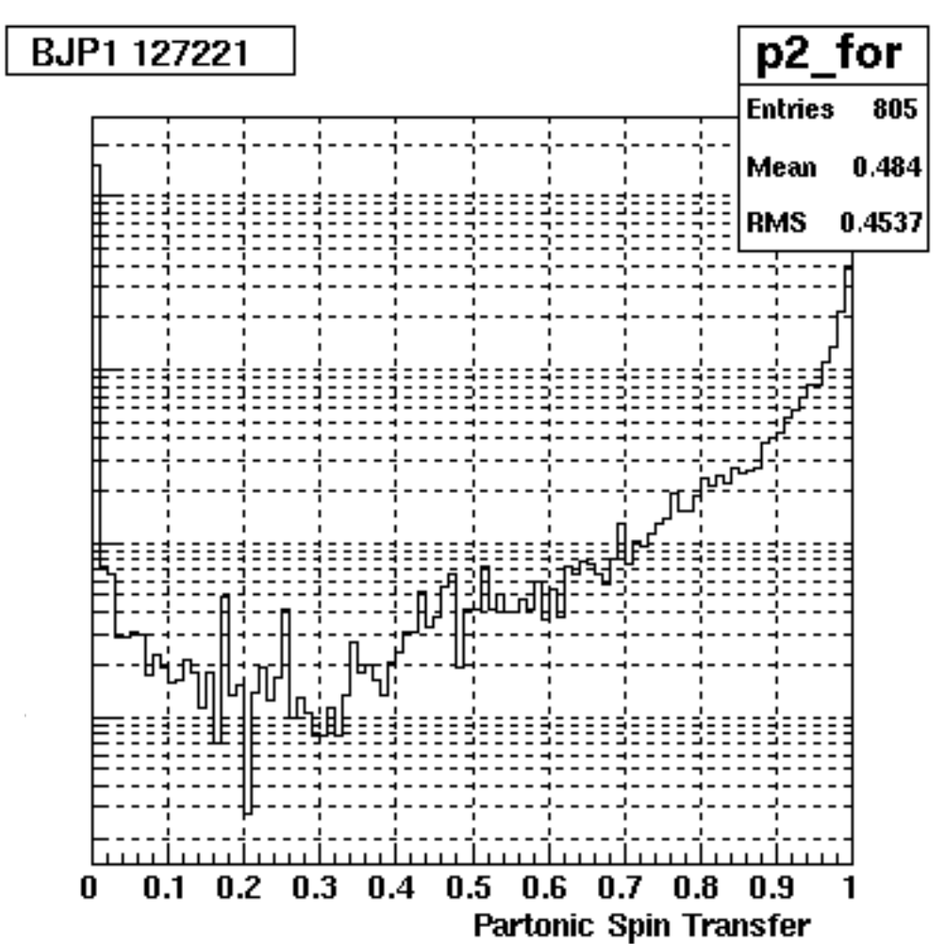

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Use inclusive jet A_{TT} measurement from same data

Statistically significant measurements ($\sigma \sim A_N$) can be made at $p_T \leq 30$ GeV

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

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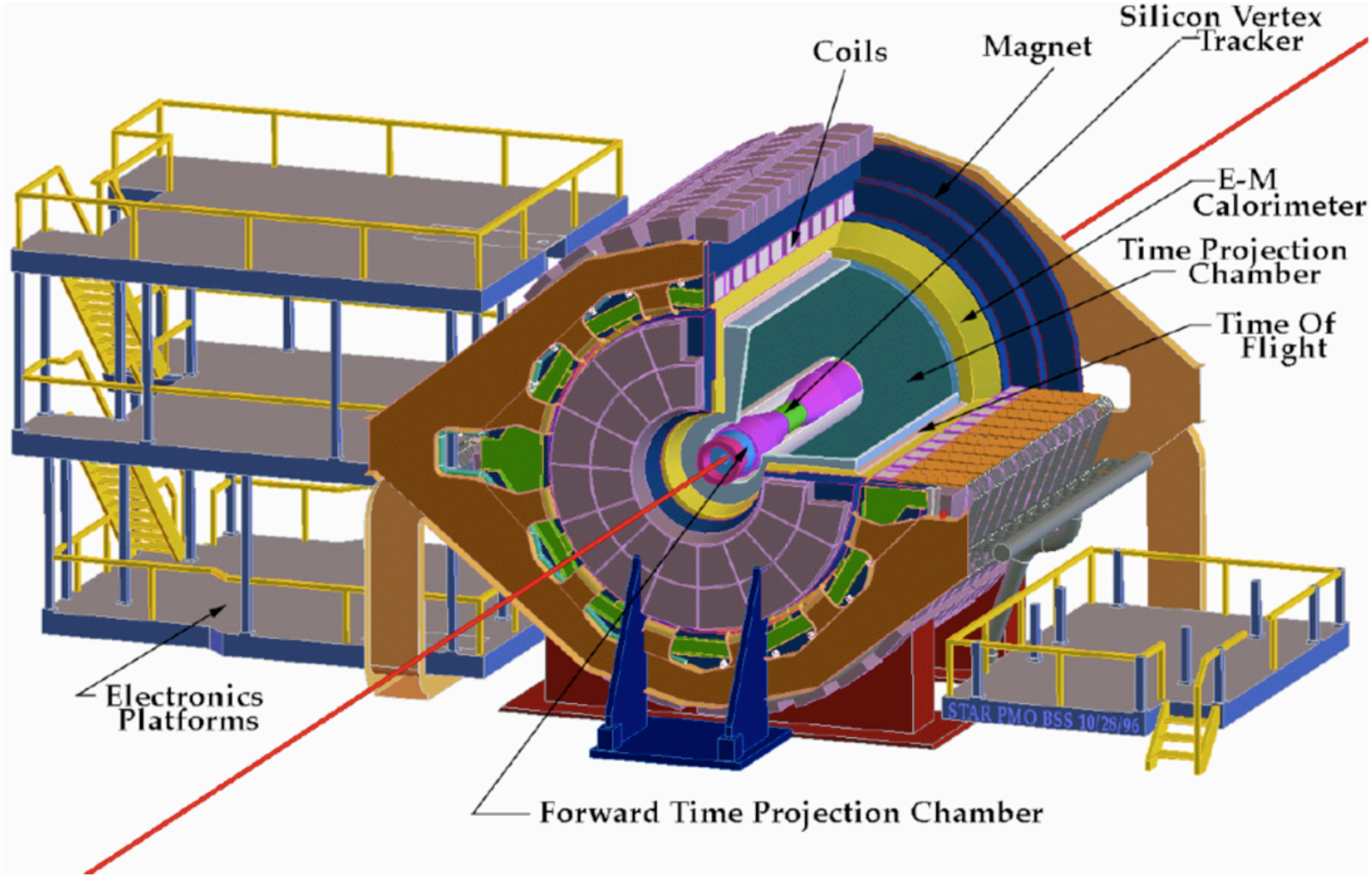

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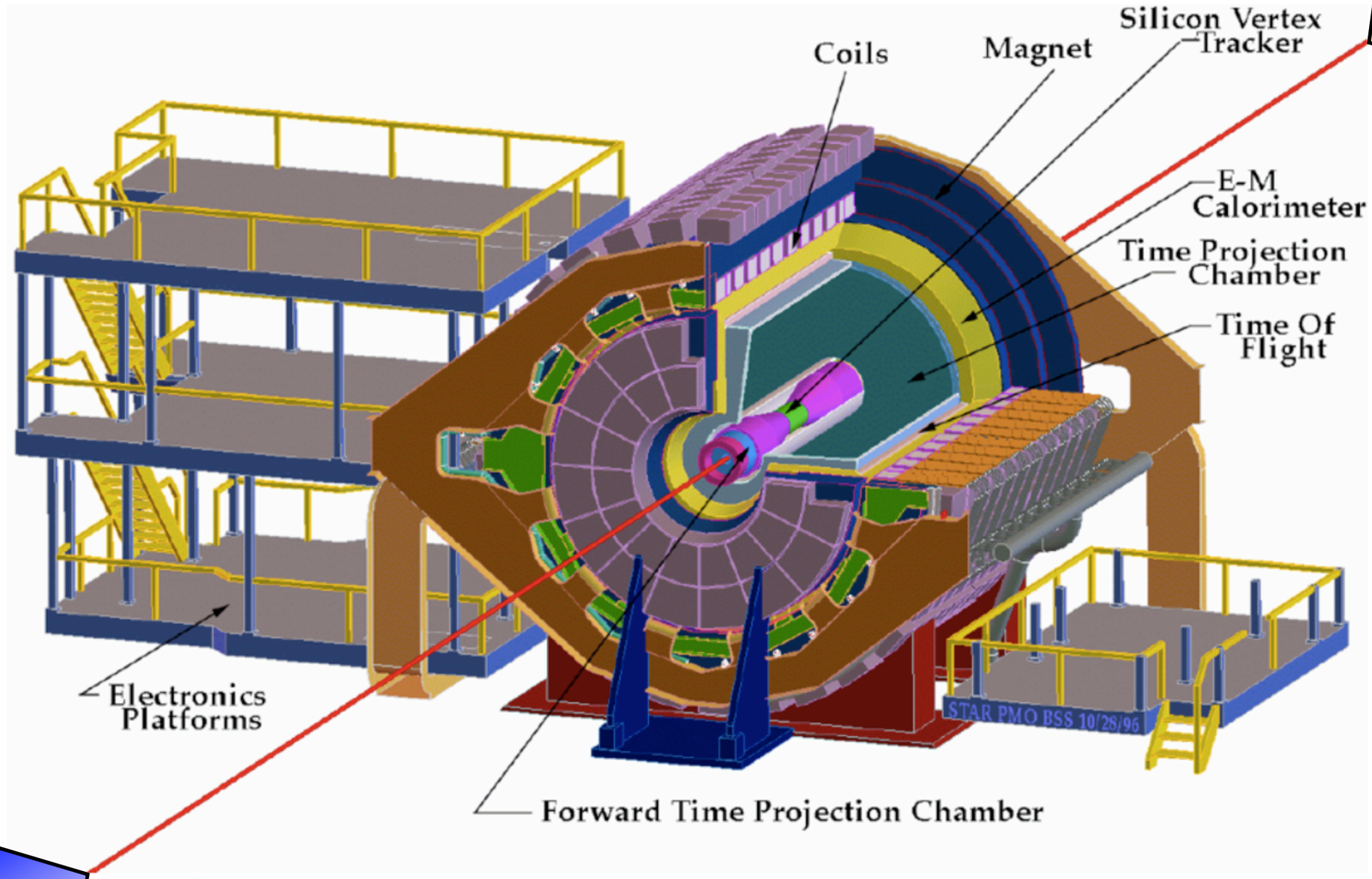

100 GeV transversely polarized (~50%) protons from RHIC

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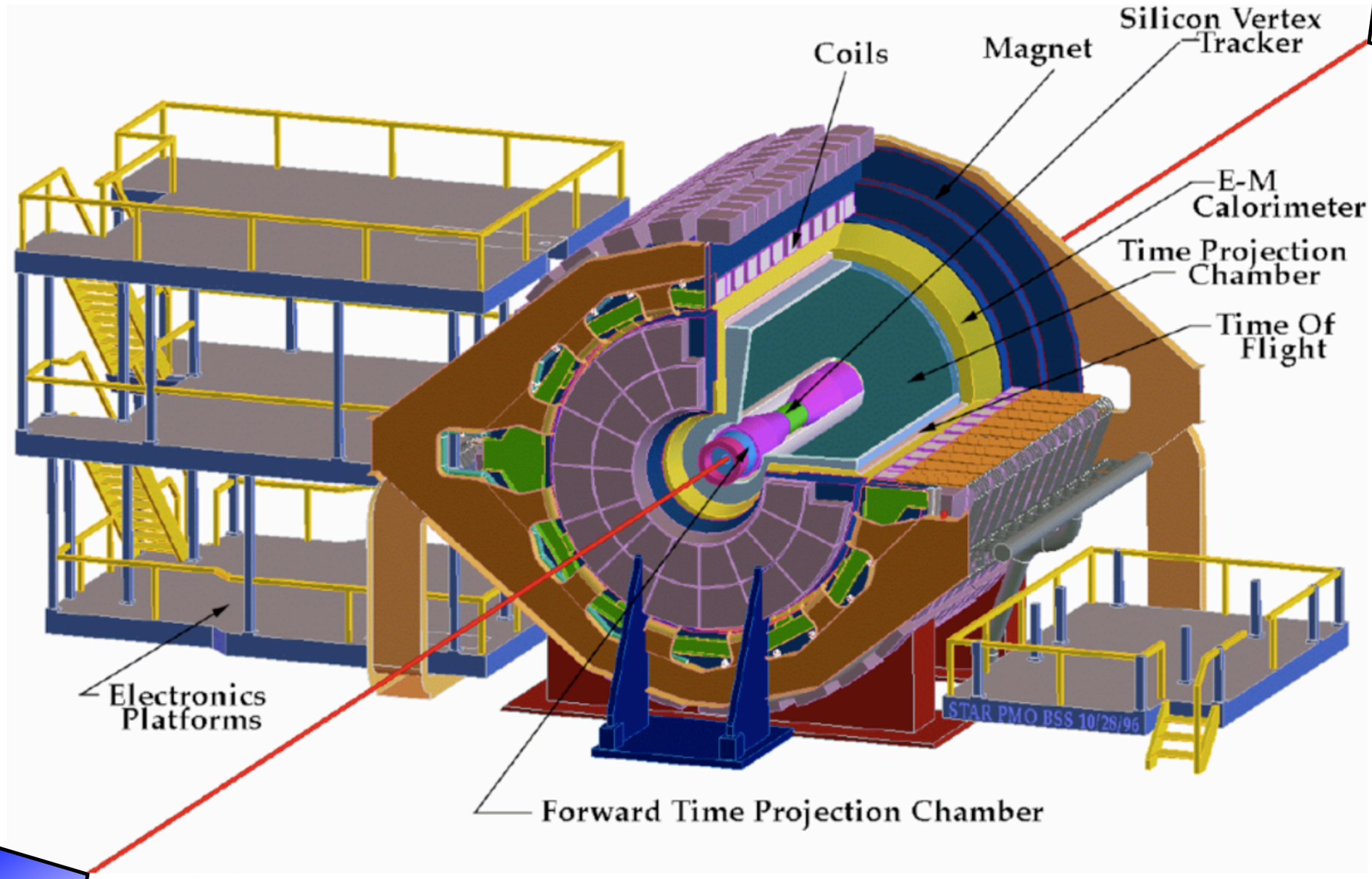

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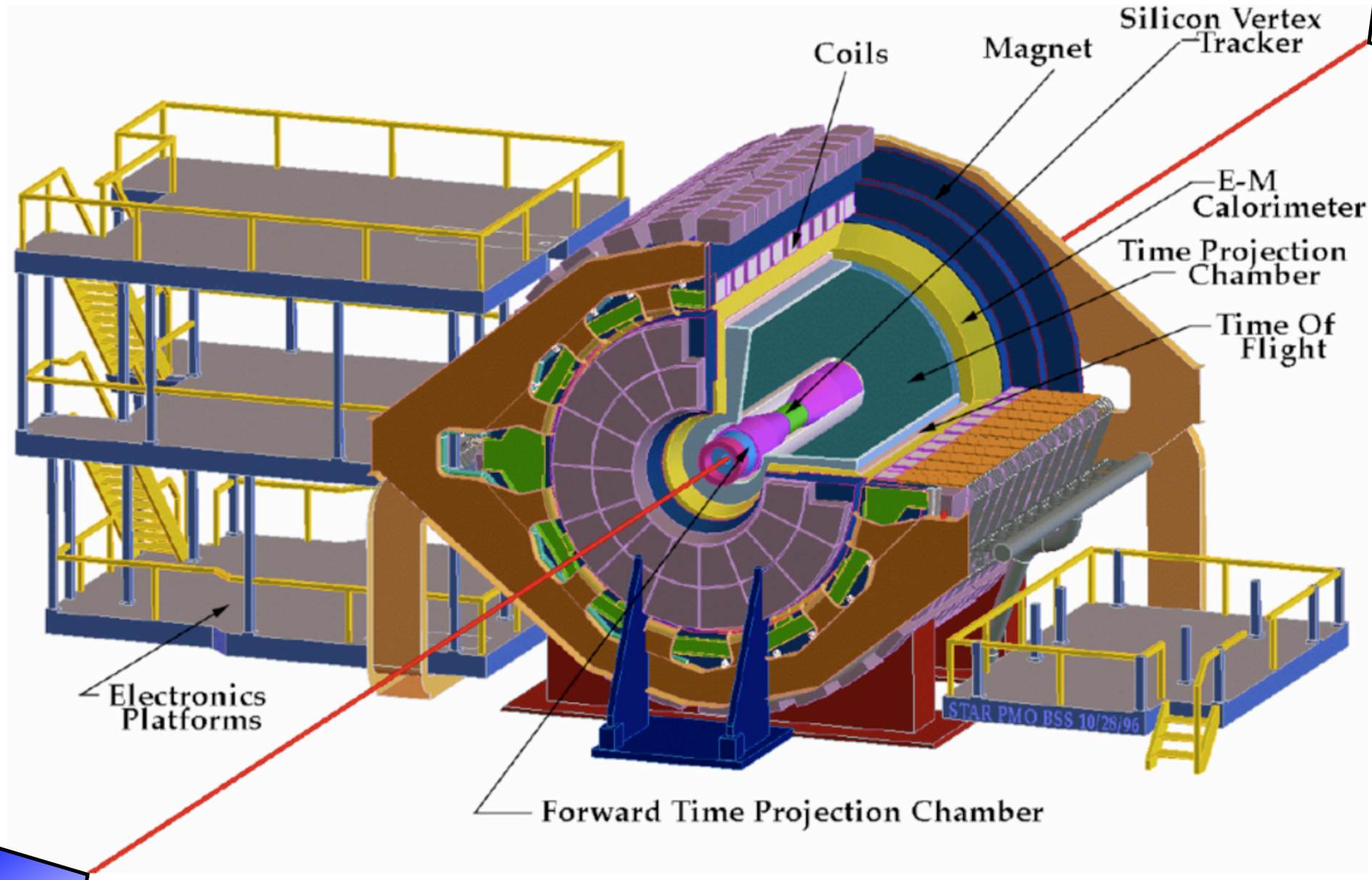

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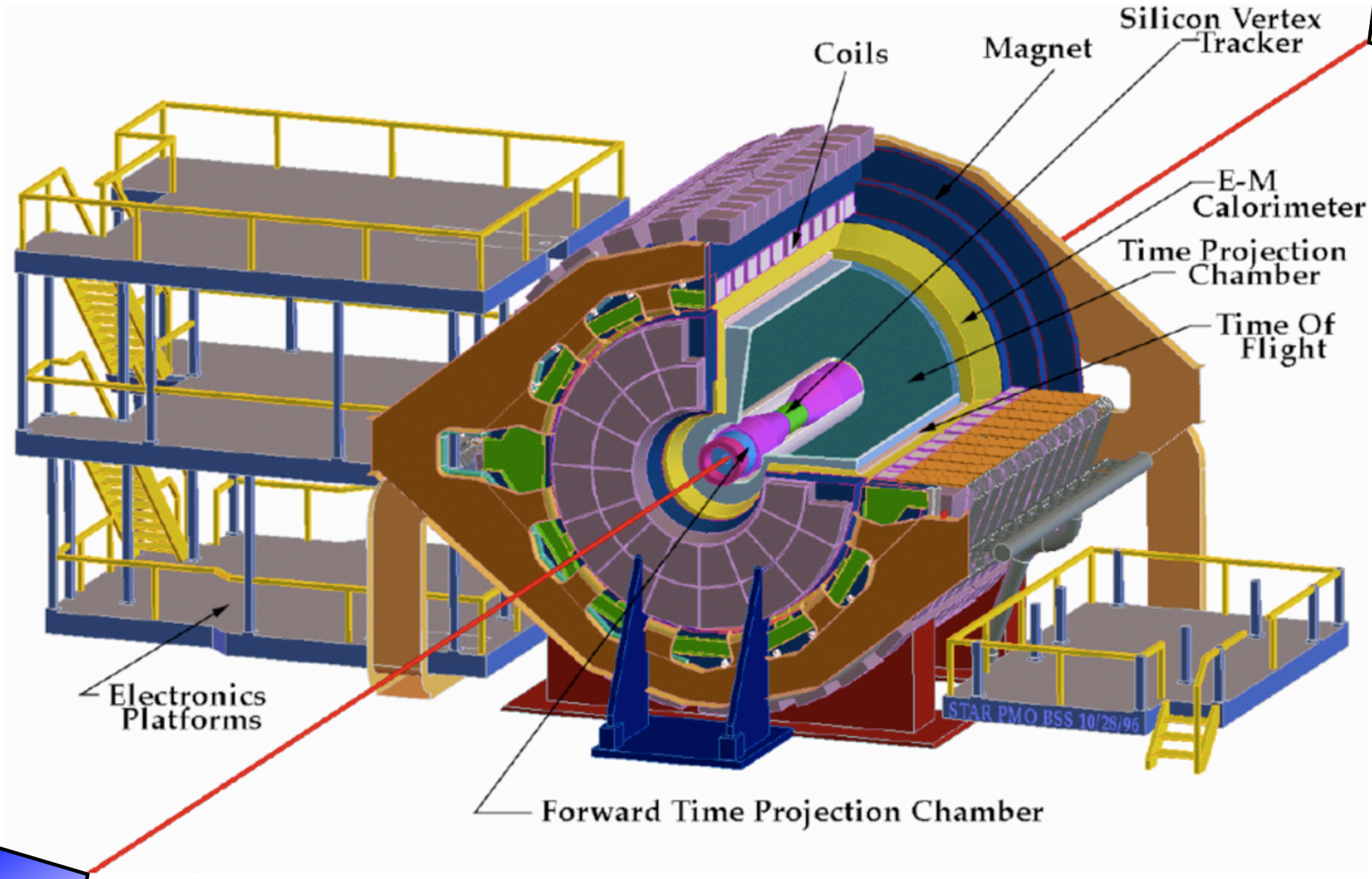

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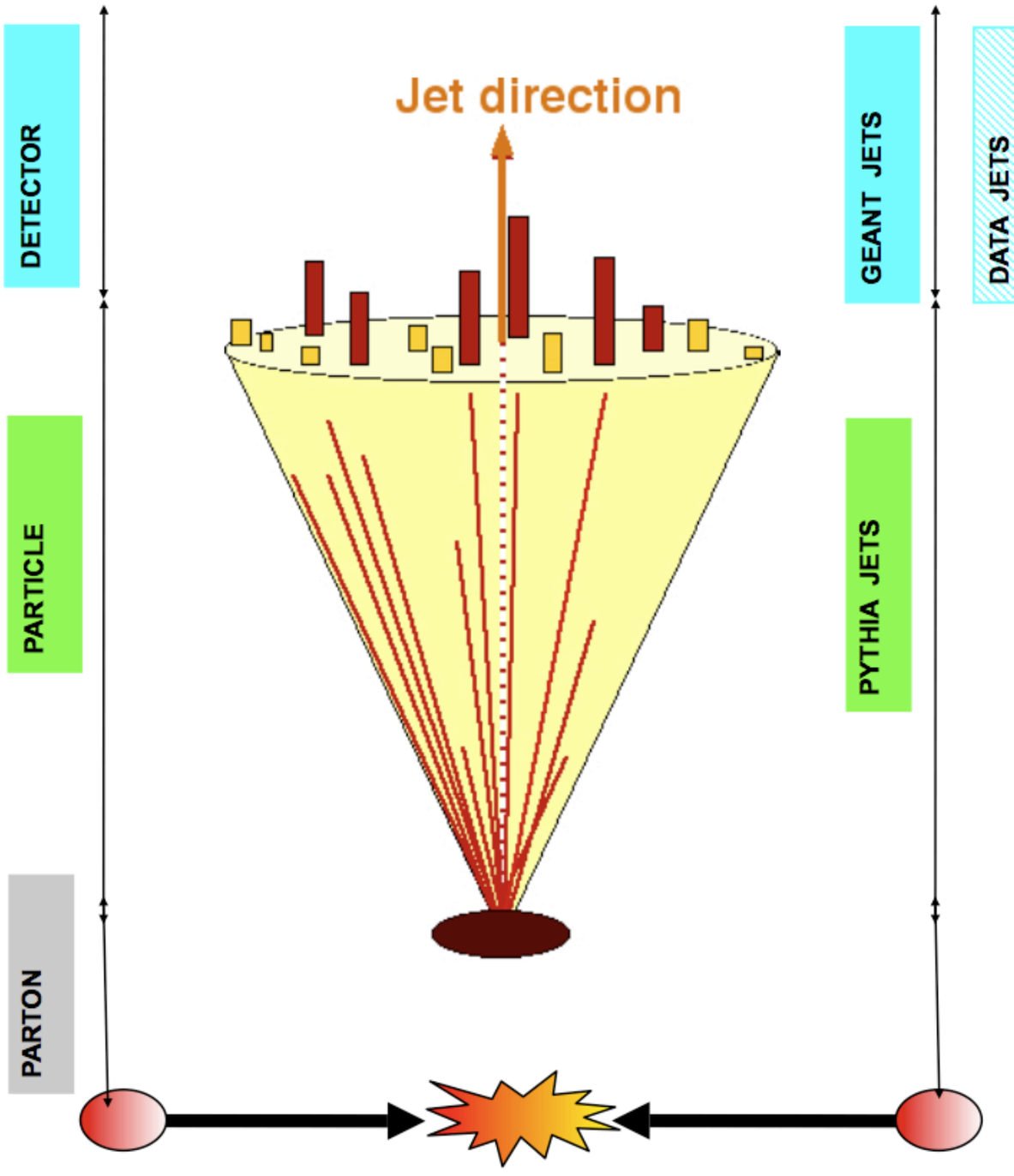
BEMC, EEMC: barrel/endcap calorimeters for triggering, jet reconstruction

Jet Reconstruction

Jet Reconstruction



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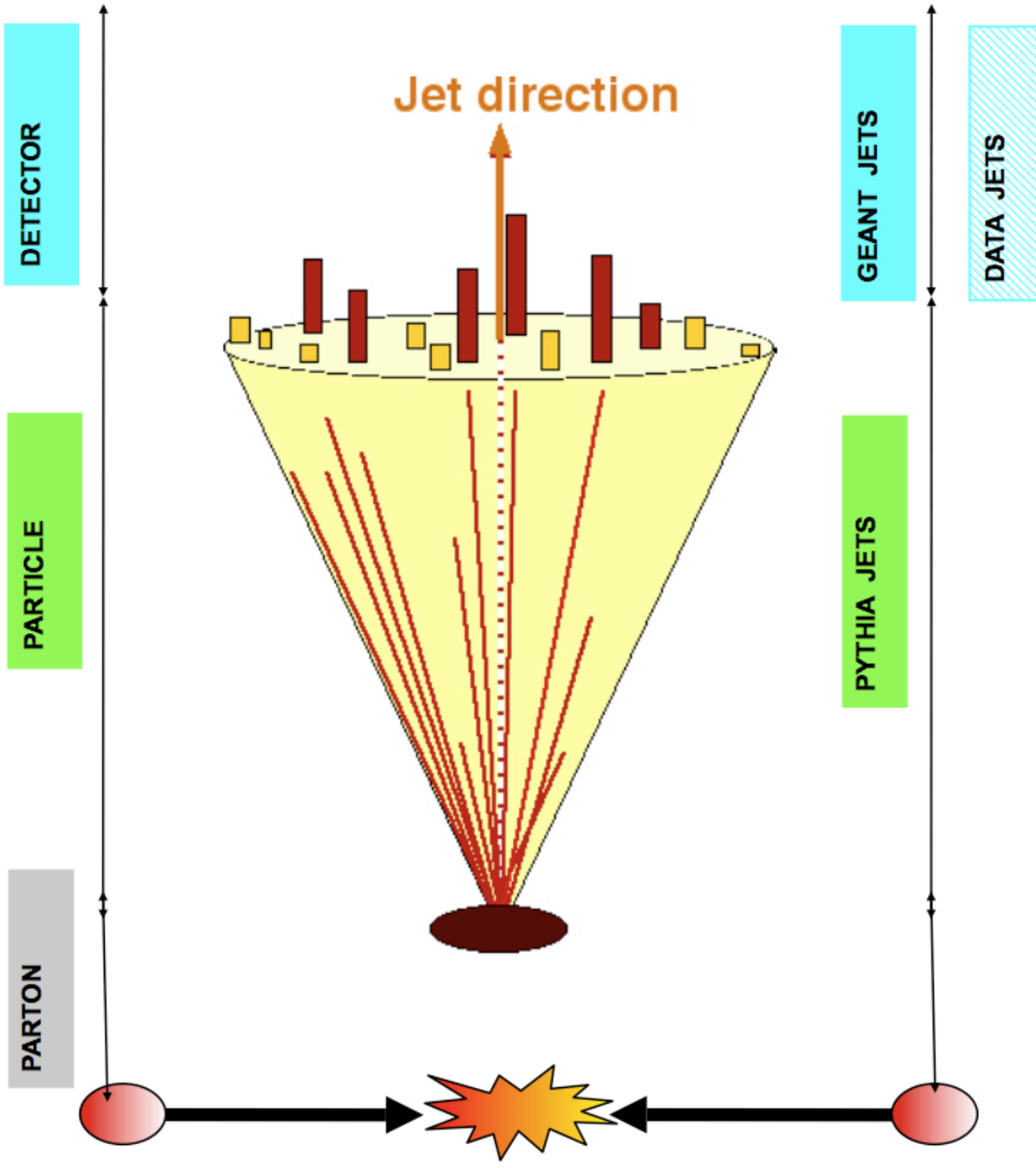


Midpoint Cone Algorithm

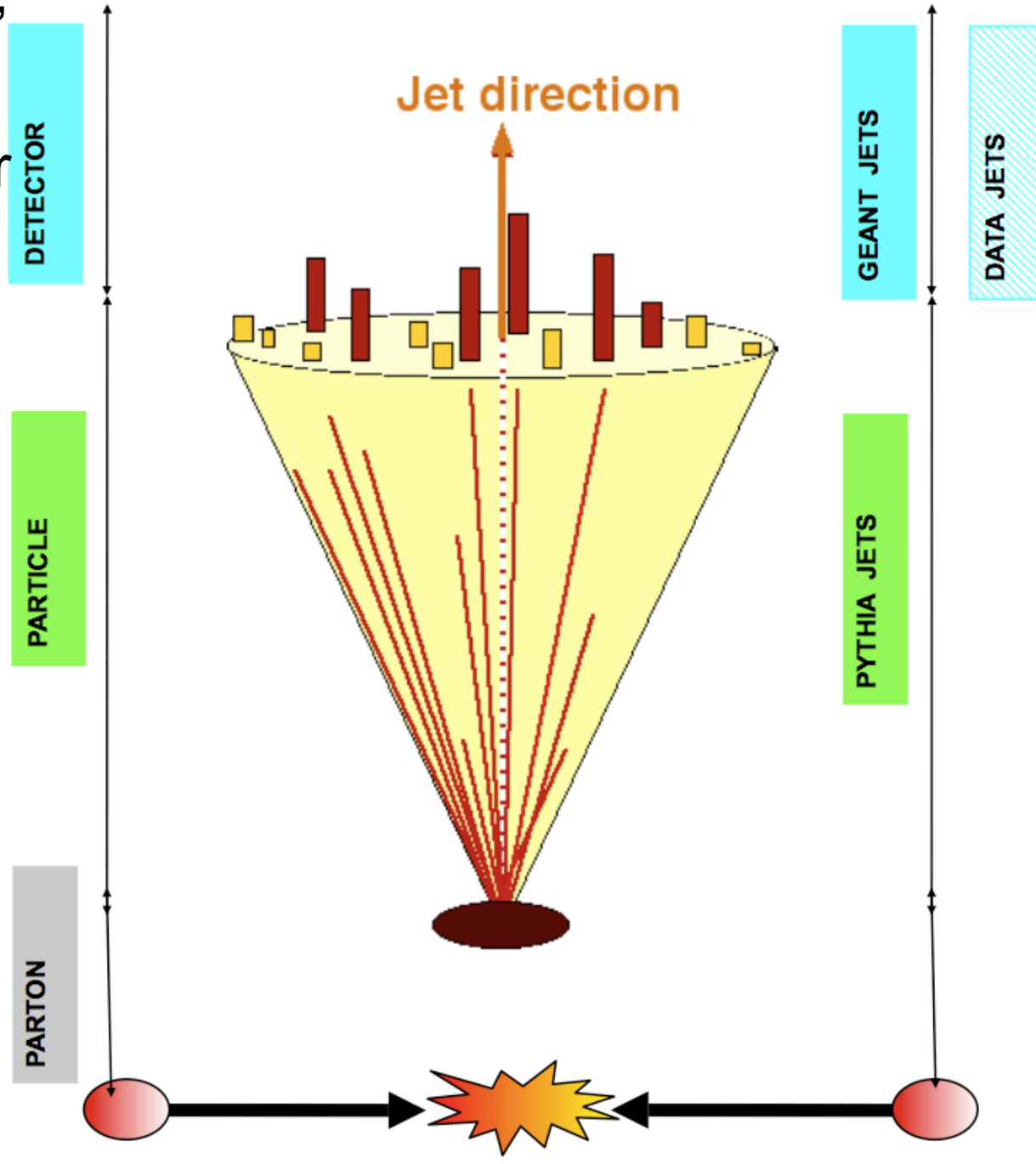
(hep-ex/0005012)

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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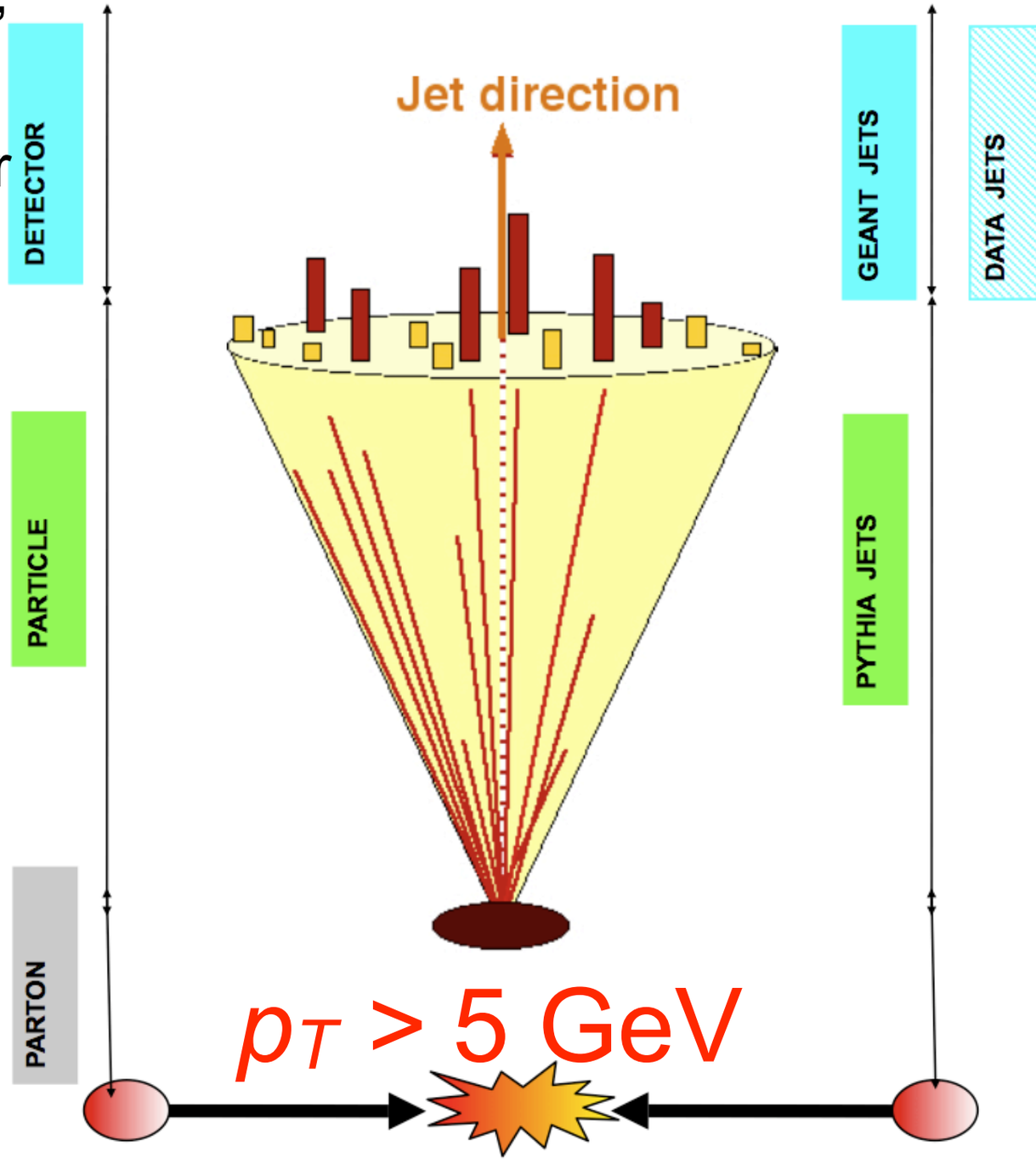

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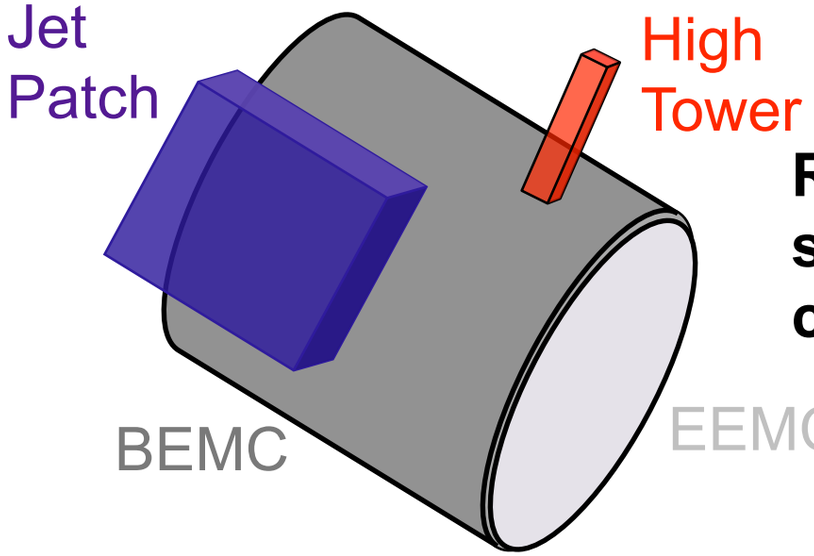
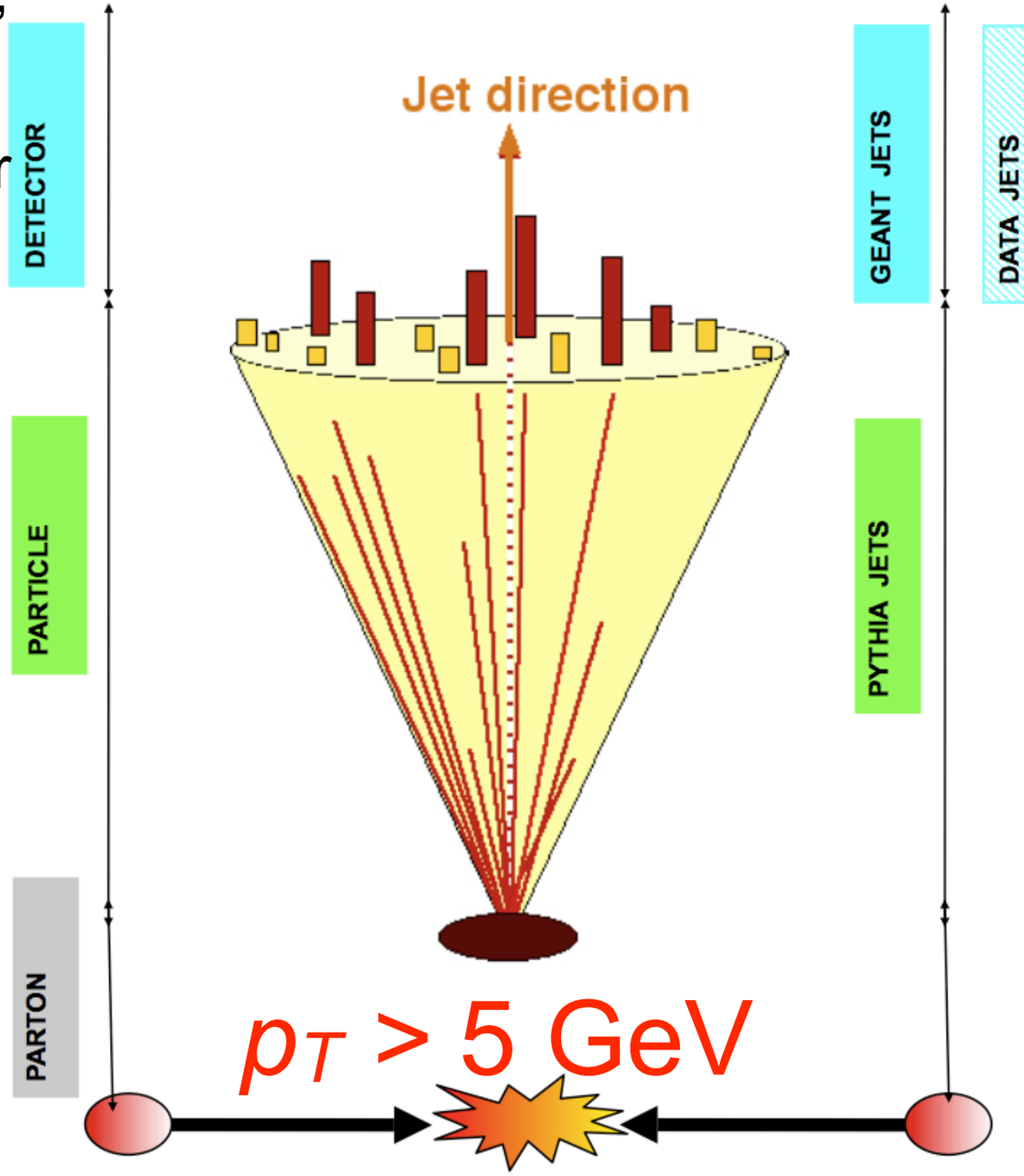


Results from several triggers compared



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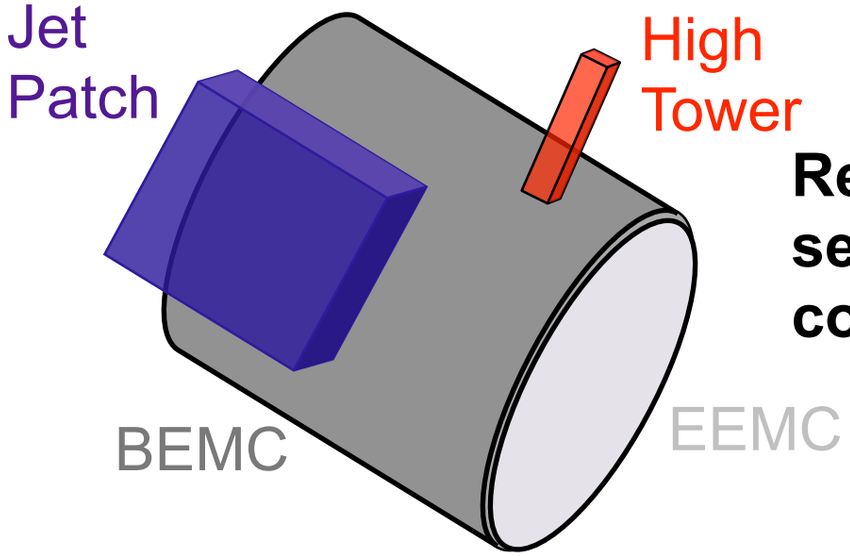
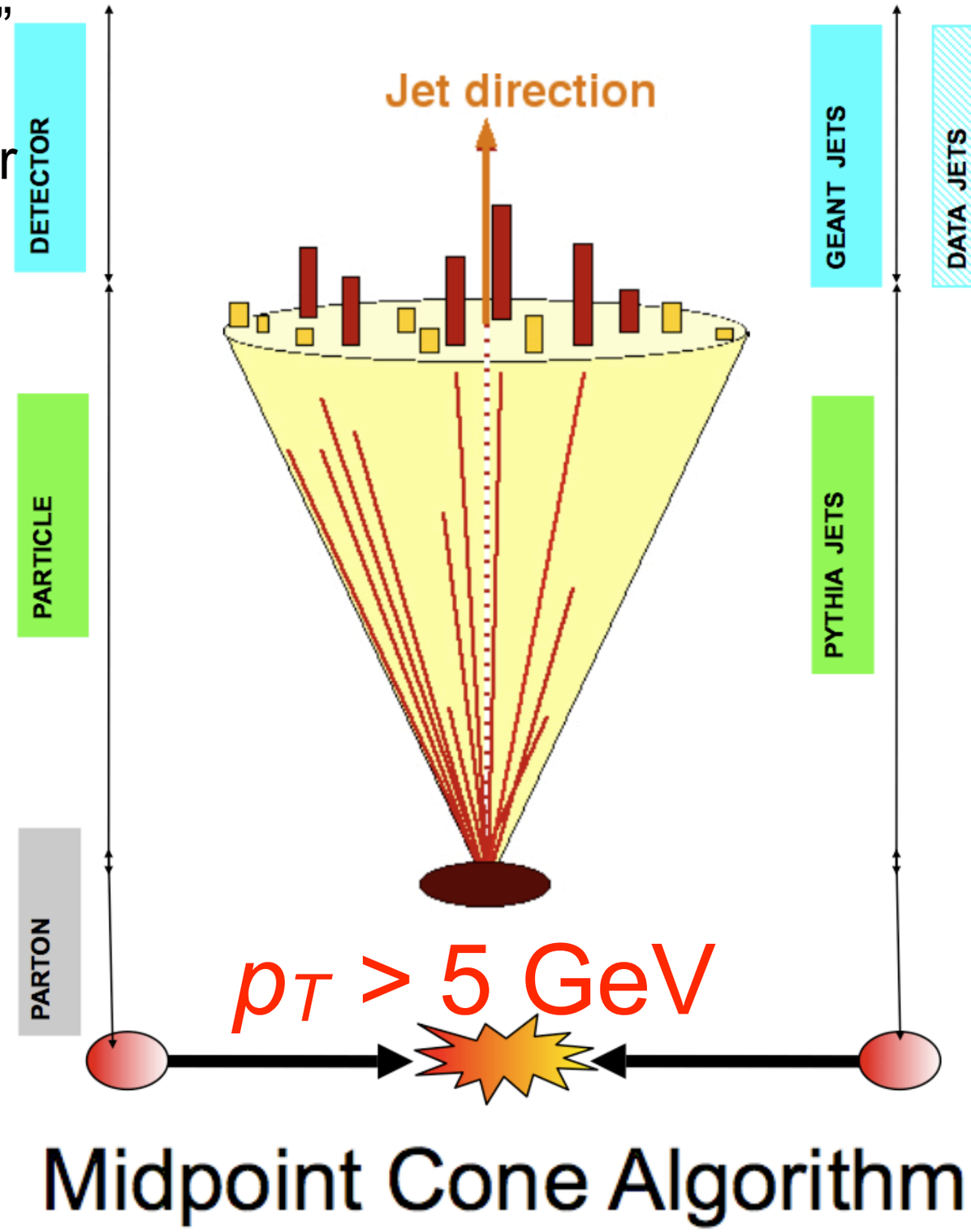


Results from several triggers compared

Jet Patch trigger:
Requires 400 localized “patches” ($\Delta\Phi = \Delta\eta = 1$) as a cluster for soft fragmentation;
threshold JP1 > 7.8 GeV



Midpoint Cone Algorithm

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Kinematic coverage

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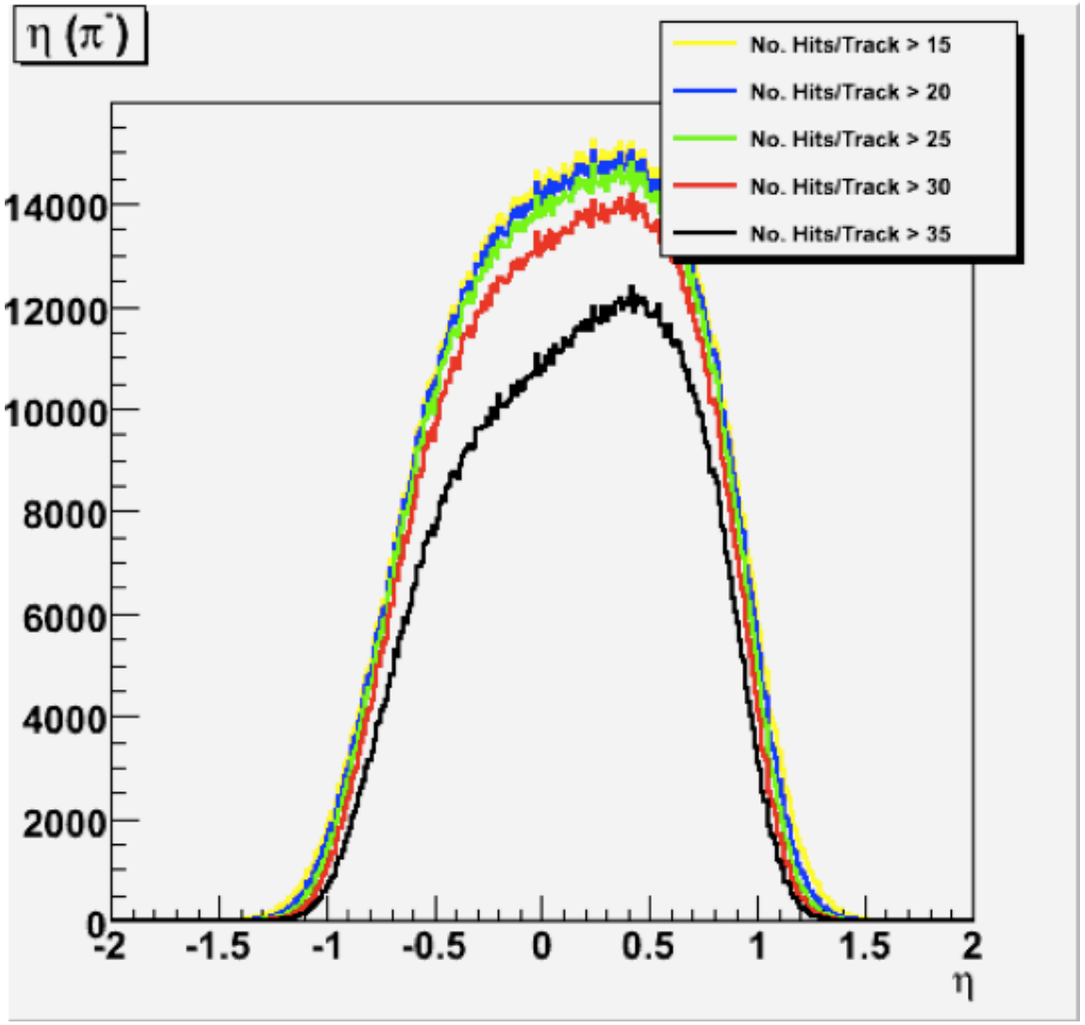

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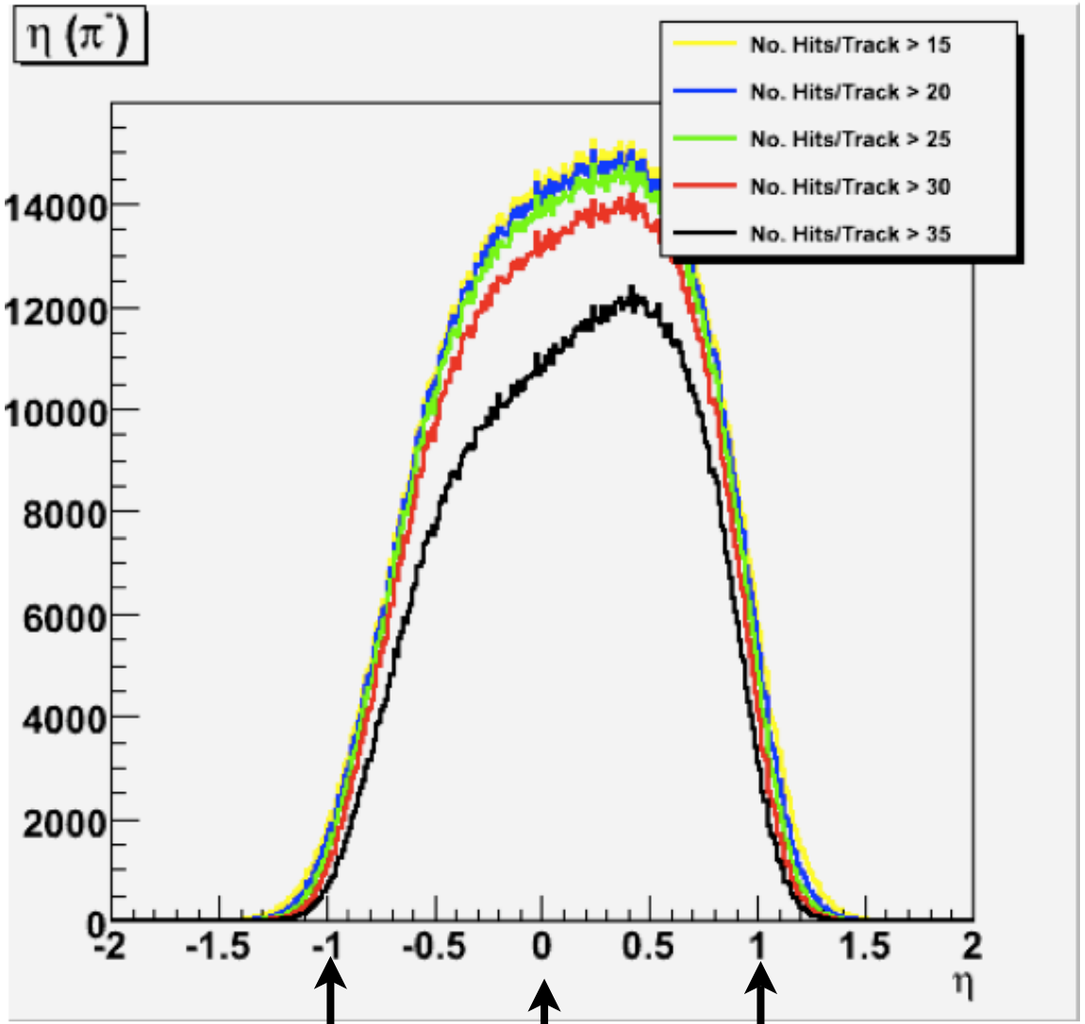
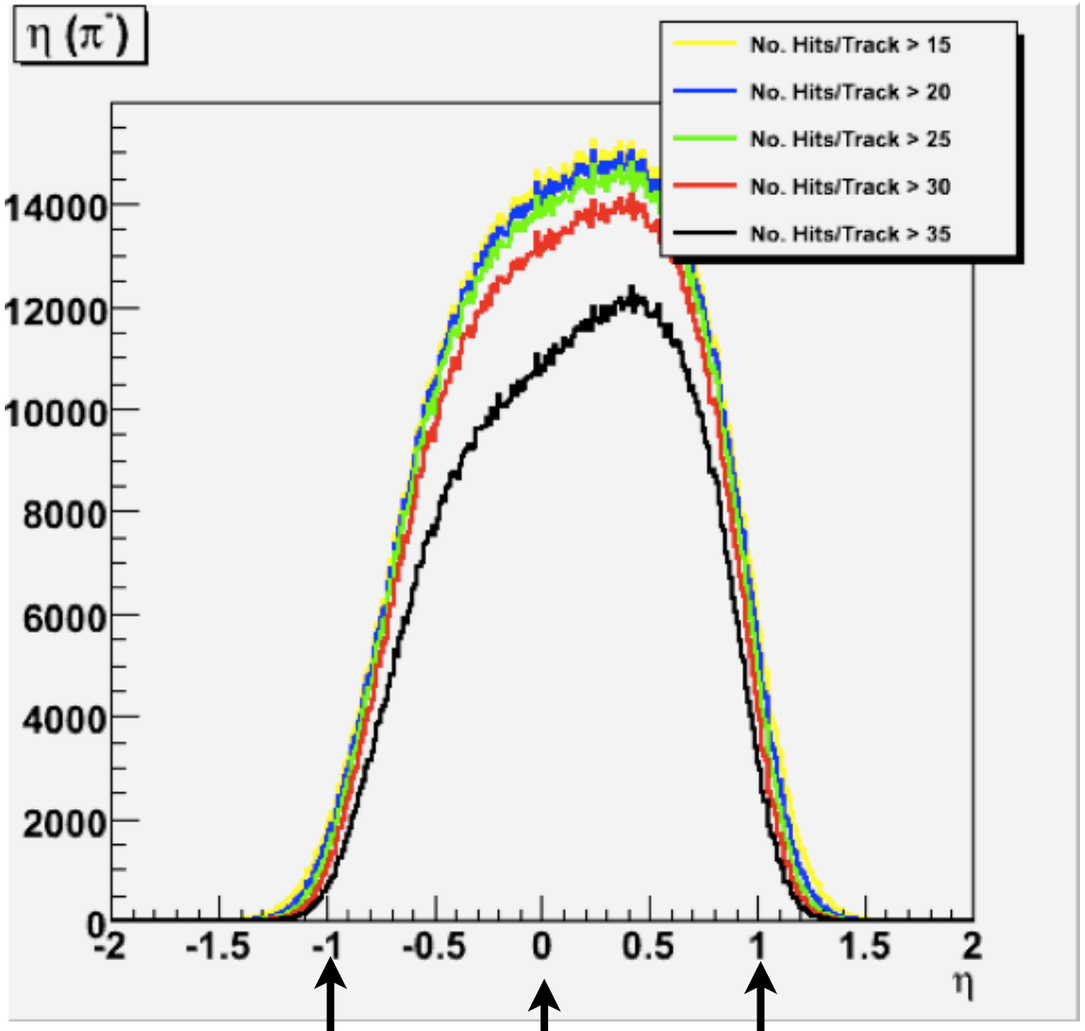


backward BEMC, TPC edge

90°

forward BEMC, TPC edge

Kinematic coverage



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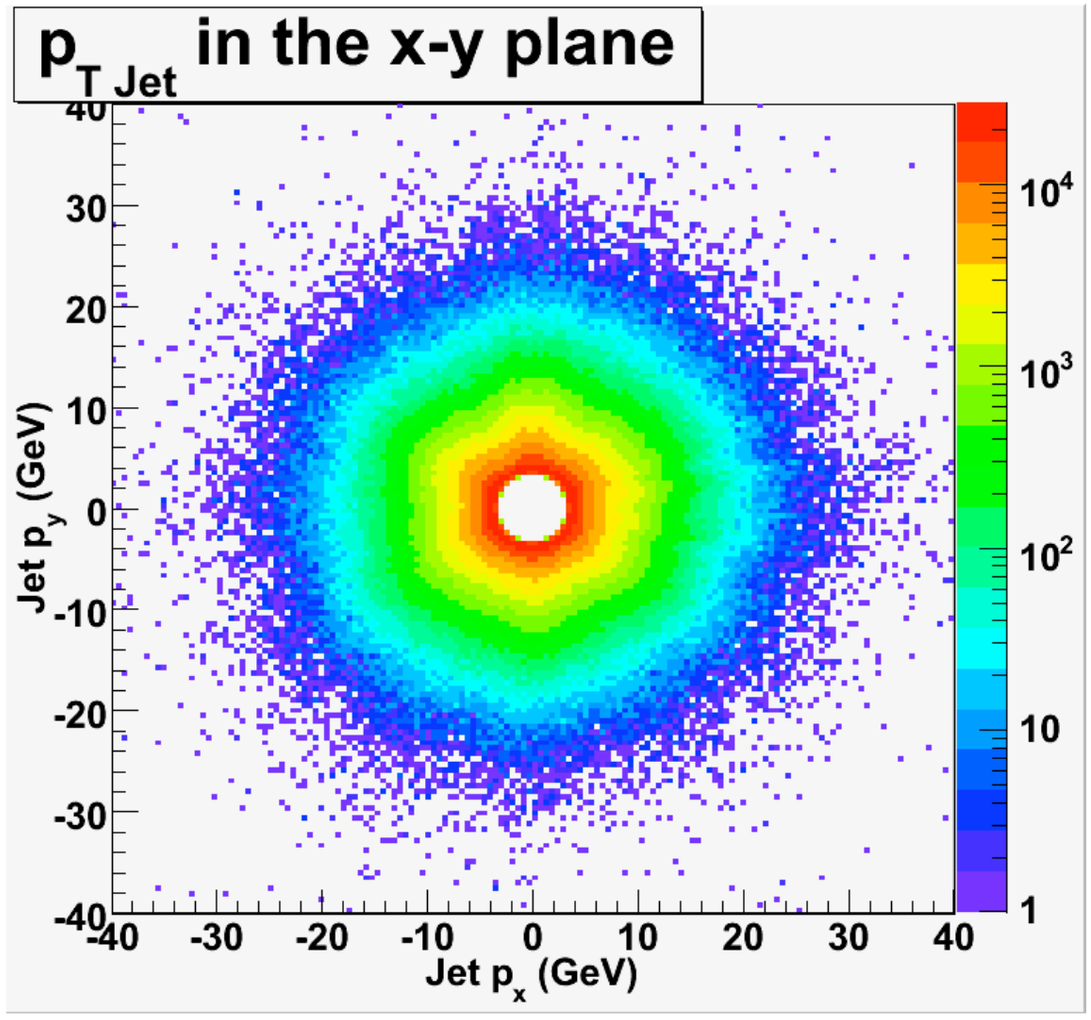

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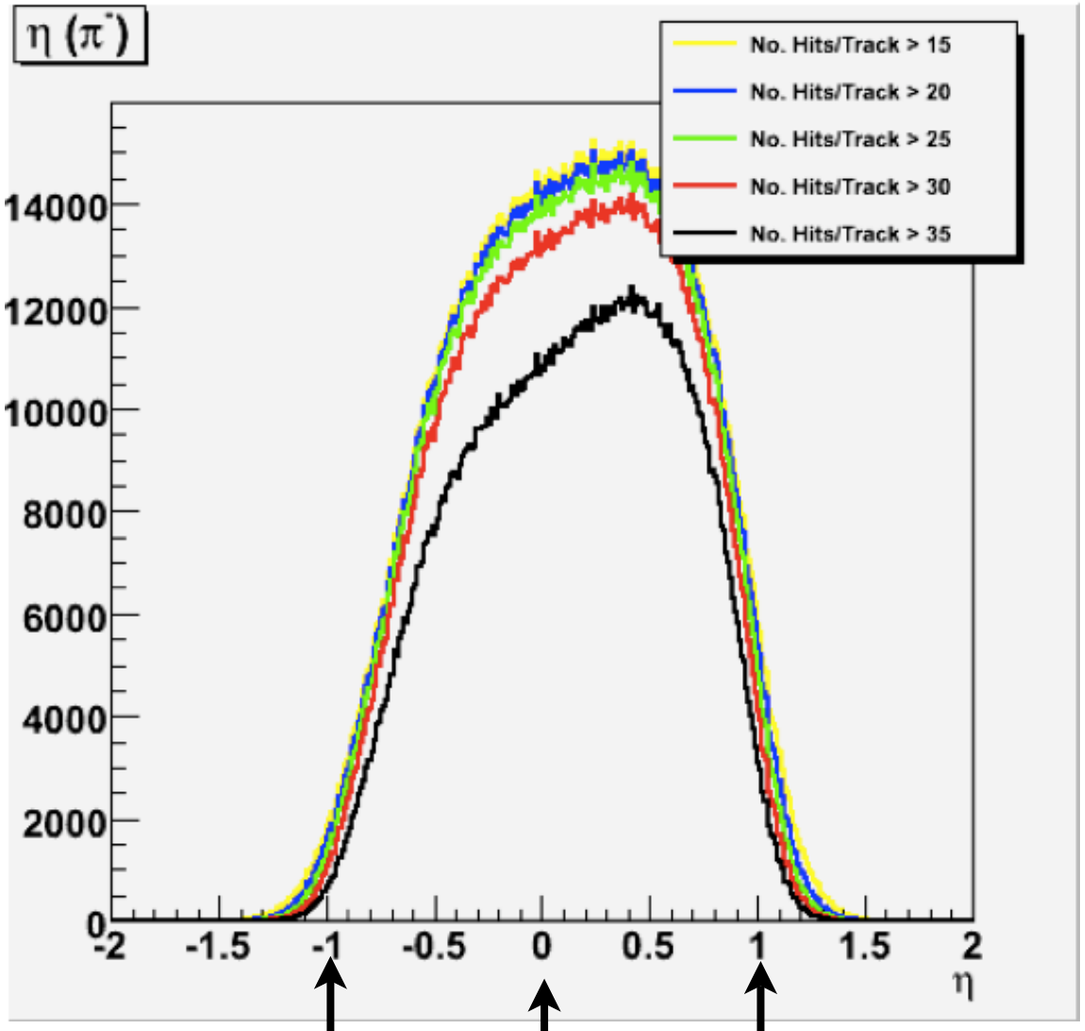

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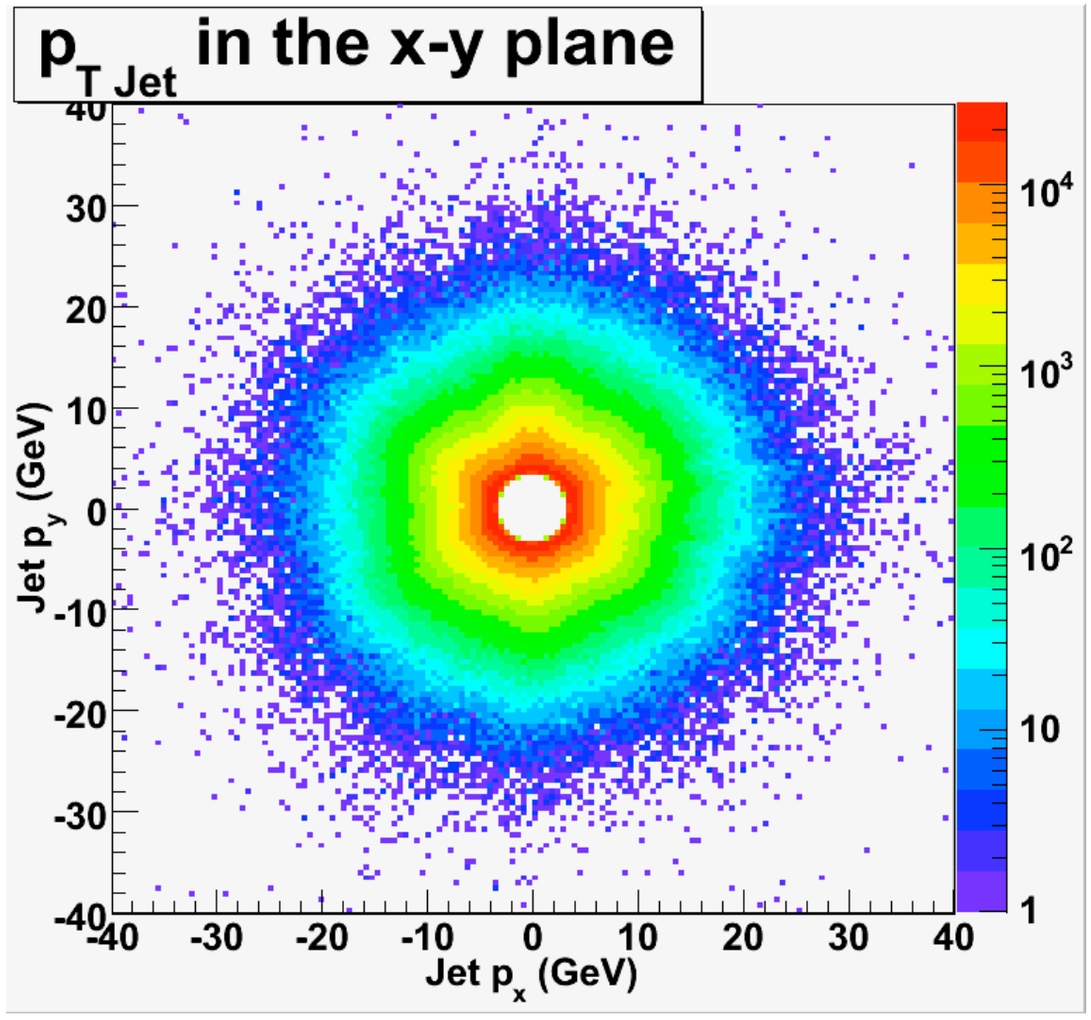
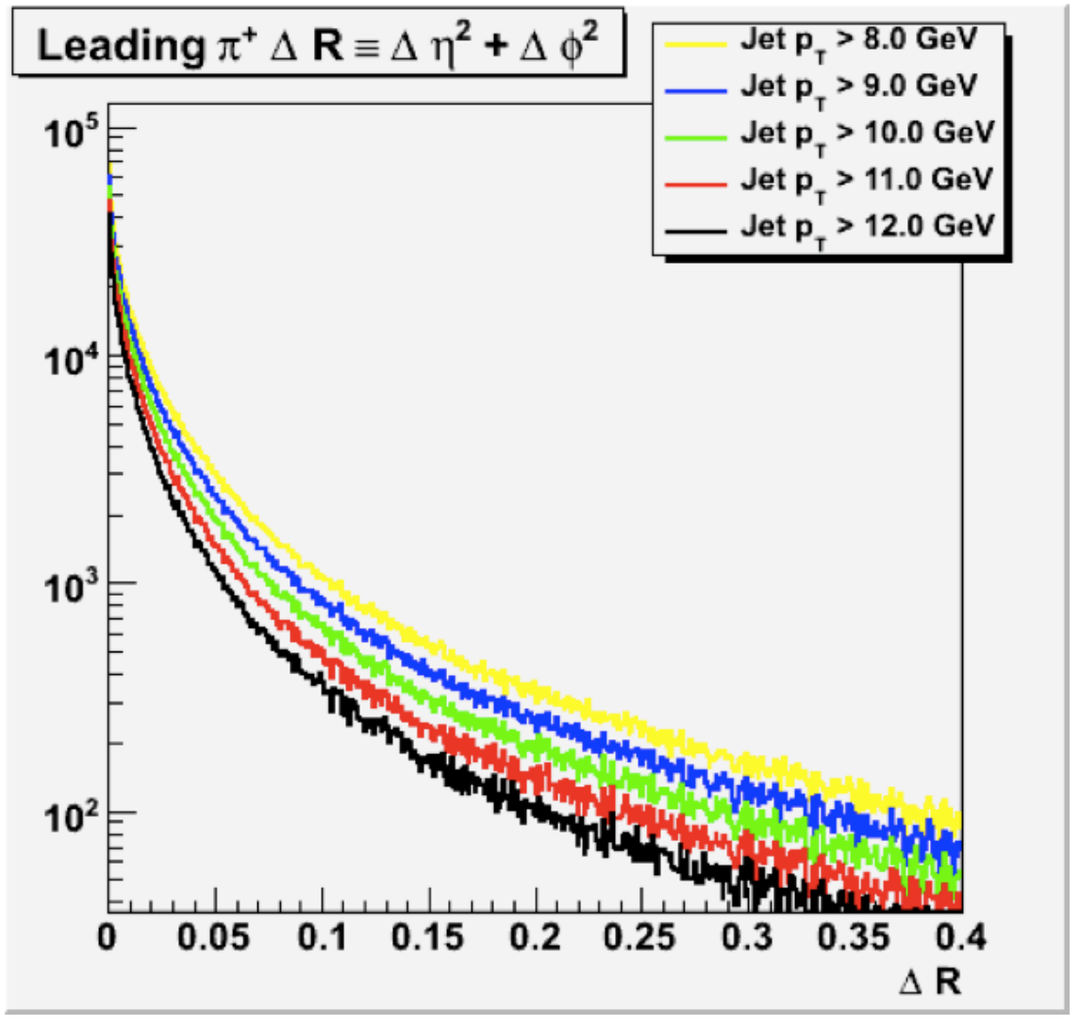
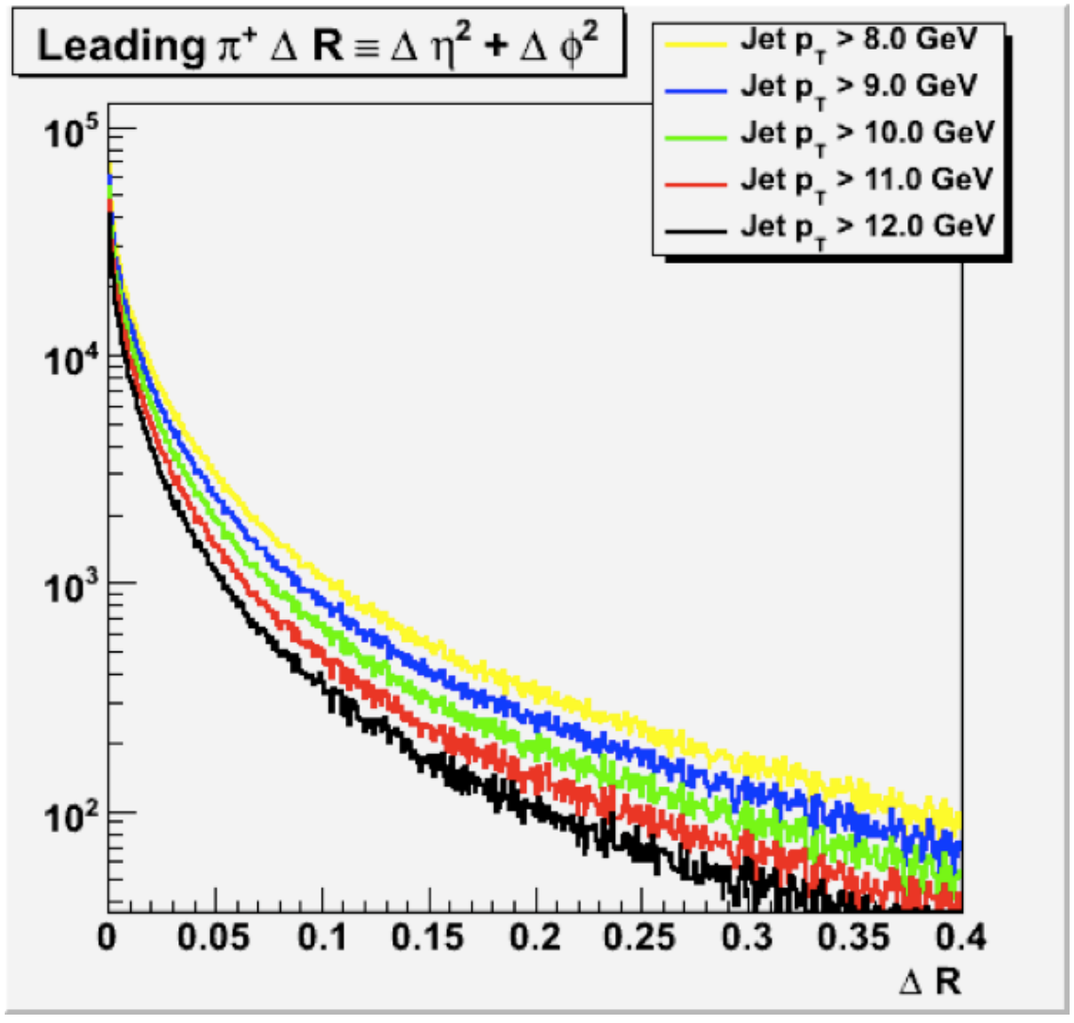


full azimuthal (Φ) coverage

Kinematic coverage

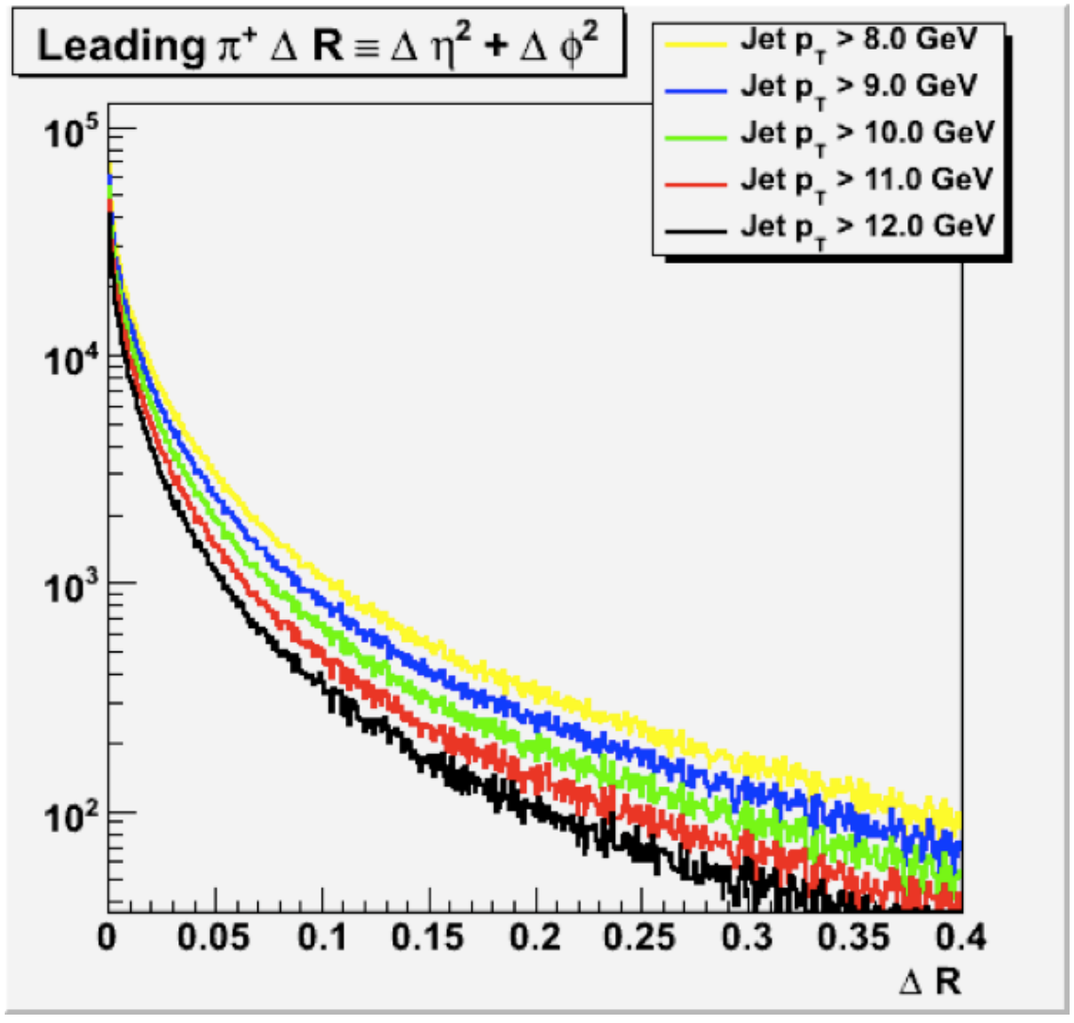


Kinematic coverage



ΔR measures collimation of particles within jet

Kinematic coverage



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

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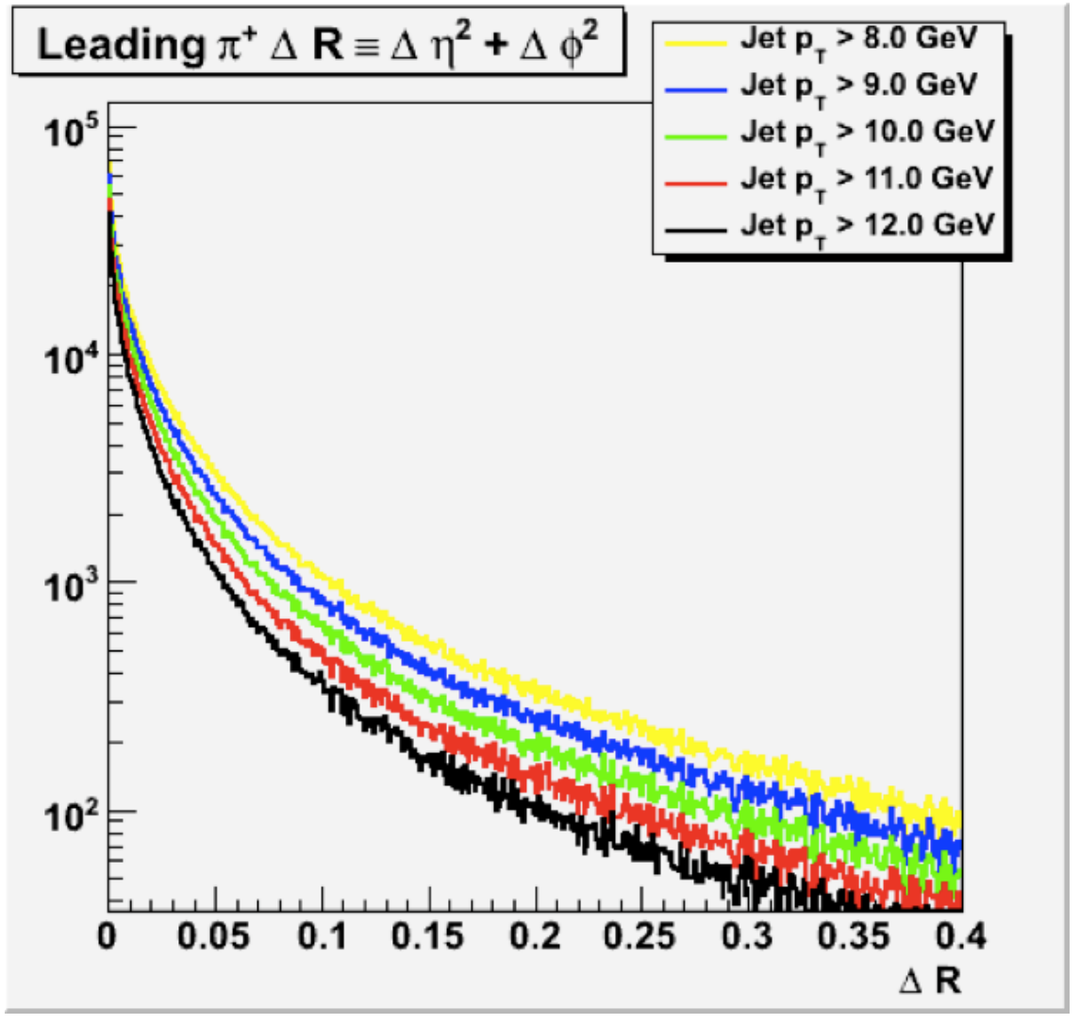

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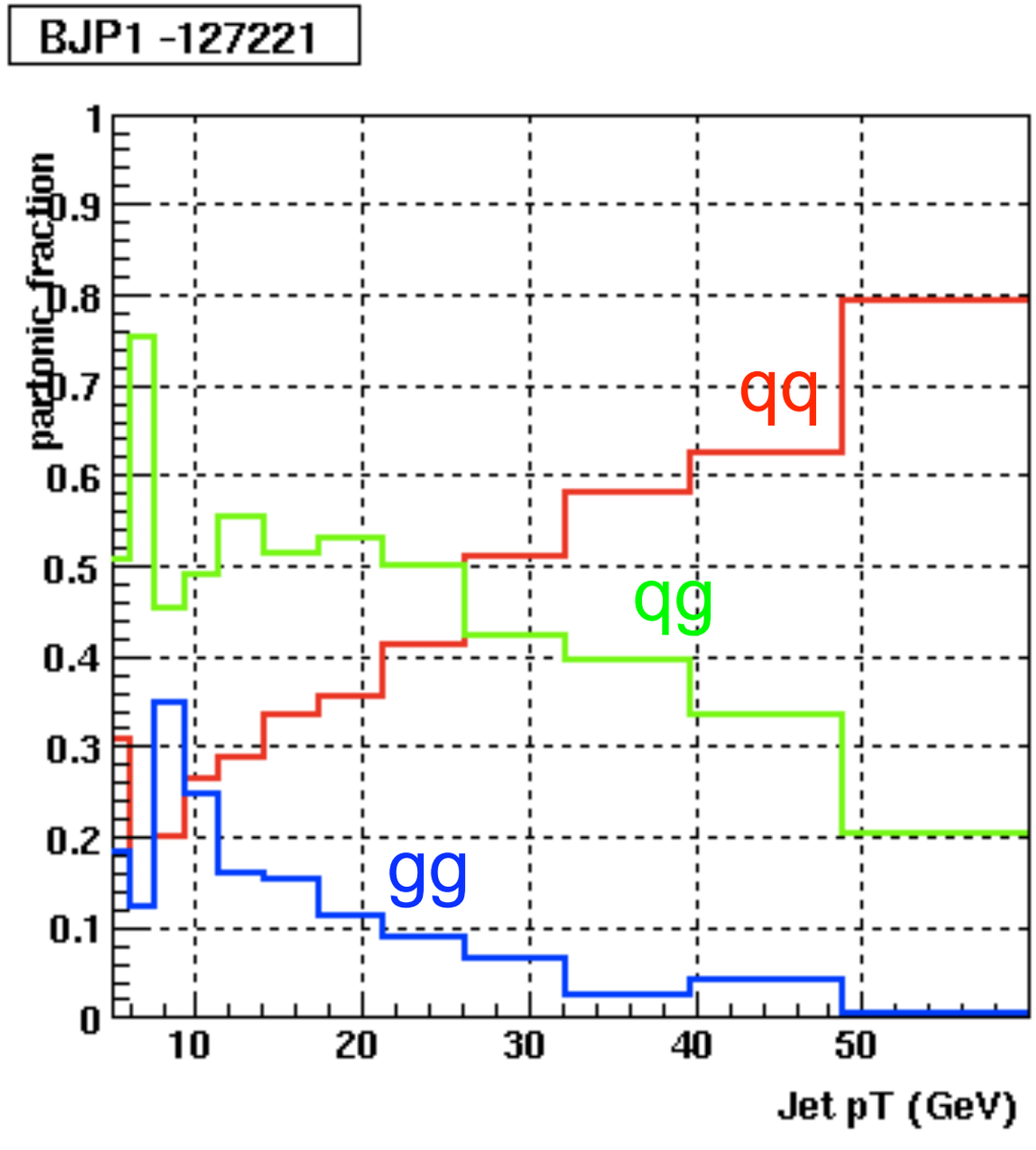
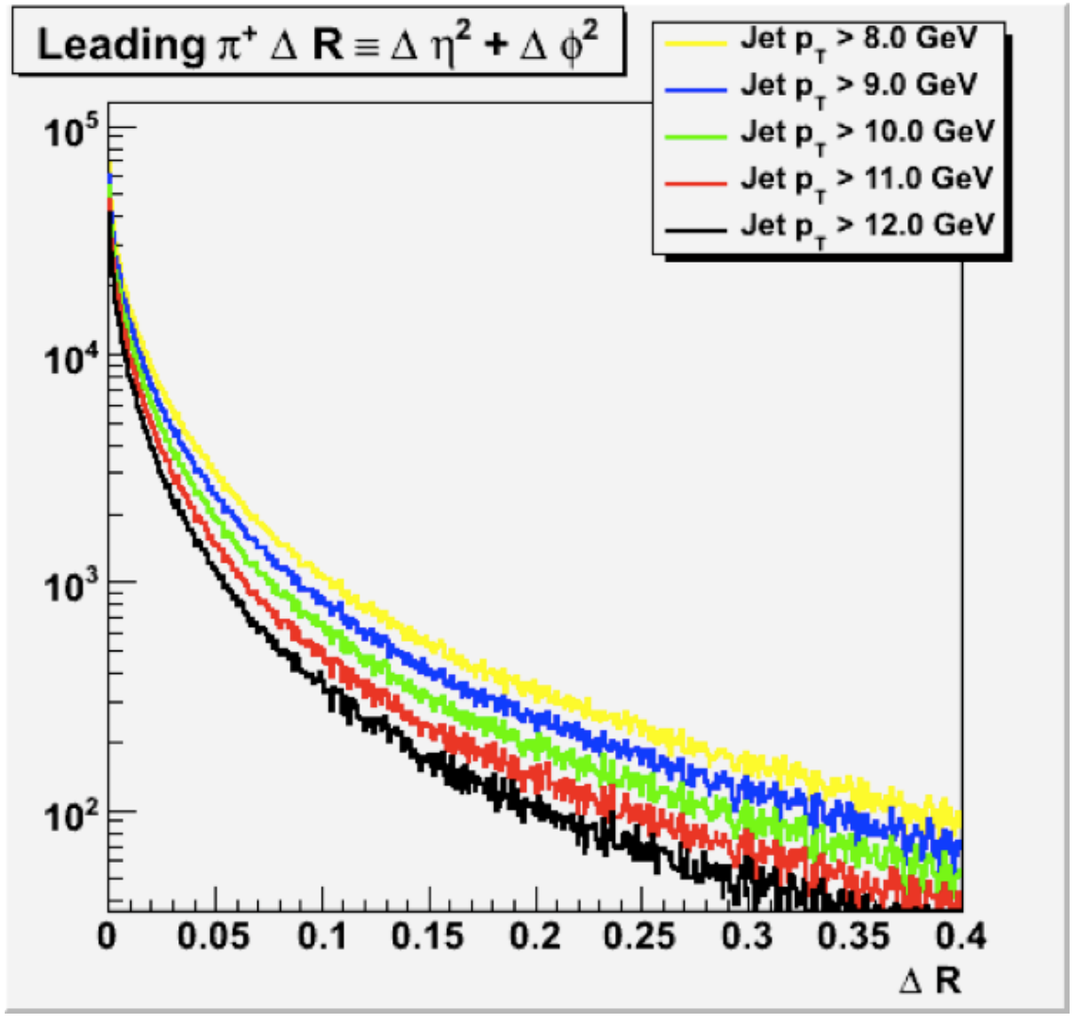


STAR simulation (PYTHIA + GEANT) at √s = 200 GeV

Kinematic coverage



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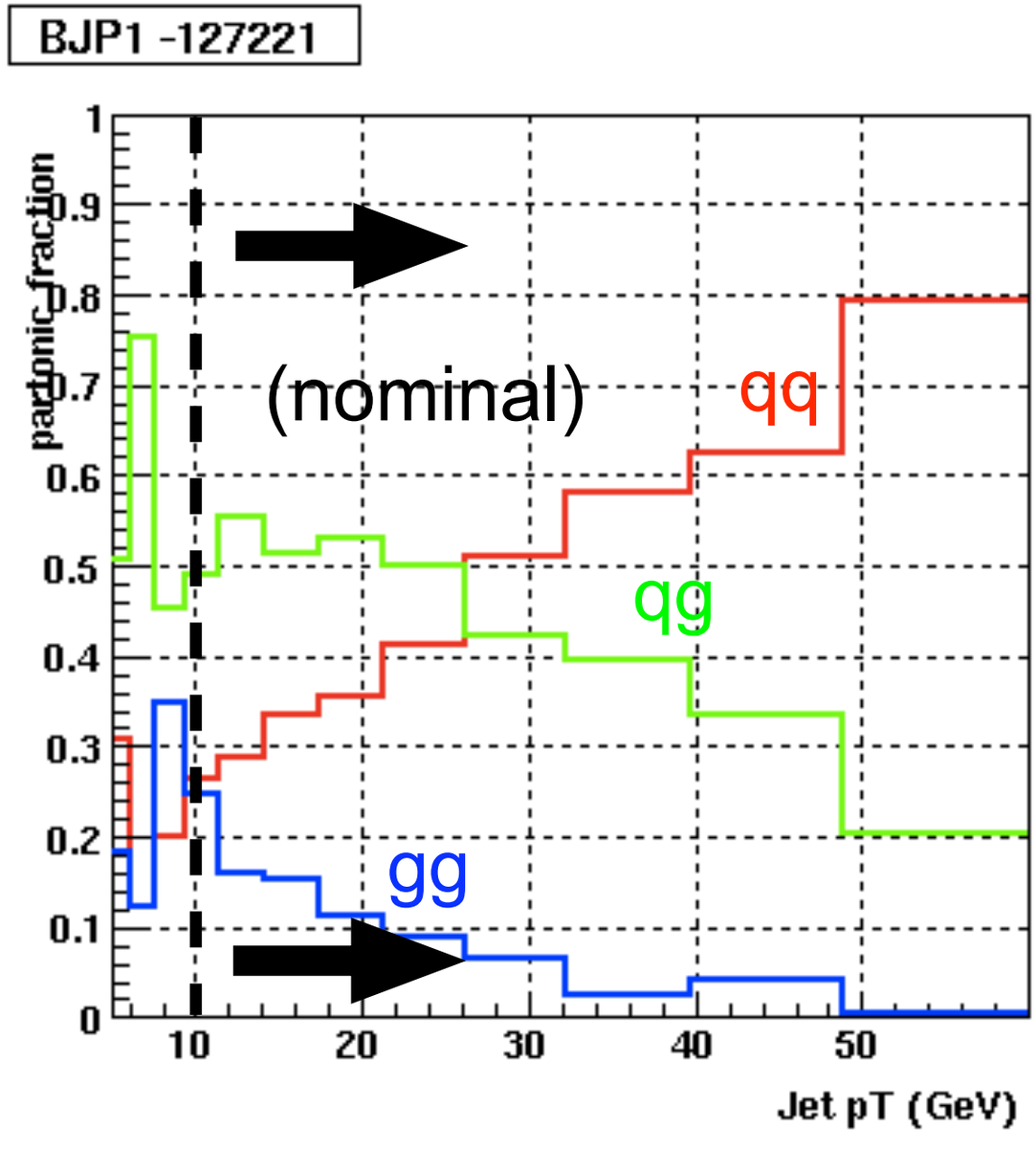

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Determining Relevant Kinematics

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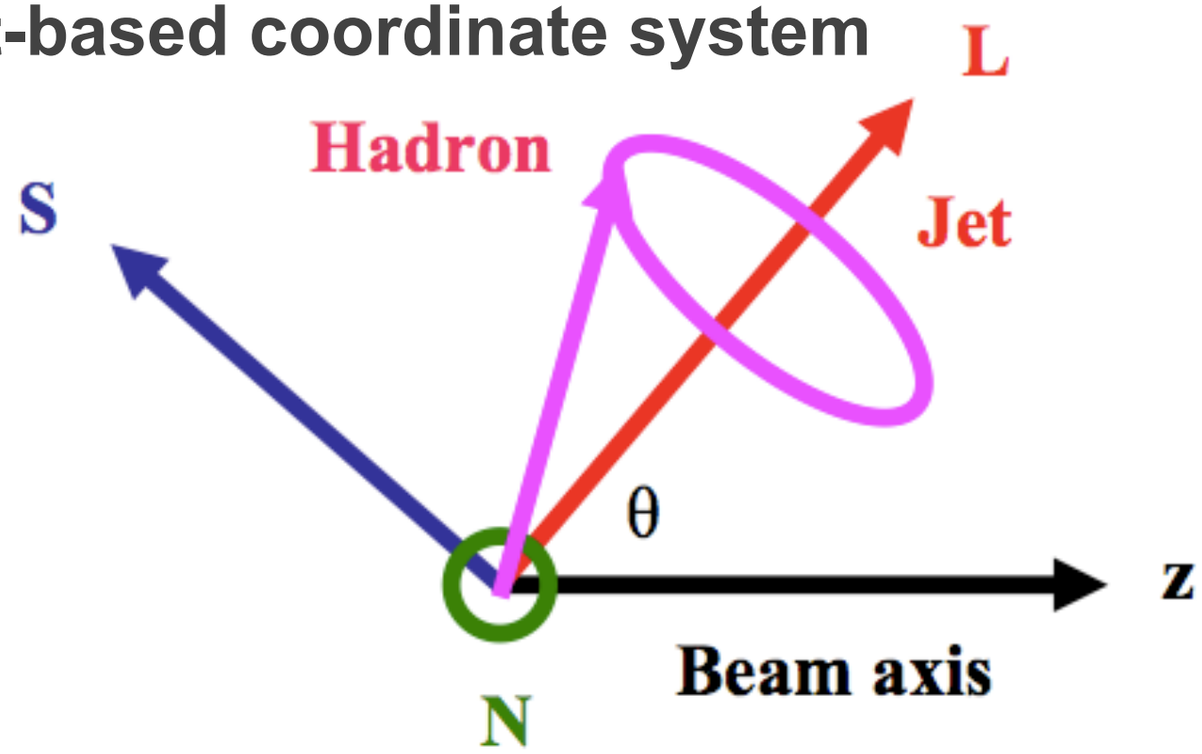
Jet-based coordinate system



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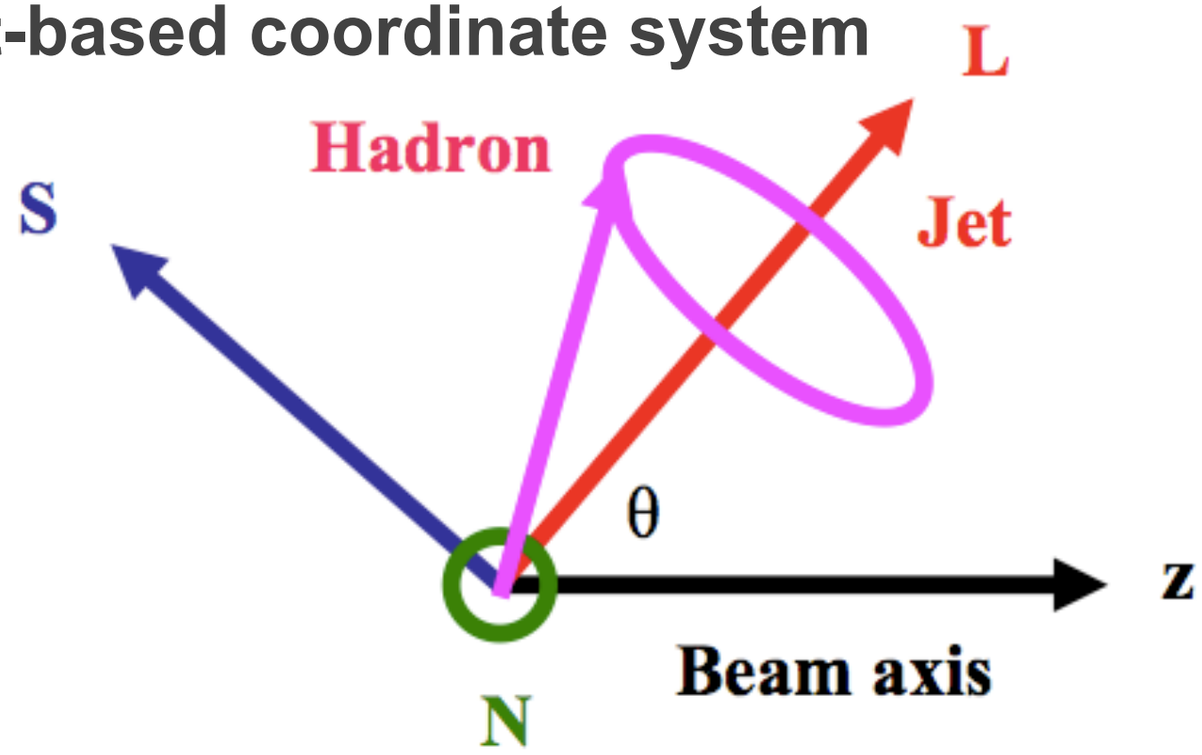

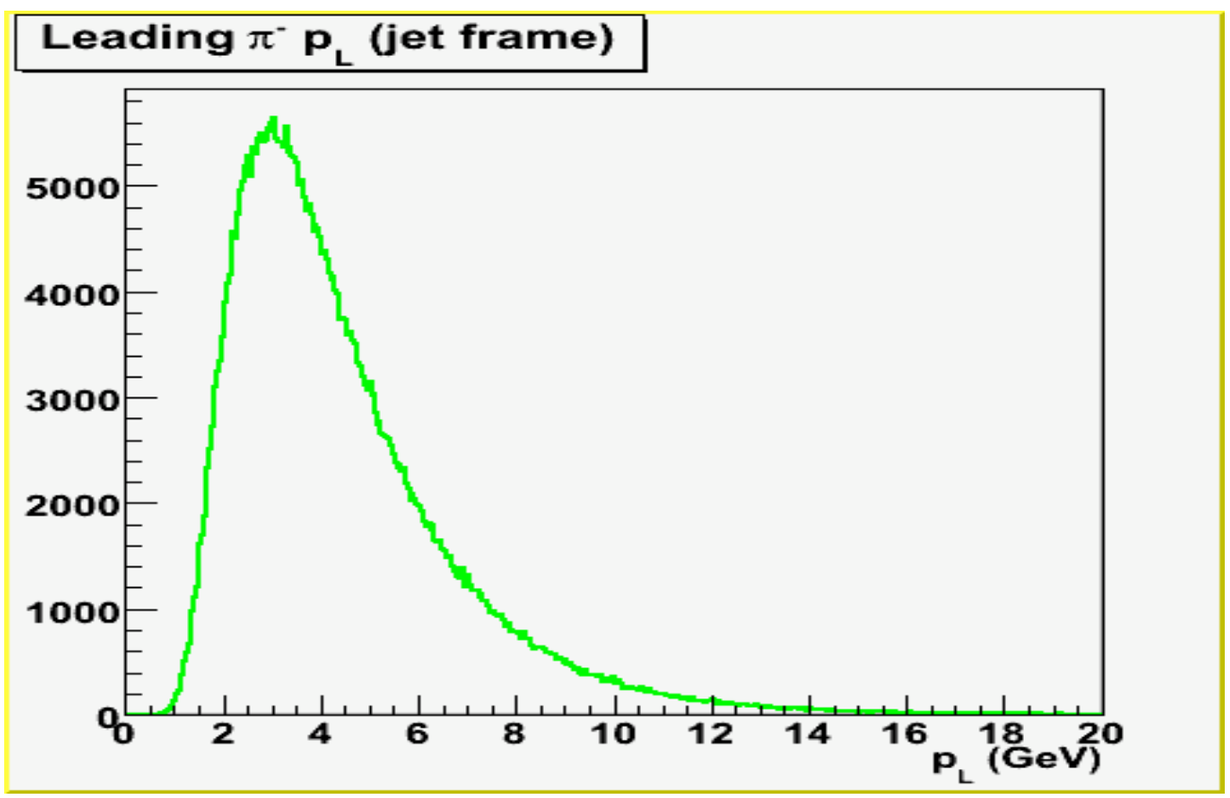

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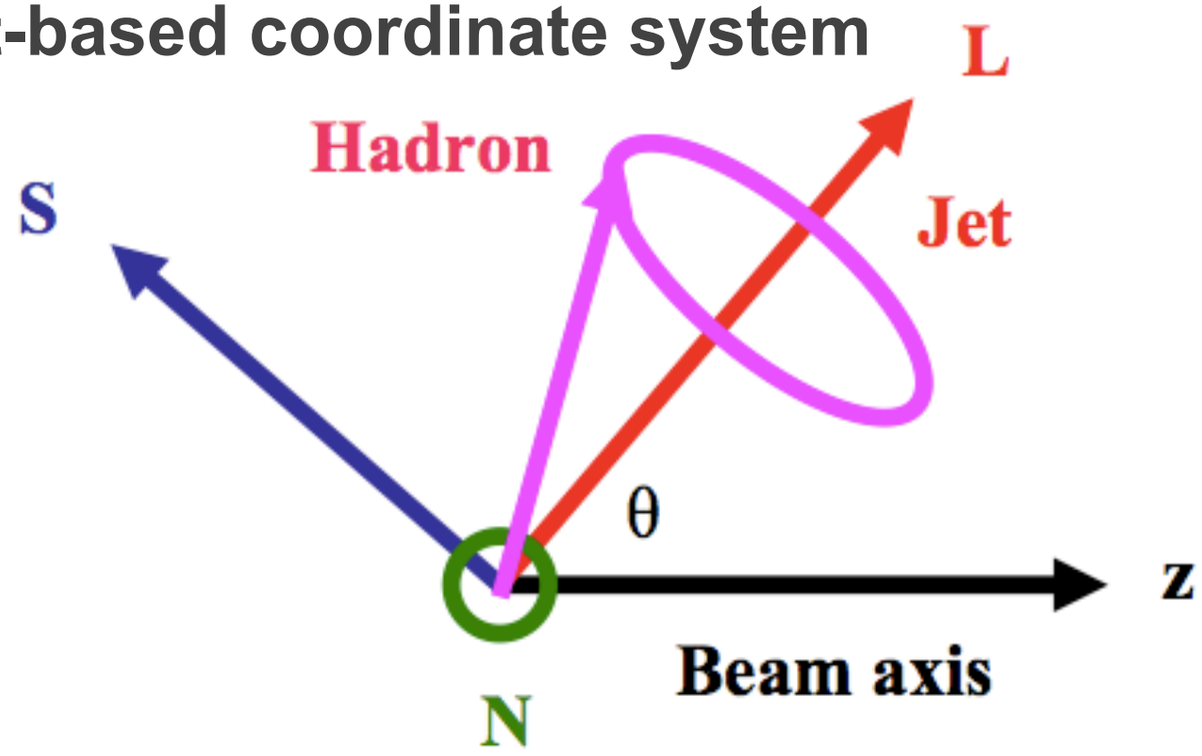

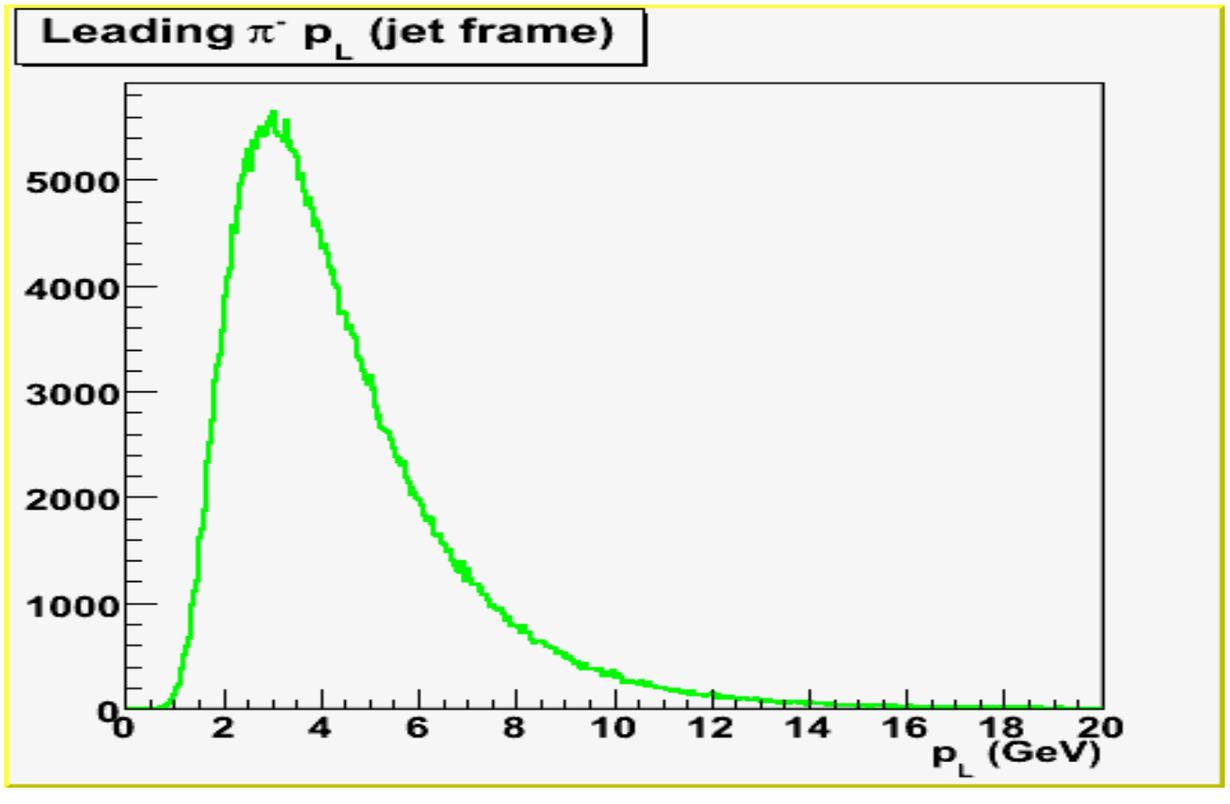

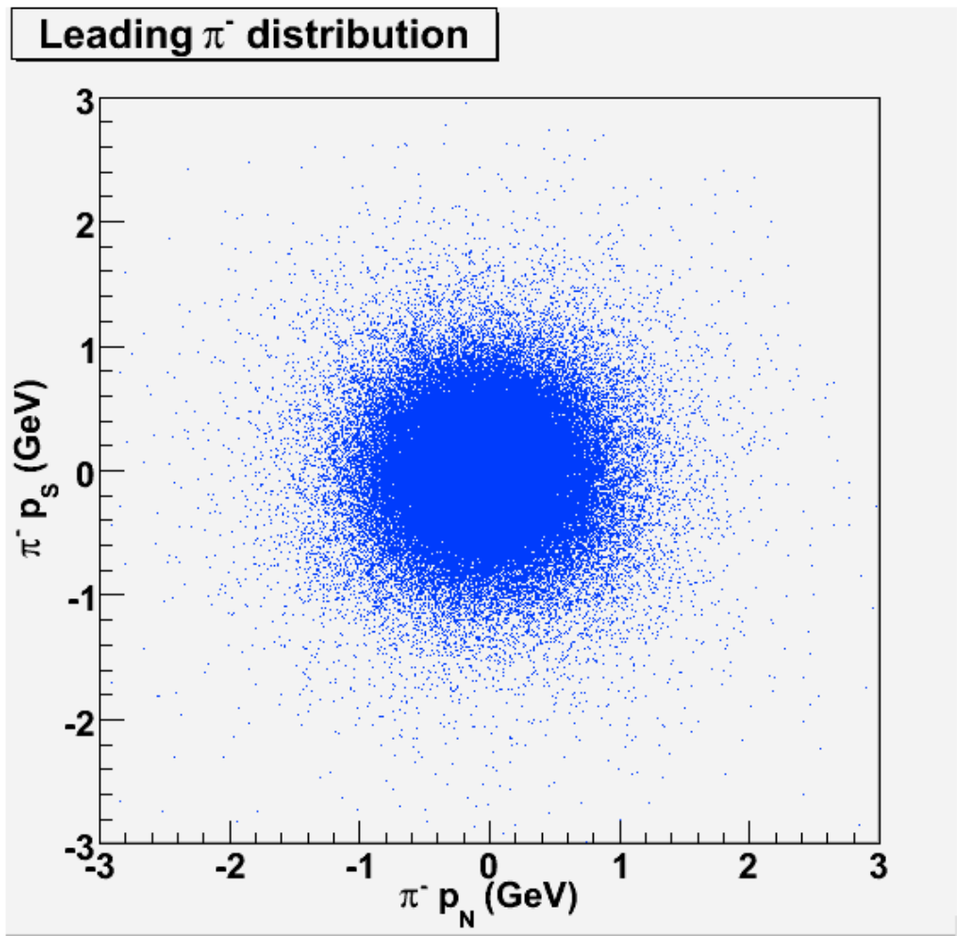

Integrated over all j_T values

Determining Relevant Kinematics

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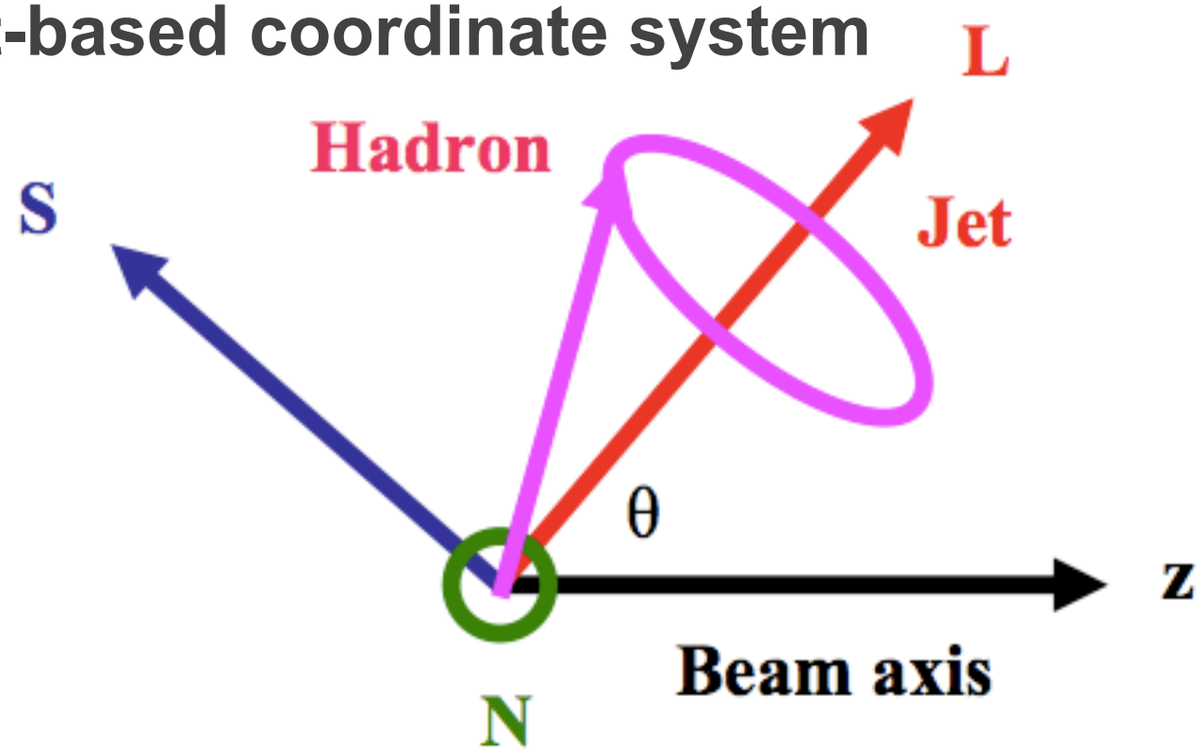
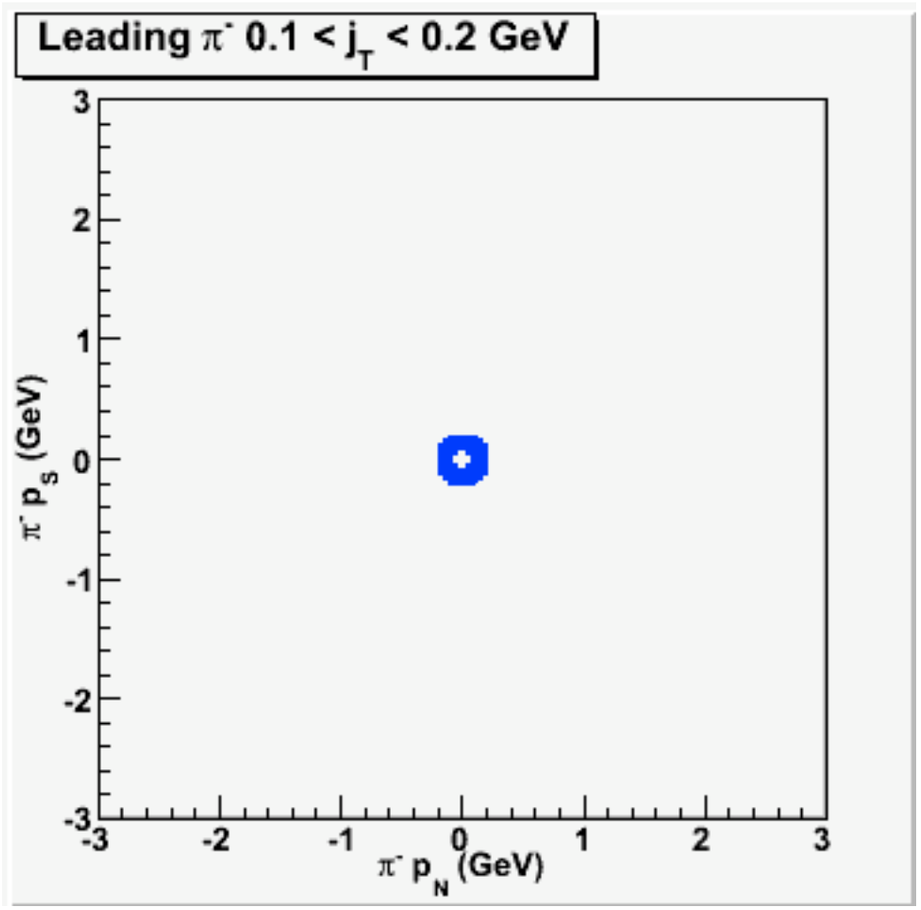
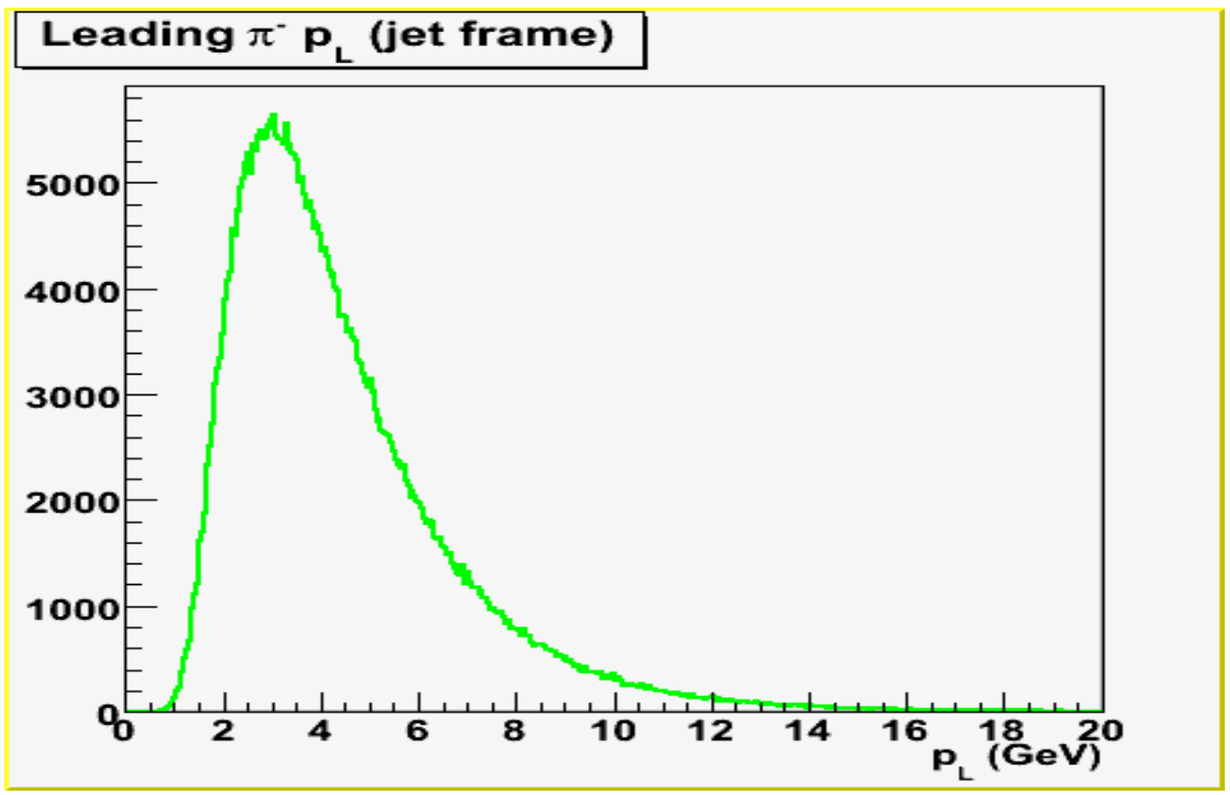




Selected j_T range



Determining Relevant Kinematics

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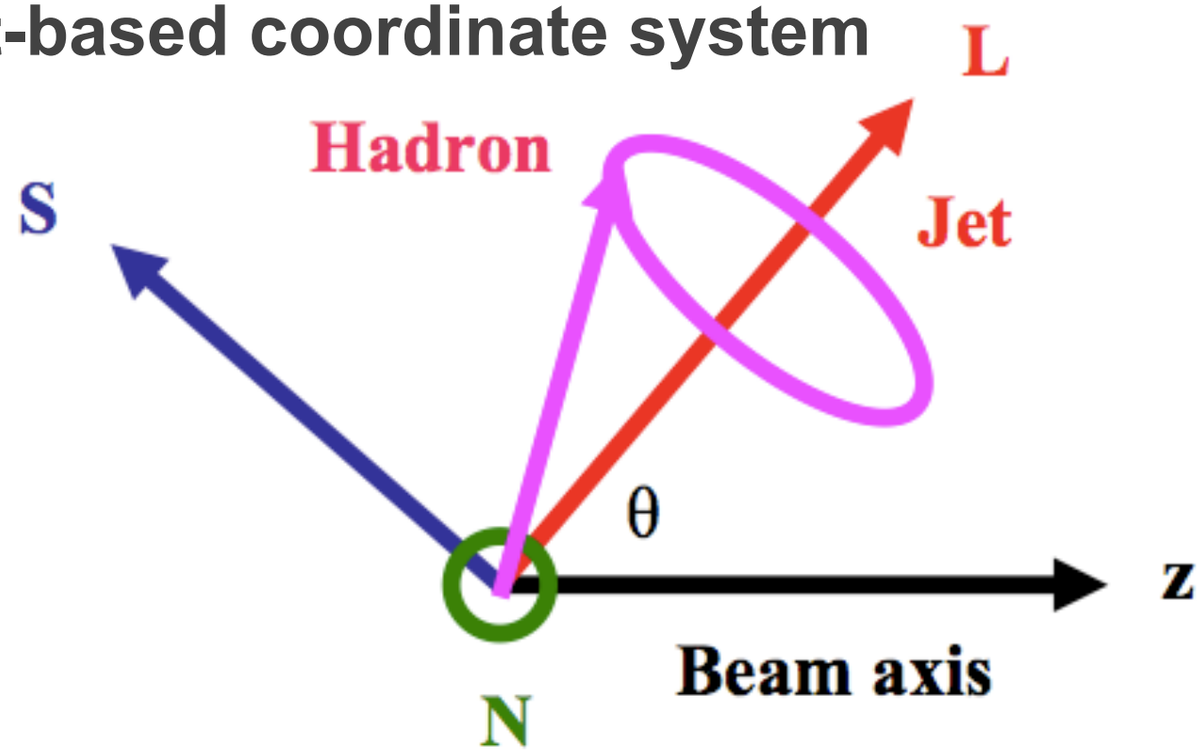

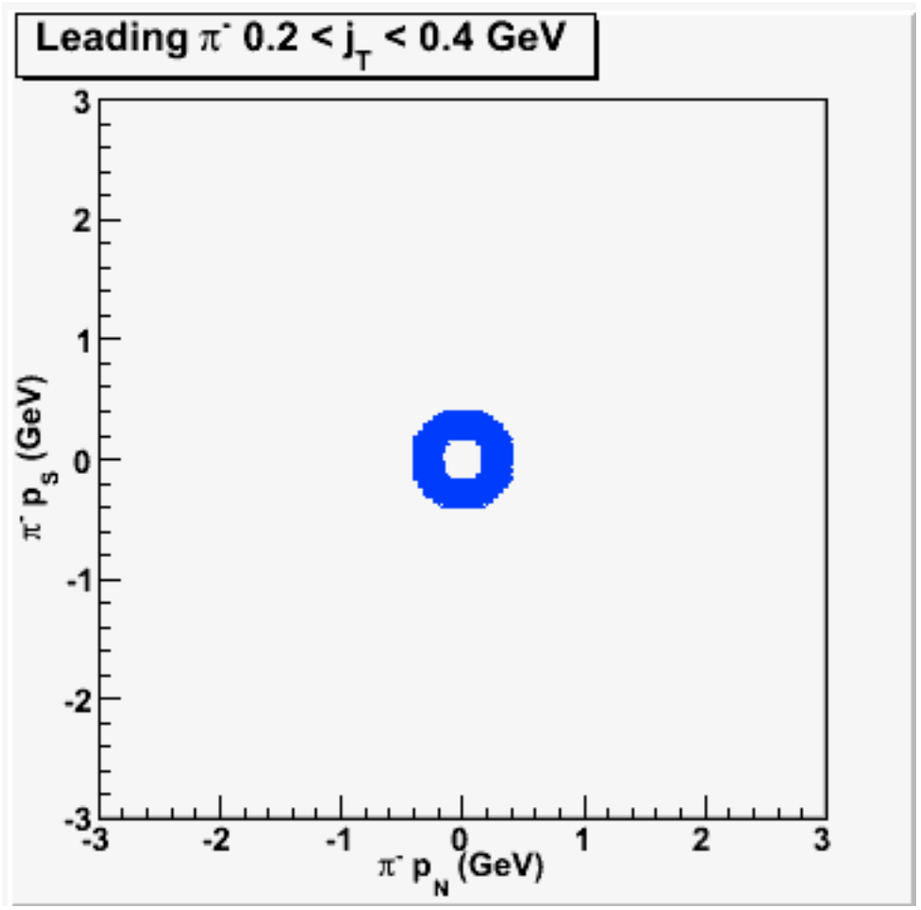

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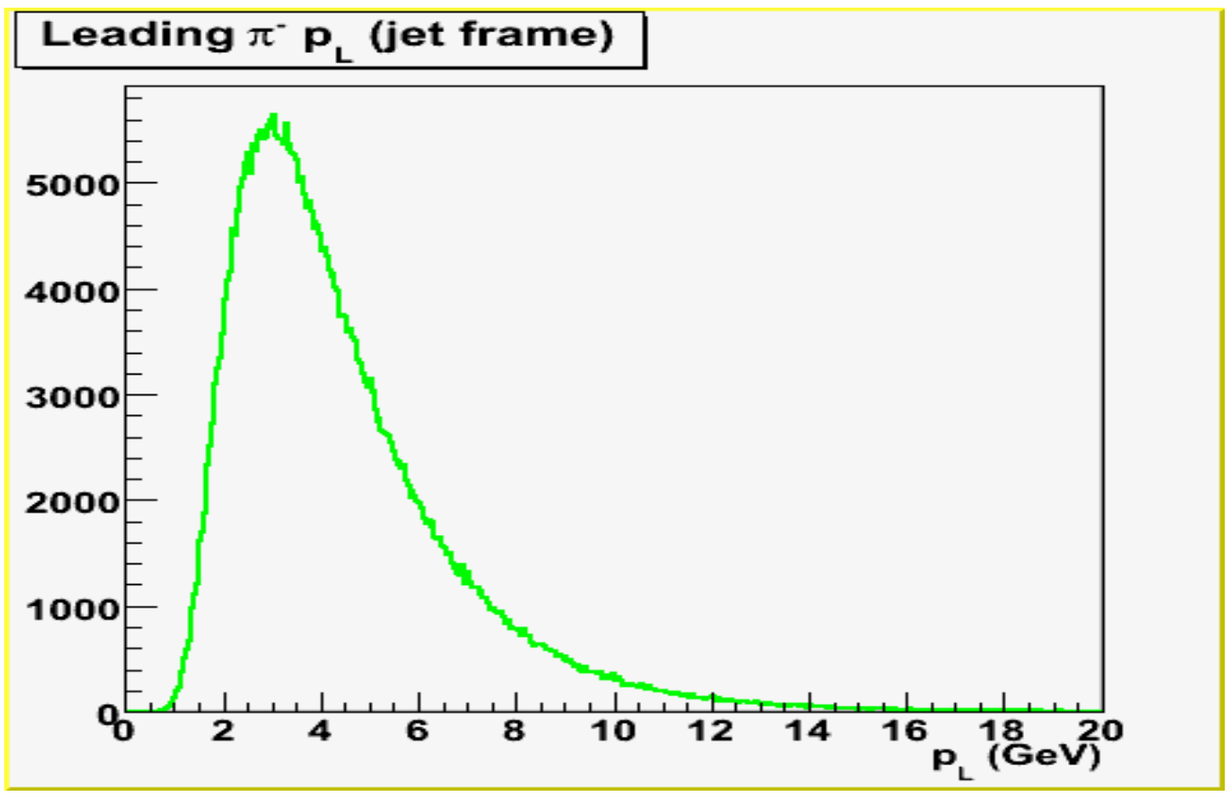

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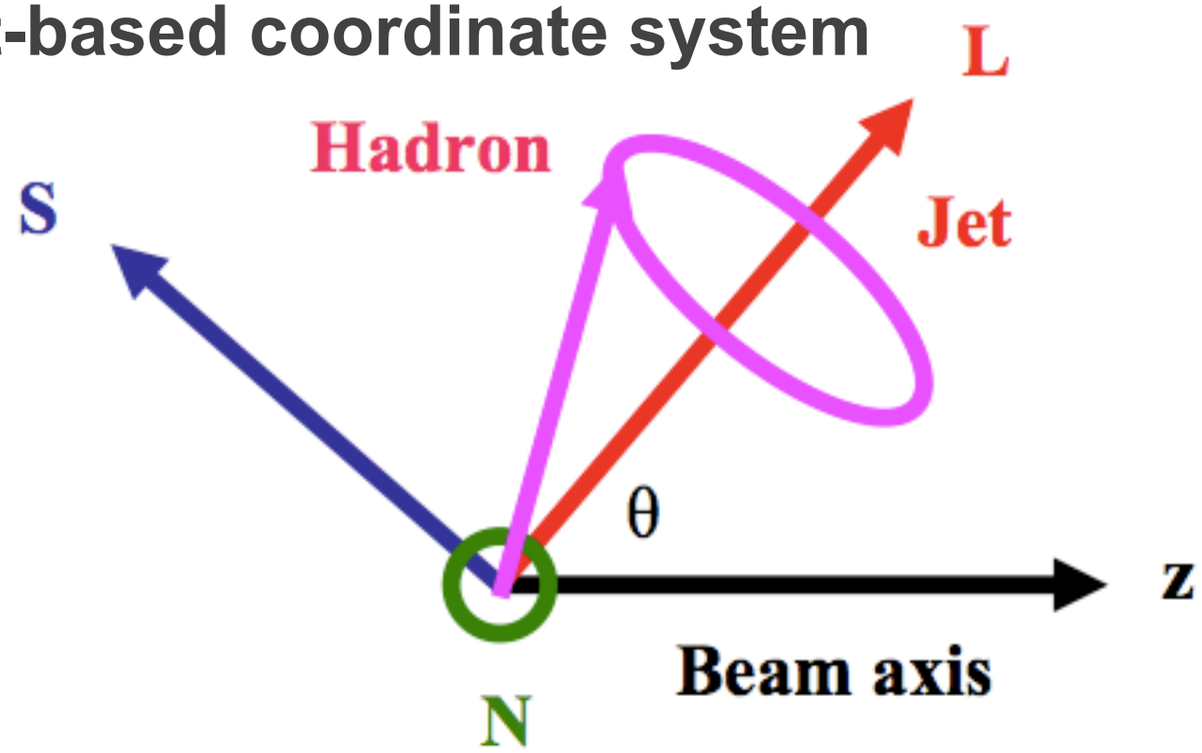

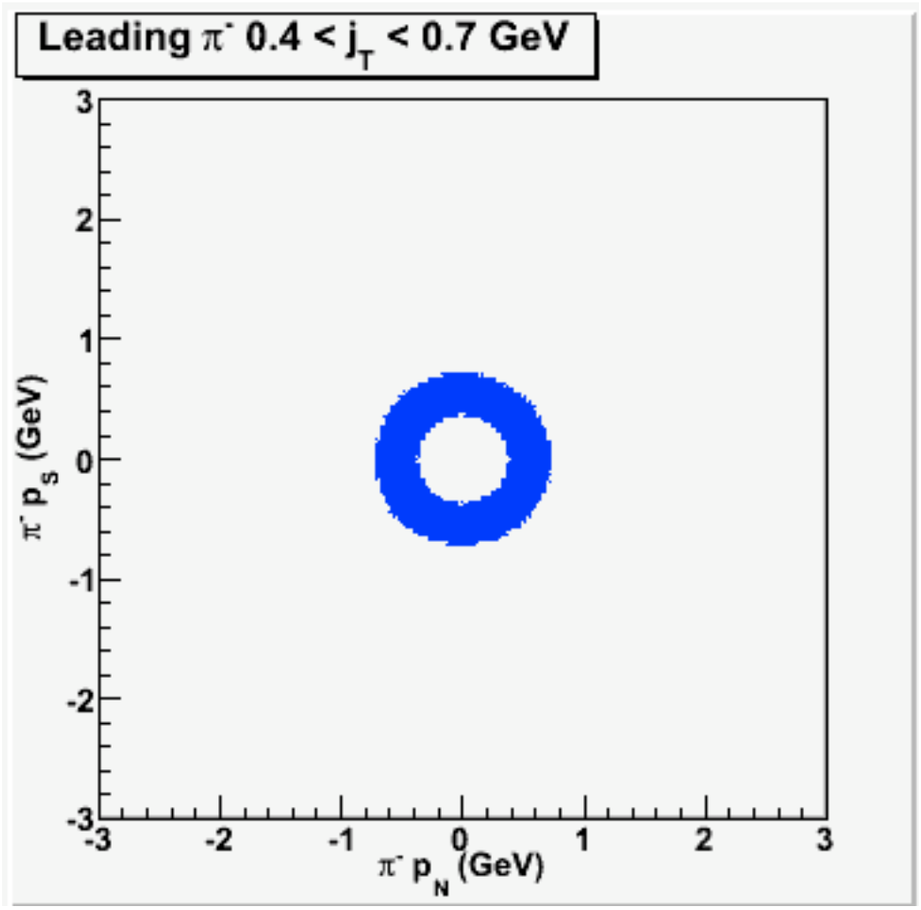

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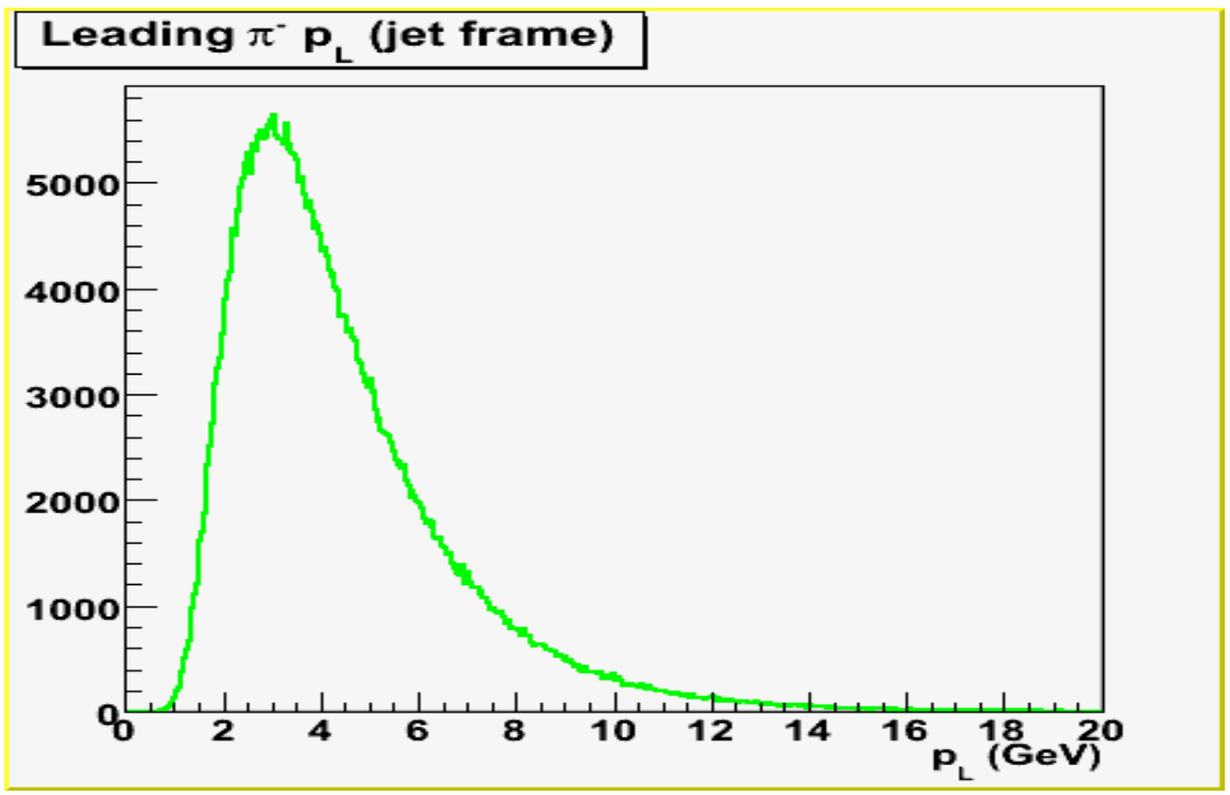

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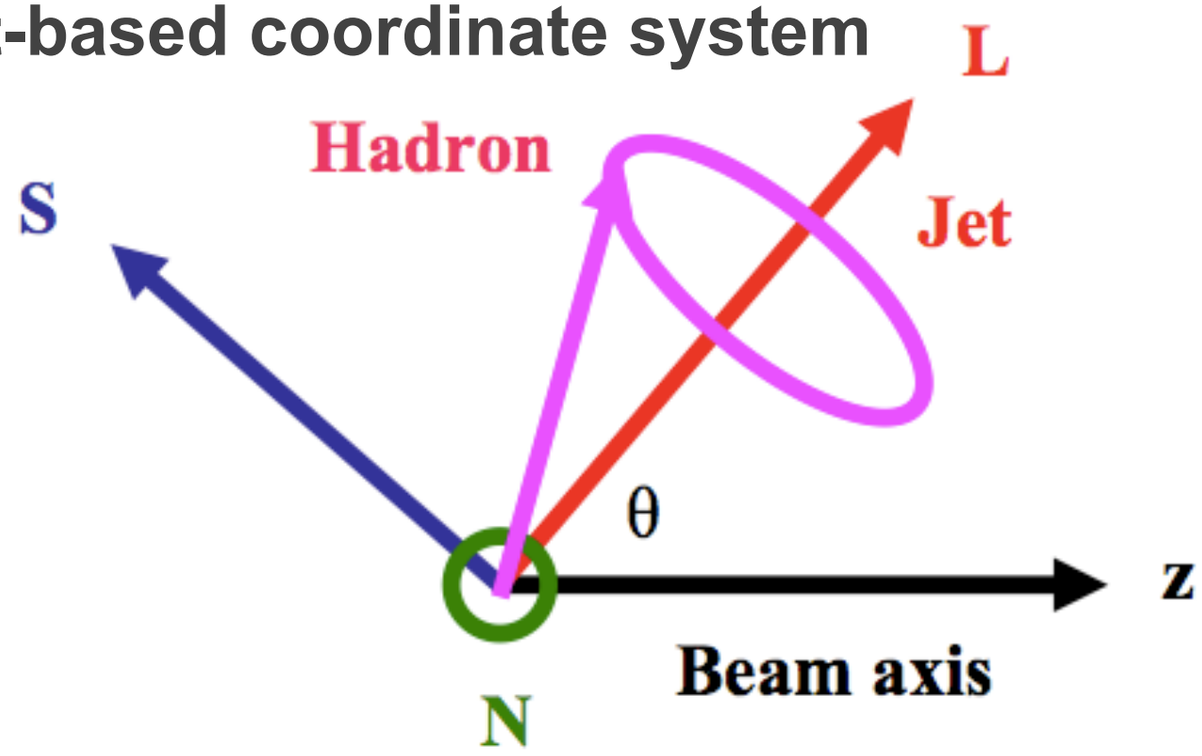

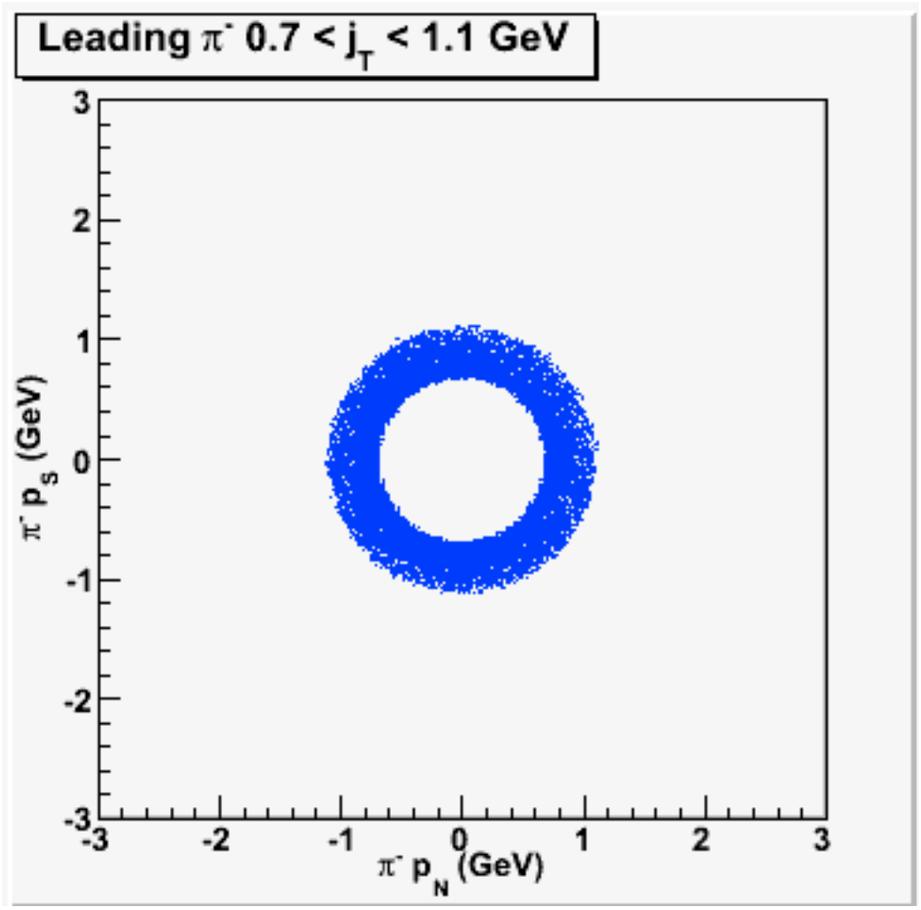

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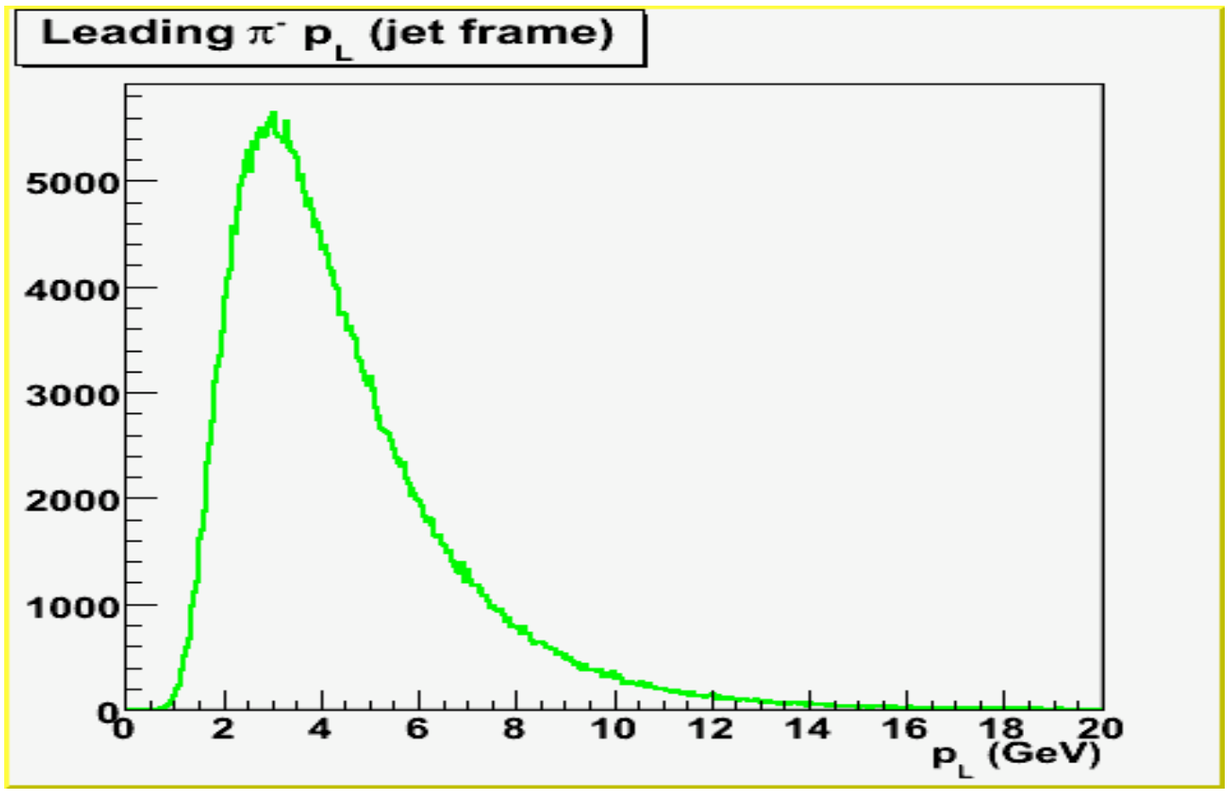

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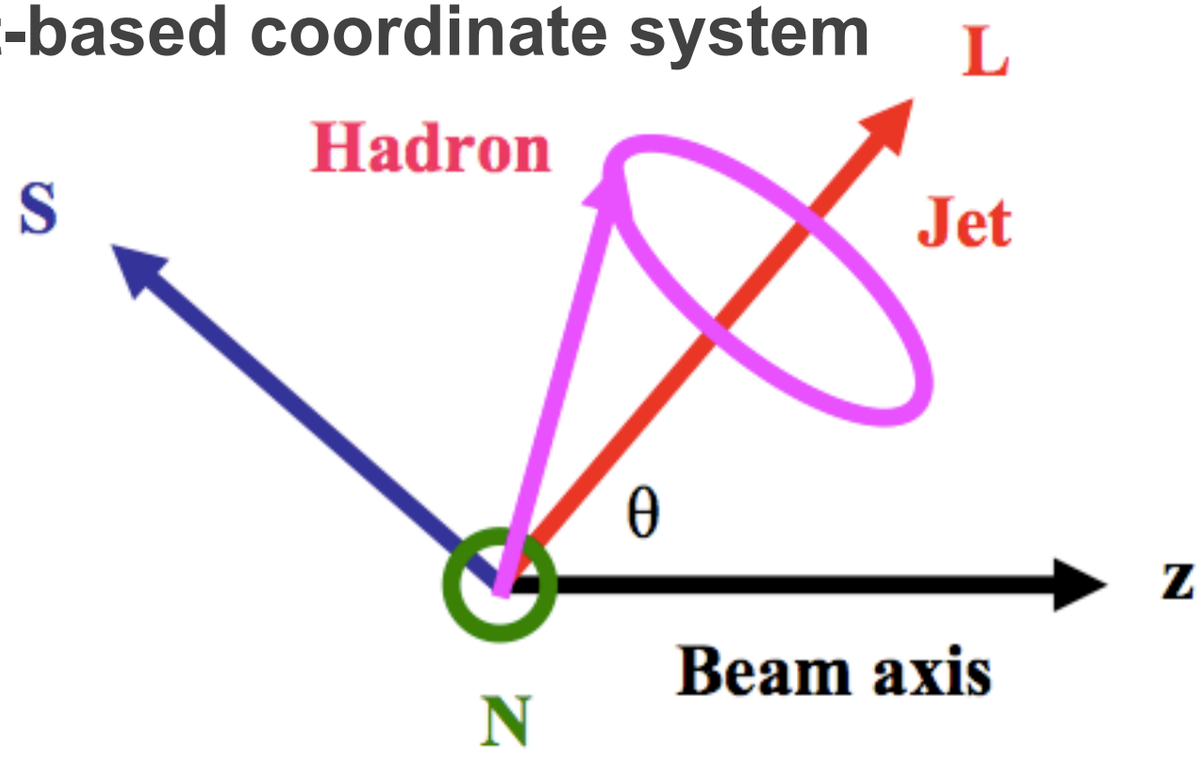

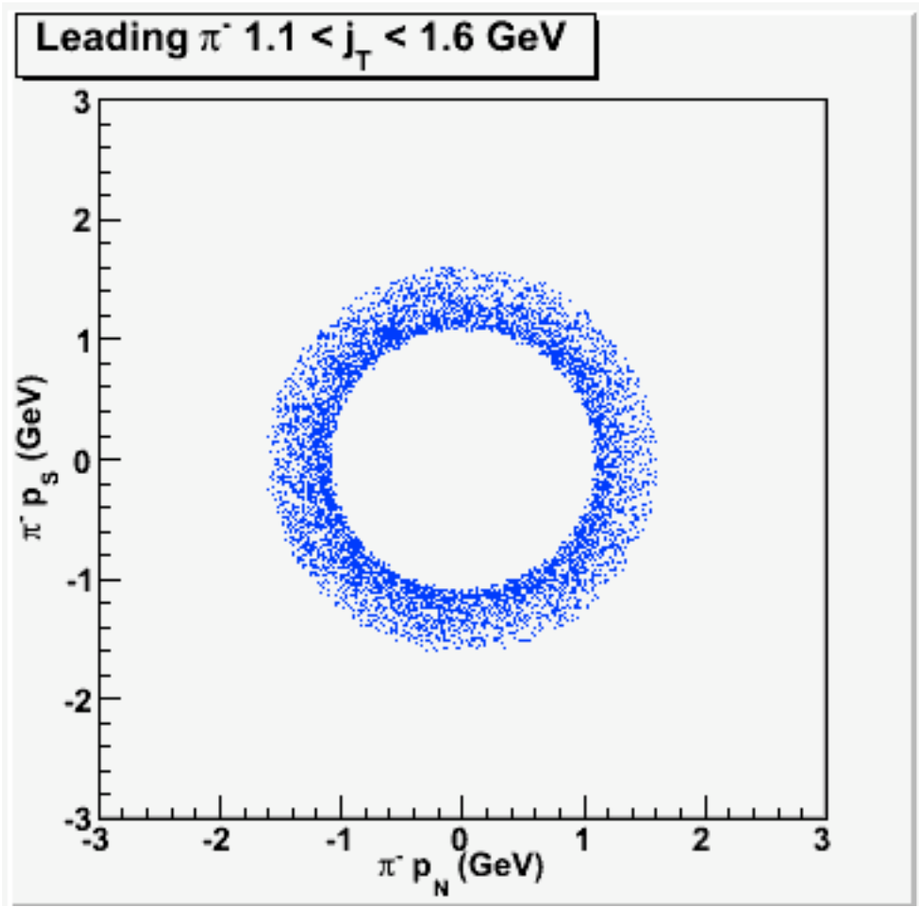

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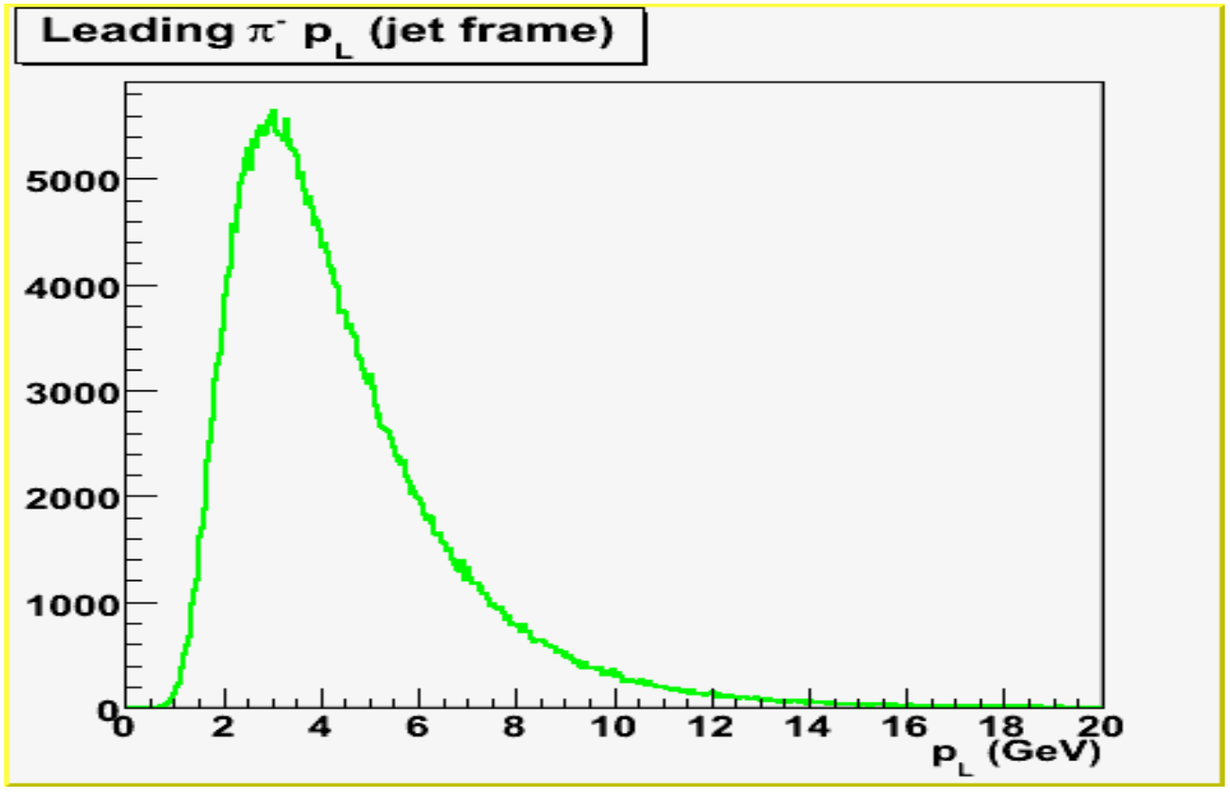

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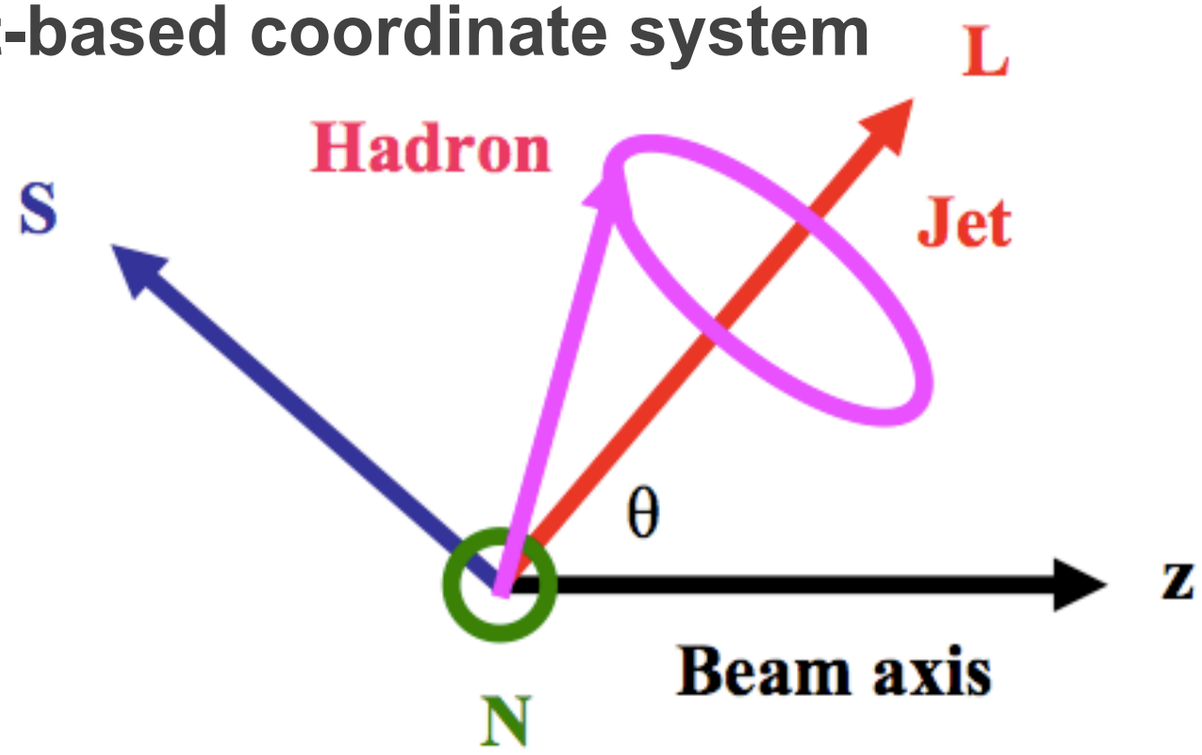
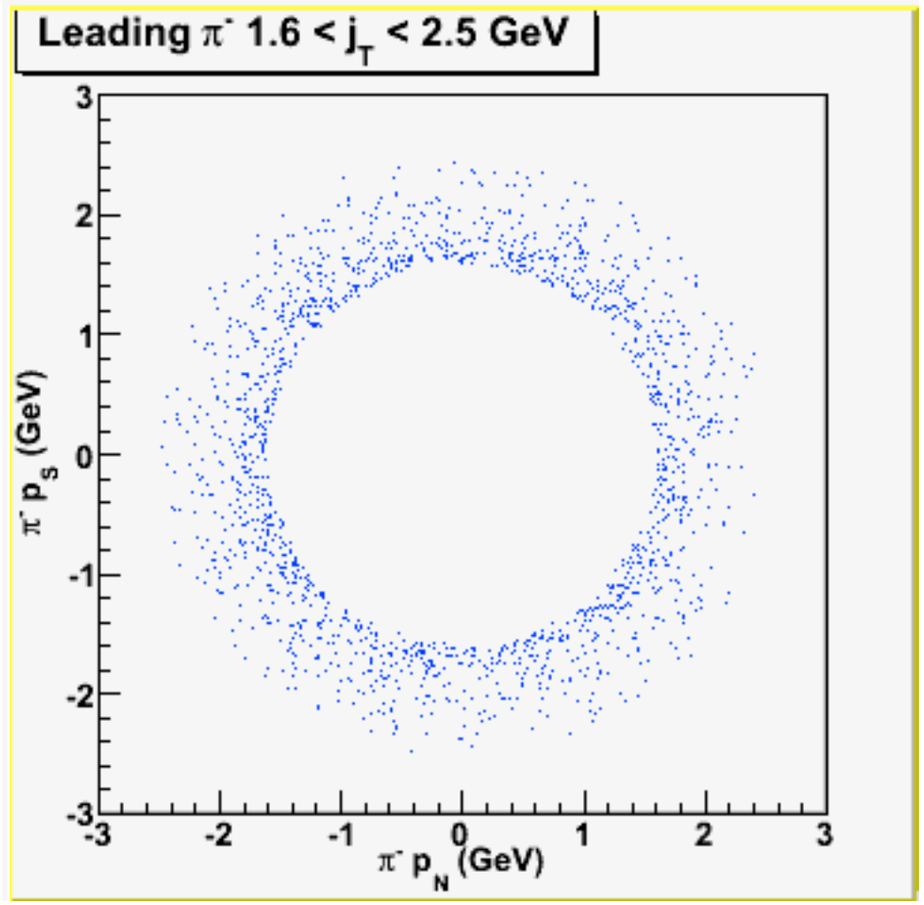
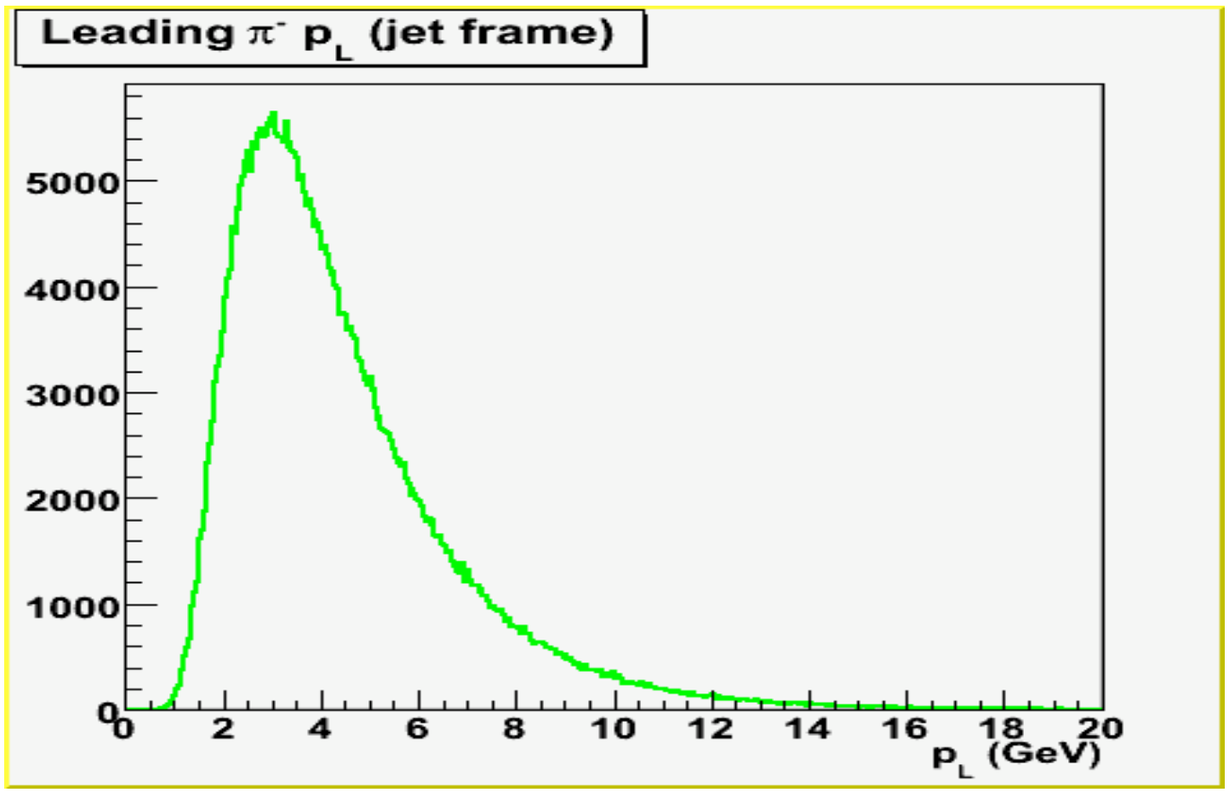
Jet-based coordinate system



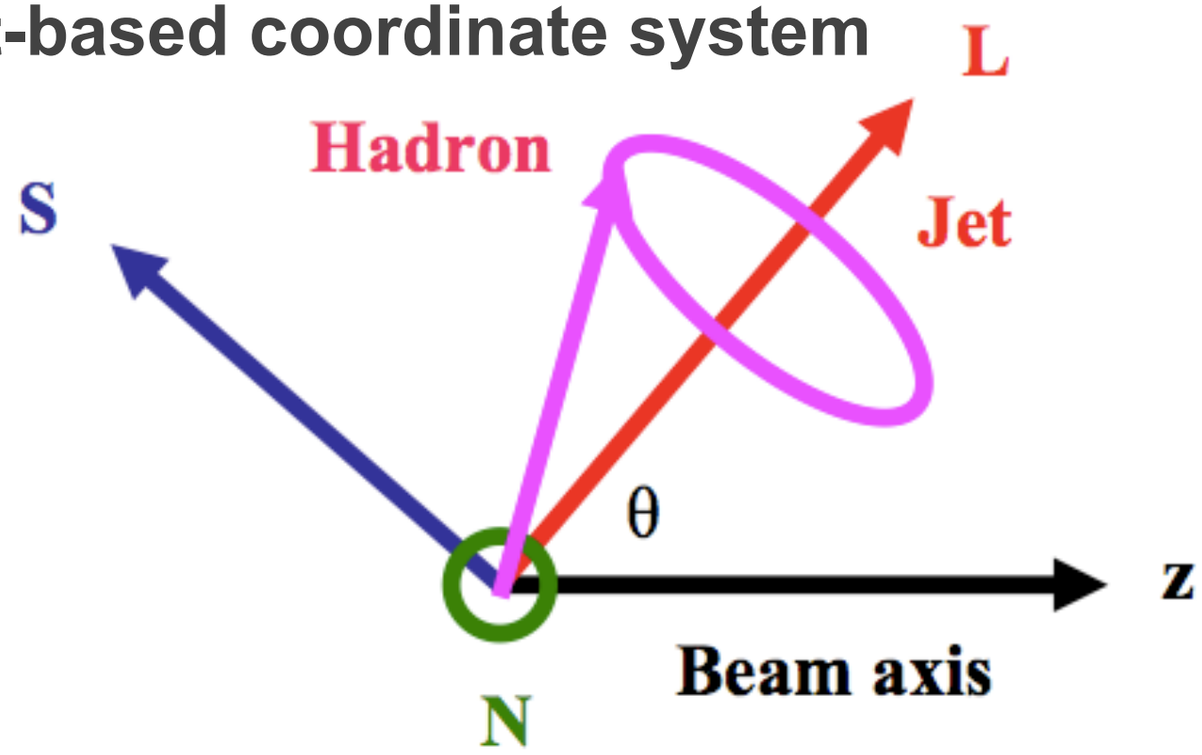


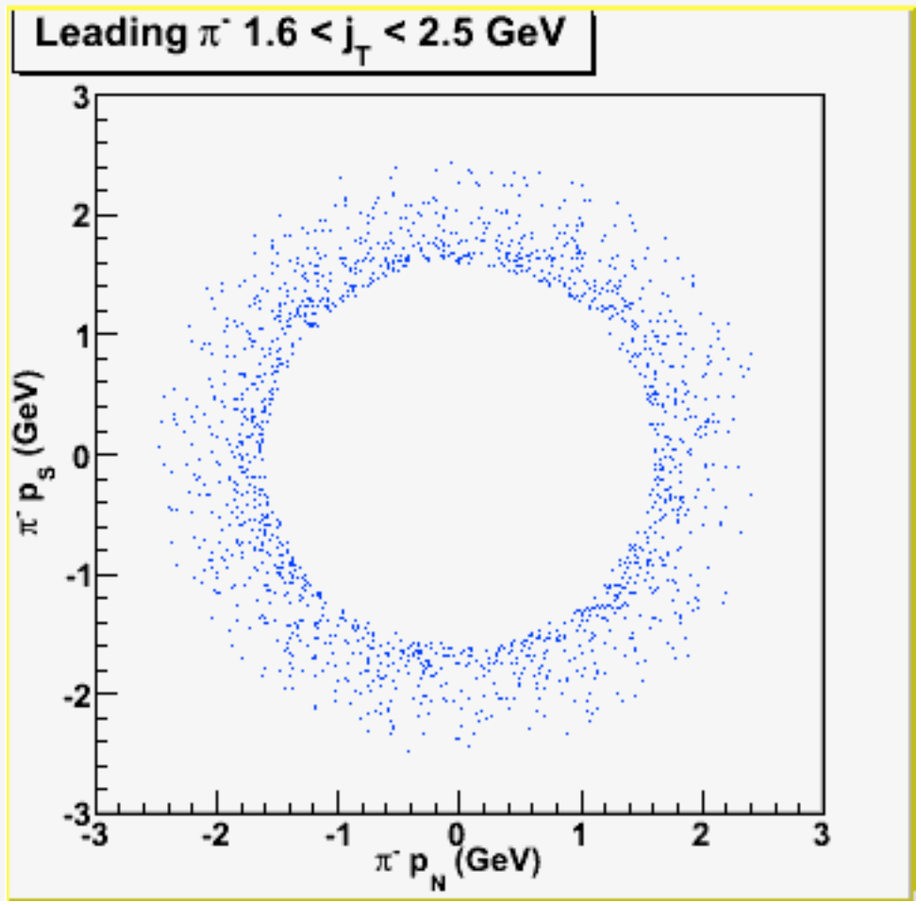
Selected j_T range



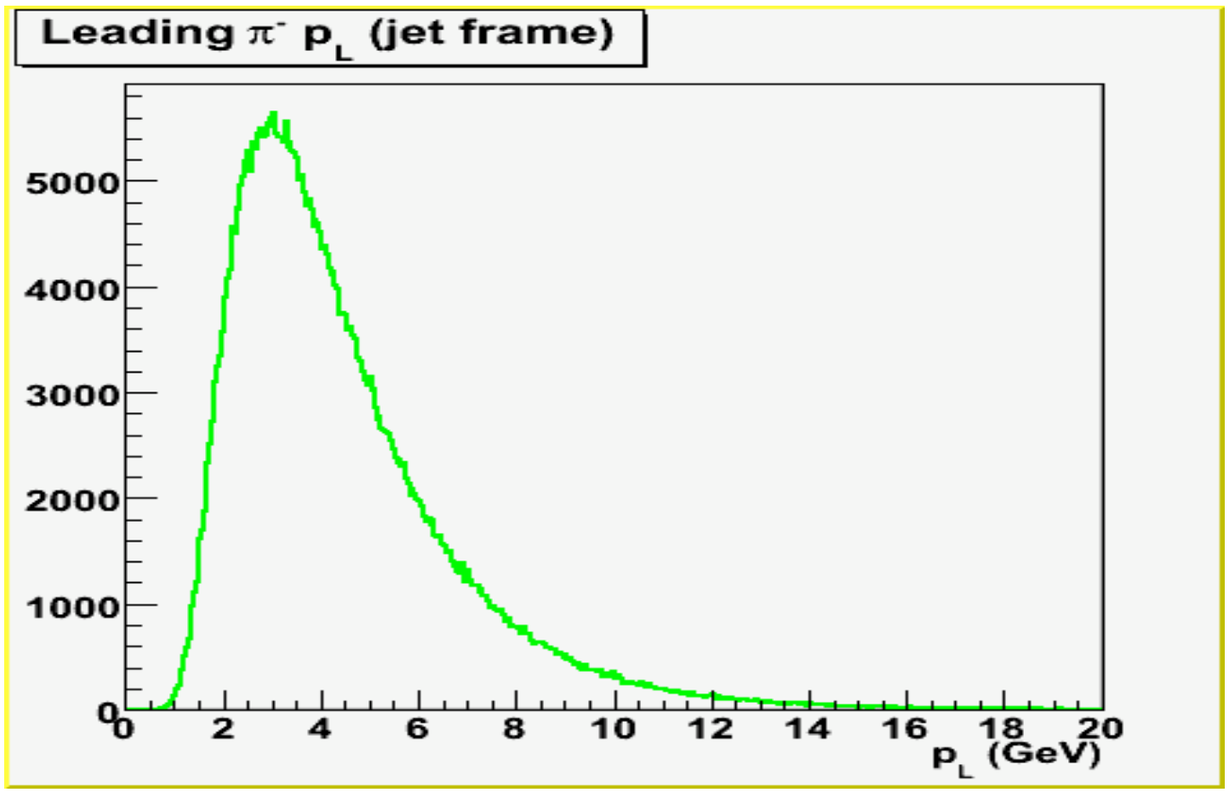
Determining Relevant Kinematics

Jet-based coordinate system





Selected j_T range



Need to separate into ↑ and ↓ spin states, weight each point by $\sin(\phi_S - \phi_\pi)$ and calculate asymmetry (also for z)

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- Spin-sorted measurements; comparison of Y, B results