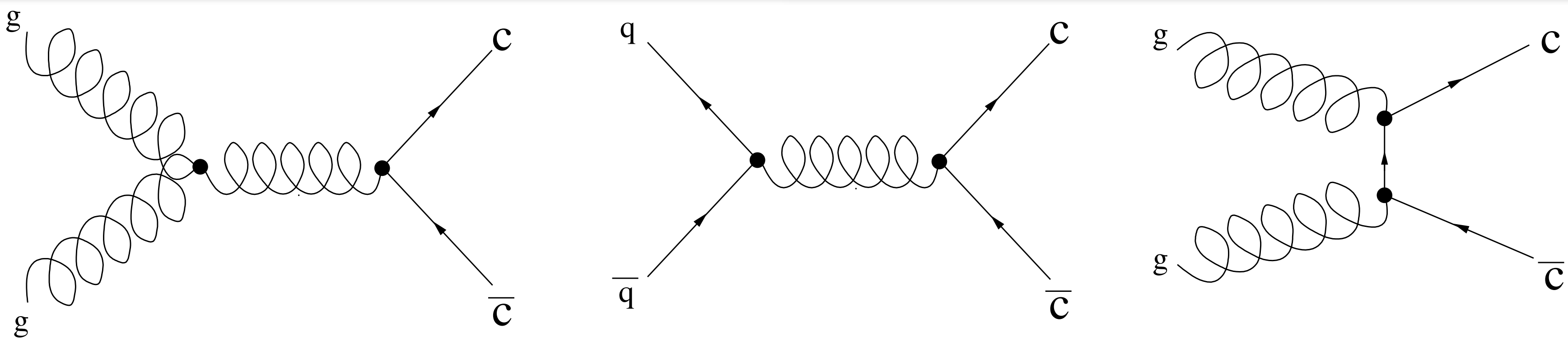
Open charm measurements in p+p collisions at STAR

David Tlusty
NPI ASCR, CTU Prague
for the STAR collaboration

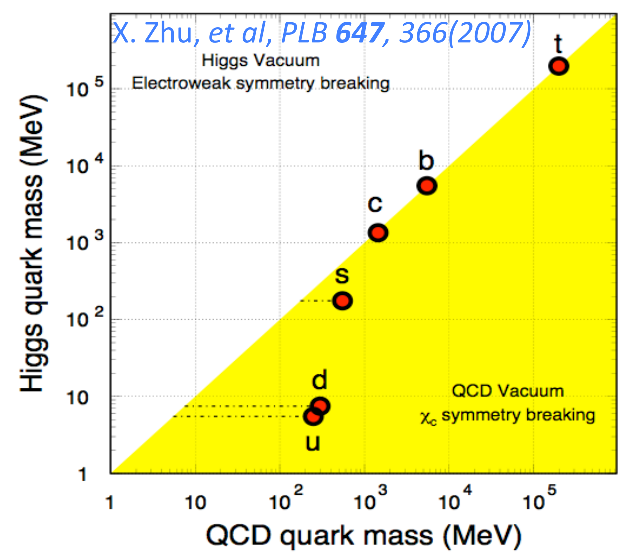
Outline

1. Motivation
2. STAR detector and analysis
3. D^0 and D* in 200 and 500 GeV collisions
4. Non-Photonic electrons in 200 GeV collisions
5. Summary

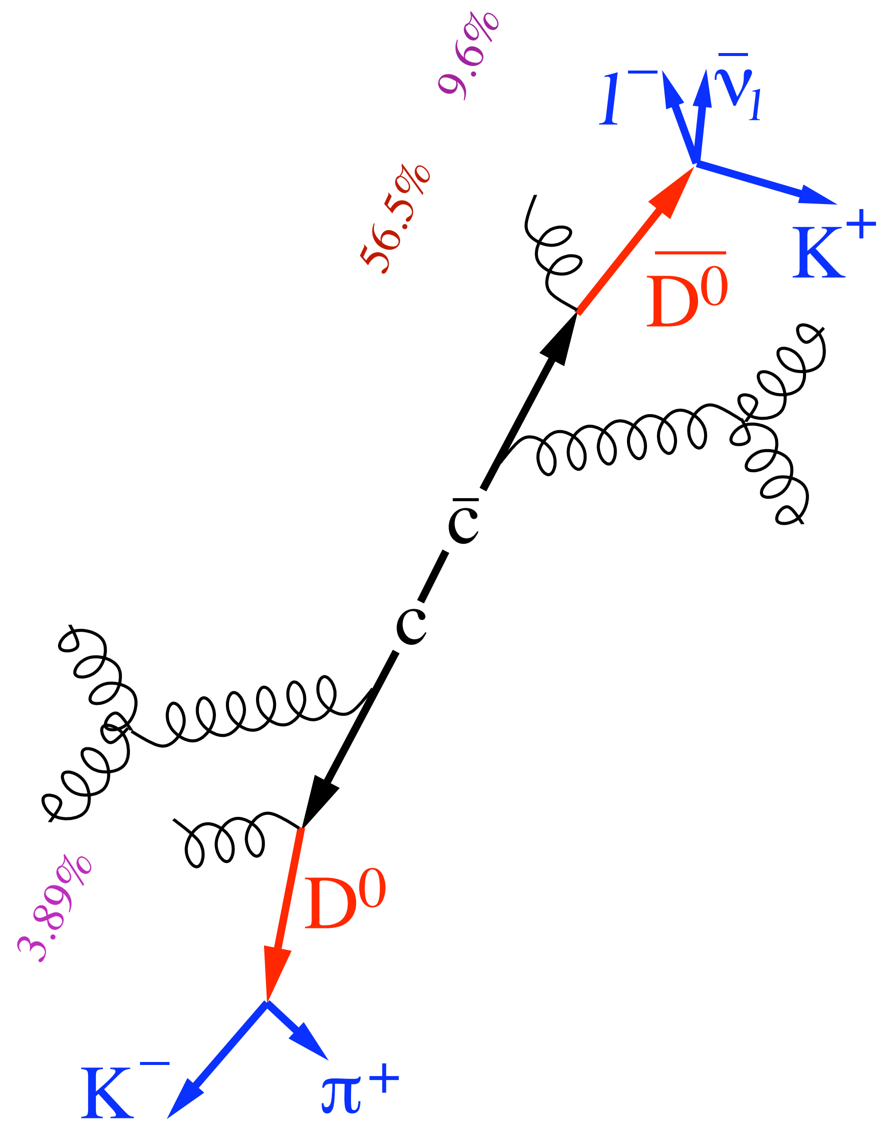
Why to study heavy quarks in p+p collisions



- ★ Sensitive to initial gluon density and gluon distribution. Due to its large mass a good pQCD test at RHIC collision energies
- ★ Provides important baseline for corresponding measurements in heavy-ion collisions



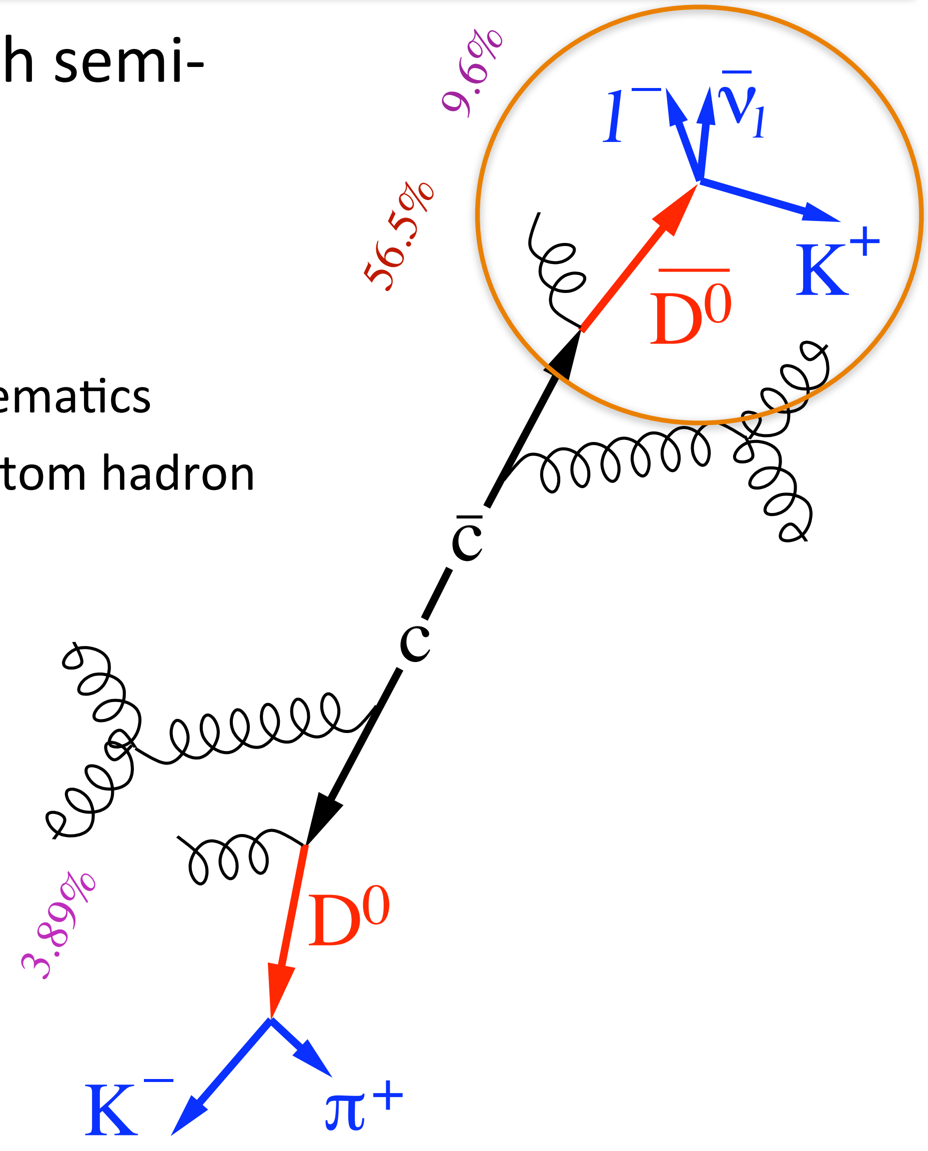
How to Measure Charm Quarks



How to Measure Charm Quarks

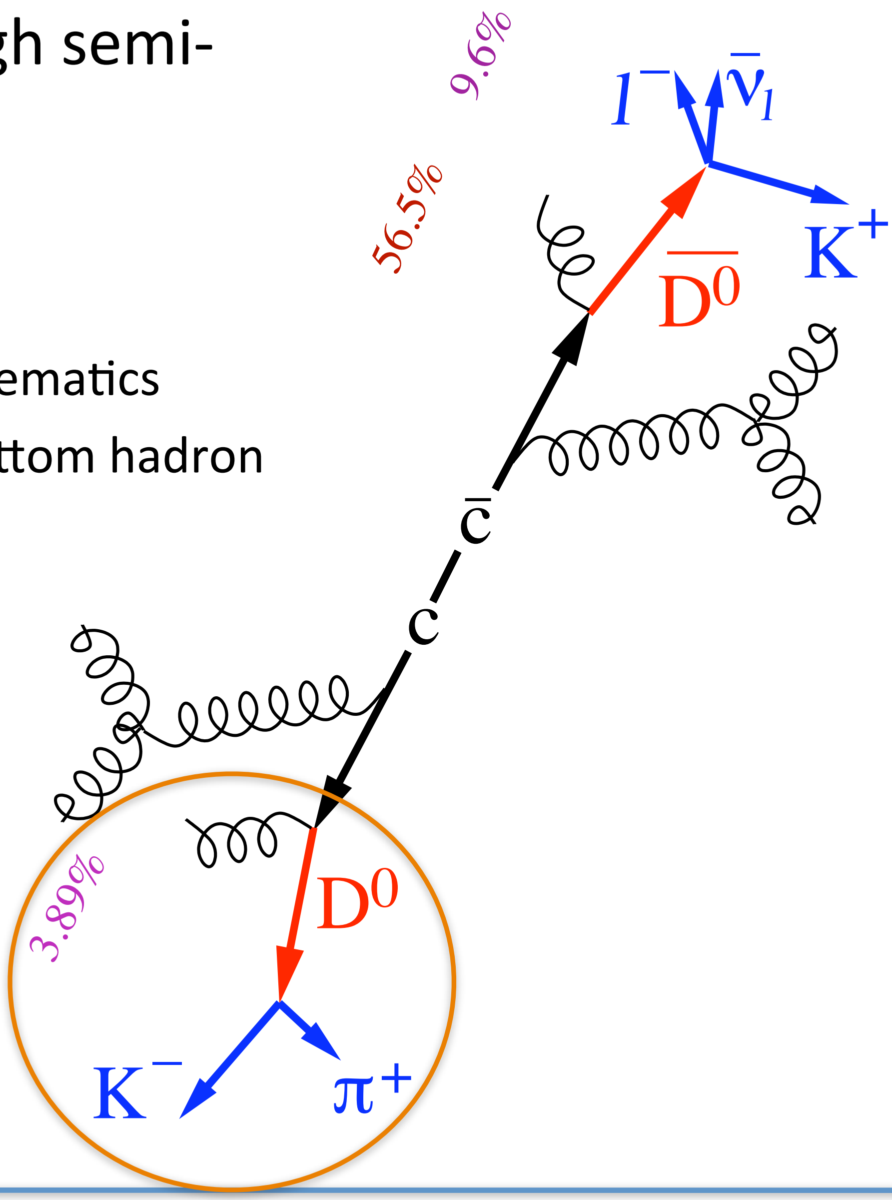
★ Indirect measurements through semi-leptonic decay

- ★ can be triggered easily (high p_T)
- ★ higher B.R.
- ★ indirect access to the heavy quark kinematics
- ★ contribution from both charm and bottom hadron decays



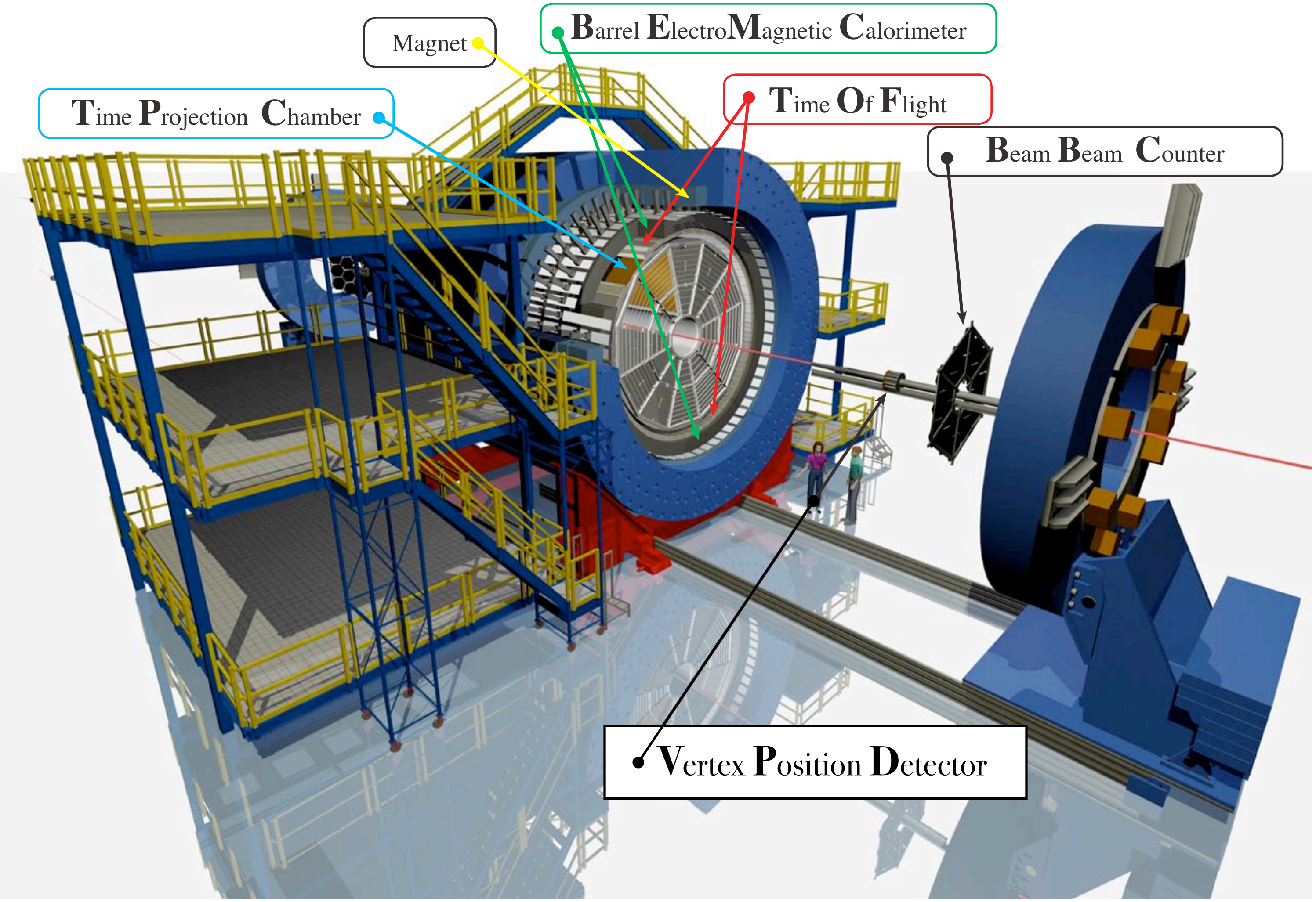
How to Measure Charm Quarks

- ★ Indirect measurements through semi-leptonic decay
  - ★ can be triggered easily (high p_T)
  - ★ higher B.R.
  - ★ indirect access to the heavy quark kinematics
  - ★ contribution from both charm and bottom hadron decays
- ★ Direct reconstruction
  - ★ direct access to heavy quark kinematics
  - ★ difficult to trigger (high energy trigger only for correlation measurements)
  - ★ smaller Branching Ratio (B.R.)
  - ★ large combinatorial background (need handle on decay vertex)



The STAR Detector

Solenoidal Tracker At RHIC : $-1 < \eta < 1$, $0 < \phi < 2\pi$



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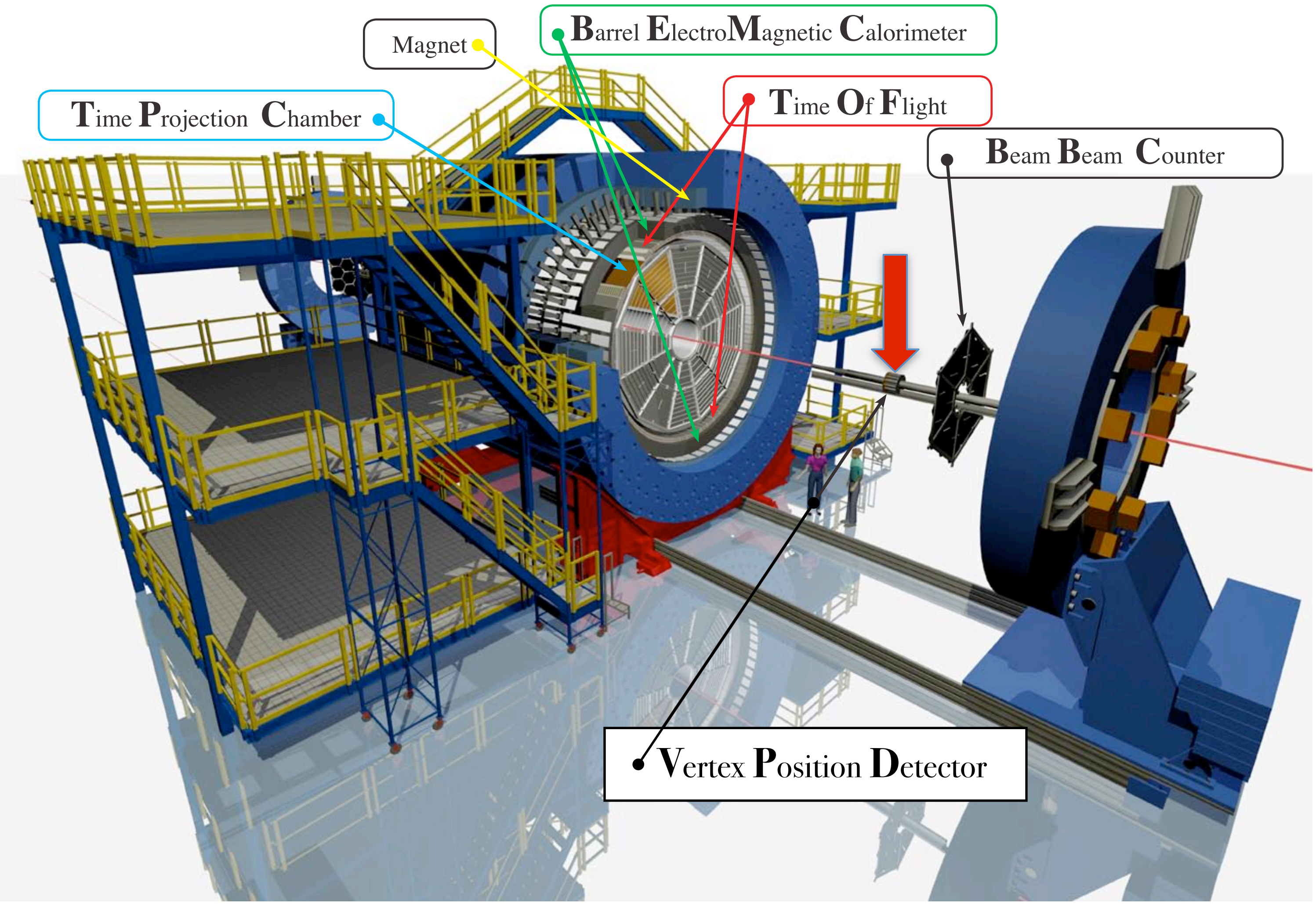

- ★ **VPD: minimum bias trigger**

The STAR Detector

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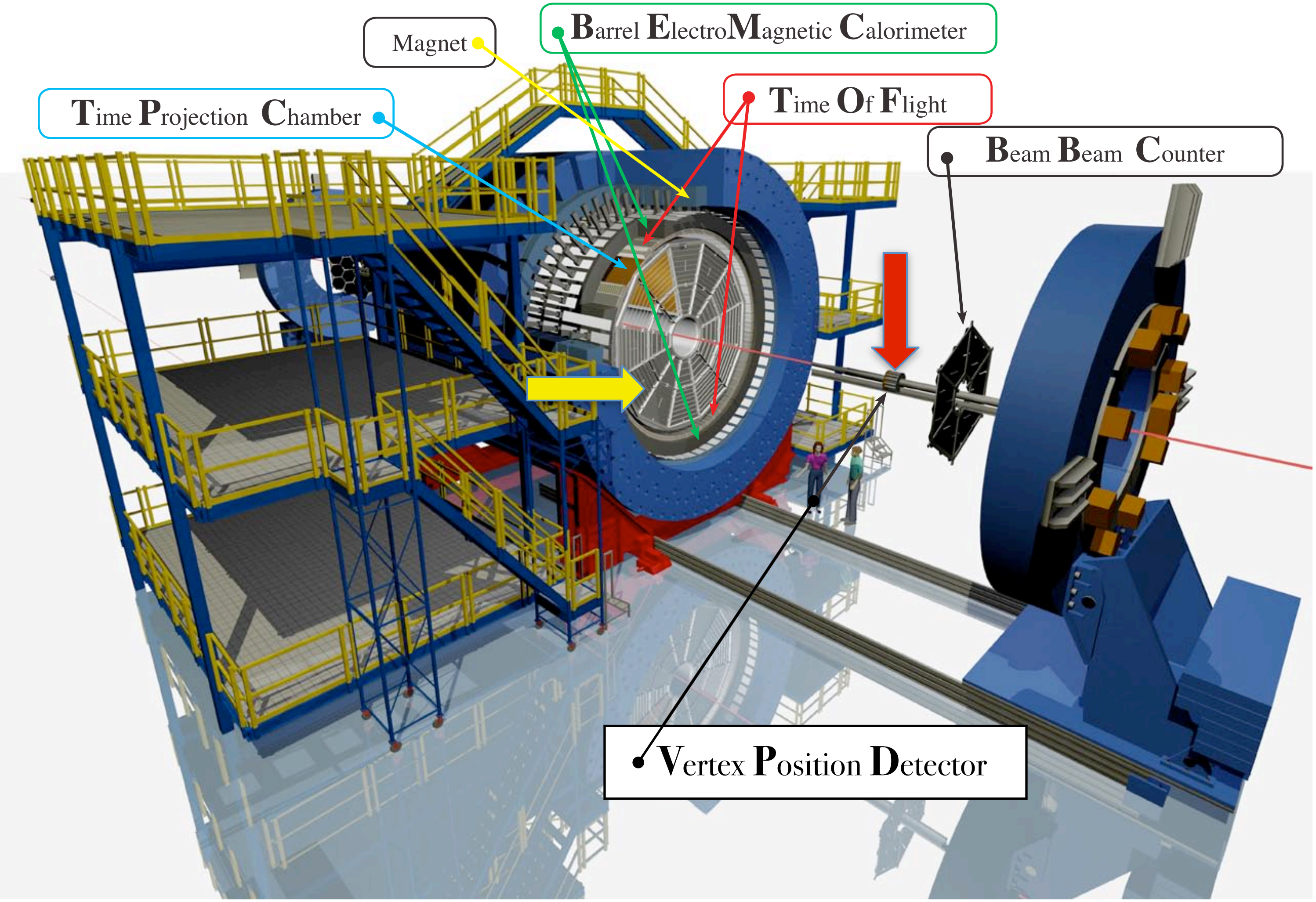
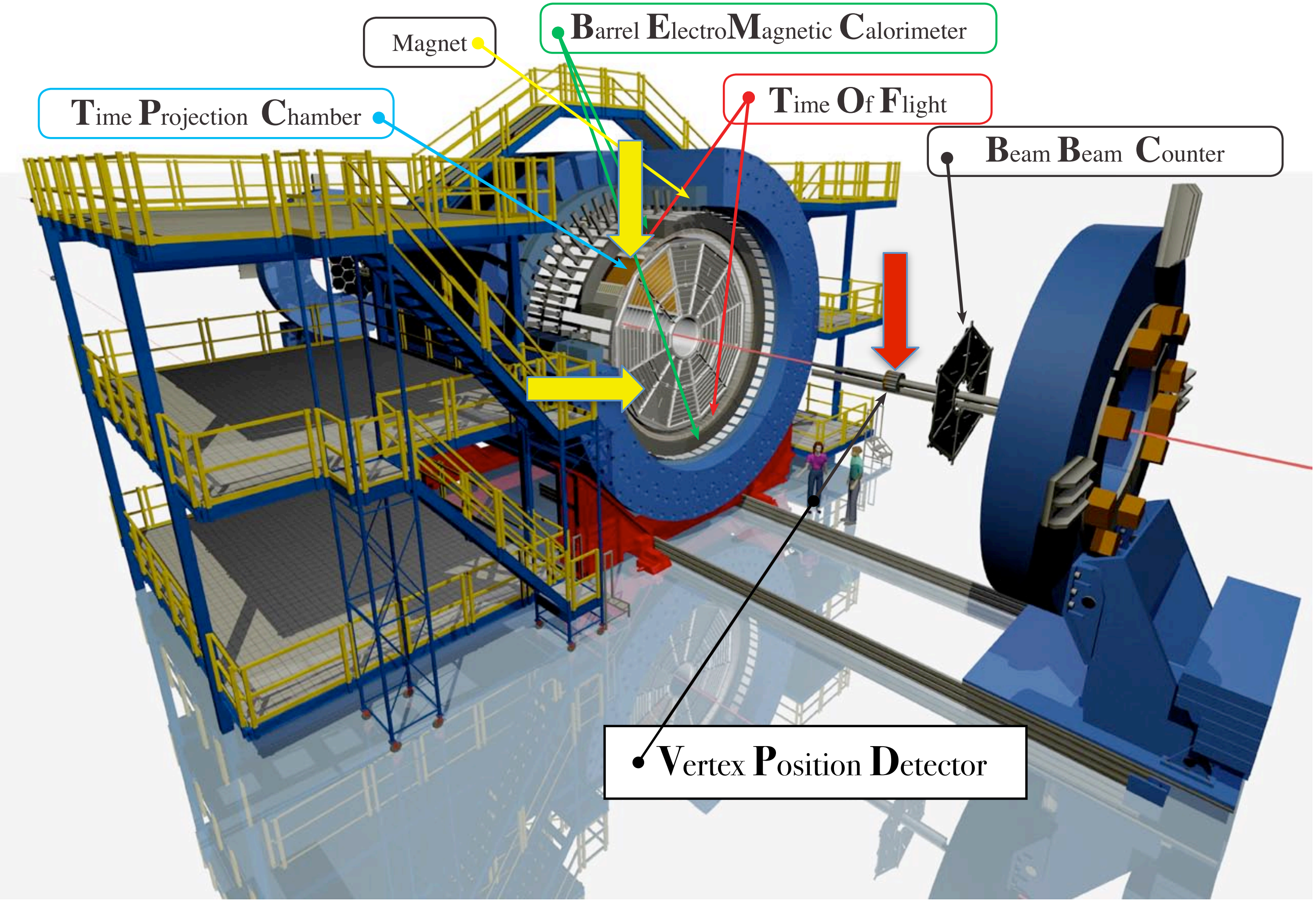


- ★ **VPD: minimum bias trigger**
- ★ **TPC: PID, tracking**

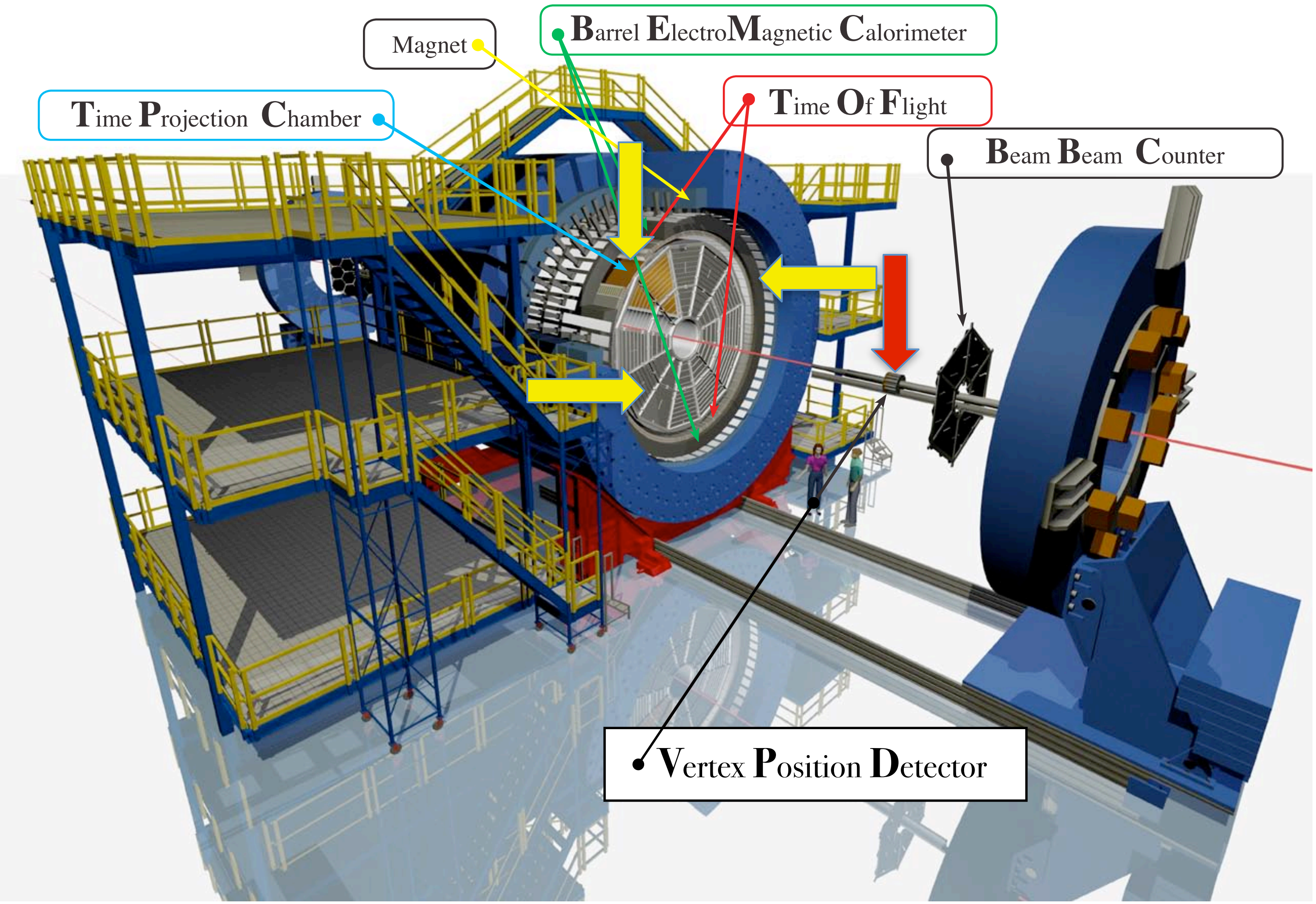
The STAR Detector

Solenoidal **T**racker **A**t **R**HIC : $-1 < \eta < 1$, $0 < \phi < 2\pi$



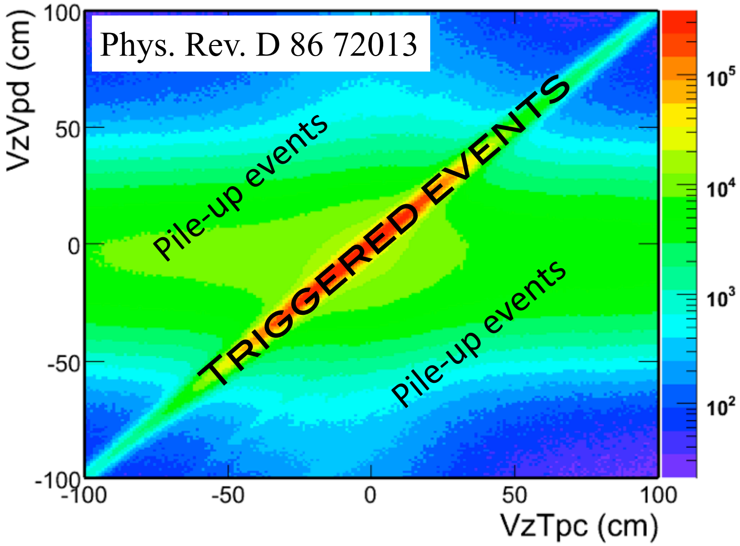
- ★ **VPD:** **minimum bias trigger**
- ★ **TPC:** **PID, tracking**
- ★ **TOF:** **PID** (time resolution 110 ps in p+p, 100 ps in Au+Au)

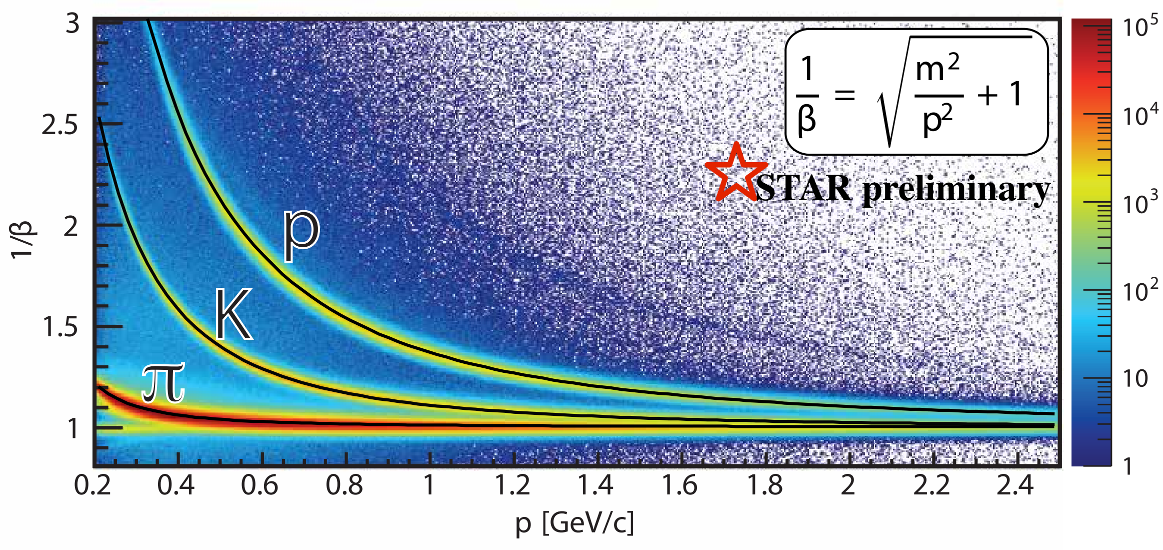
Solenoidal **T**racker **A**t **R**HIC : $-1 < \eta < 1, 0 < \phi < 2\pi$

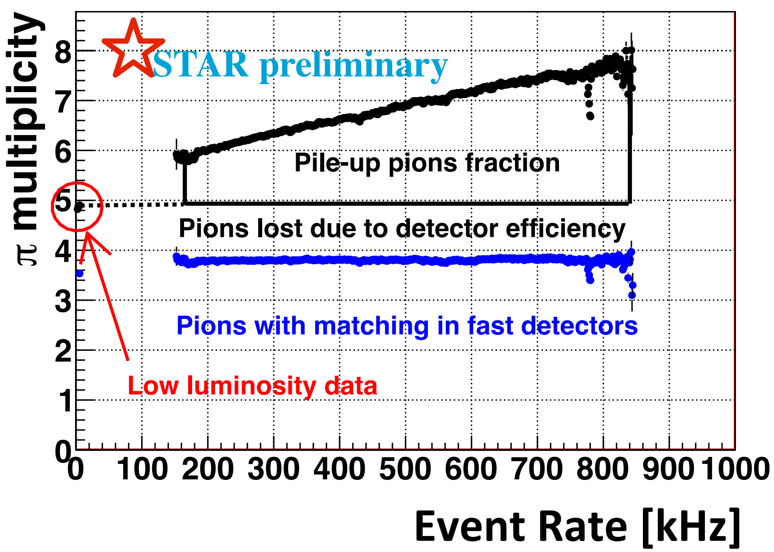


- **VPD:** **minimum bias trigger**
- **TPC:** **PID, tracking**
- **TOF:** **PID** (time resolution 110 ps in p+p, 100 ps in Au+Au)
- **BEMC:** **removes pile-up tracks, electron identification improvement**

Event Selection and Particle Identification







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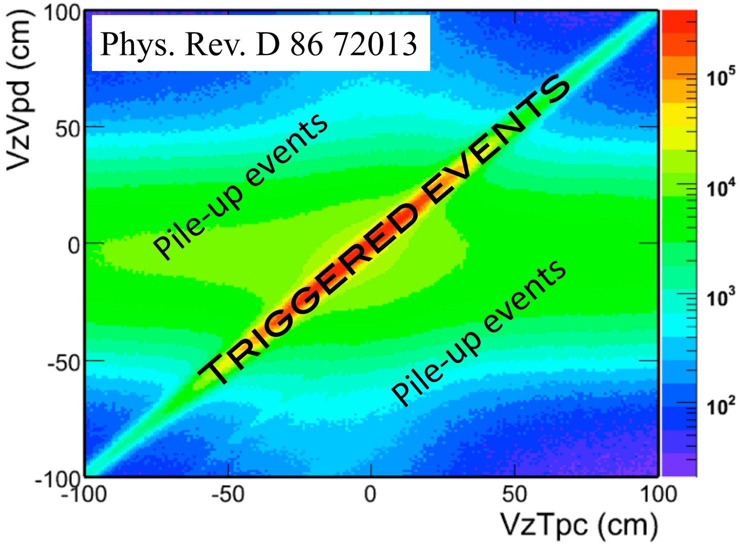
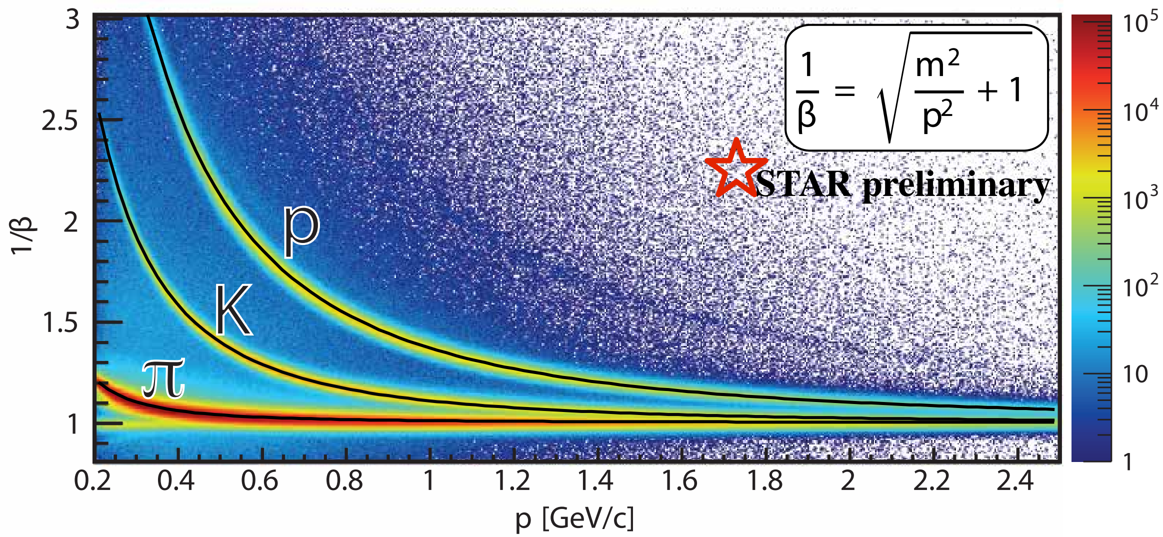
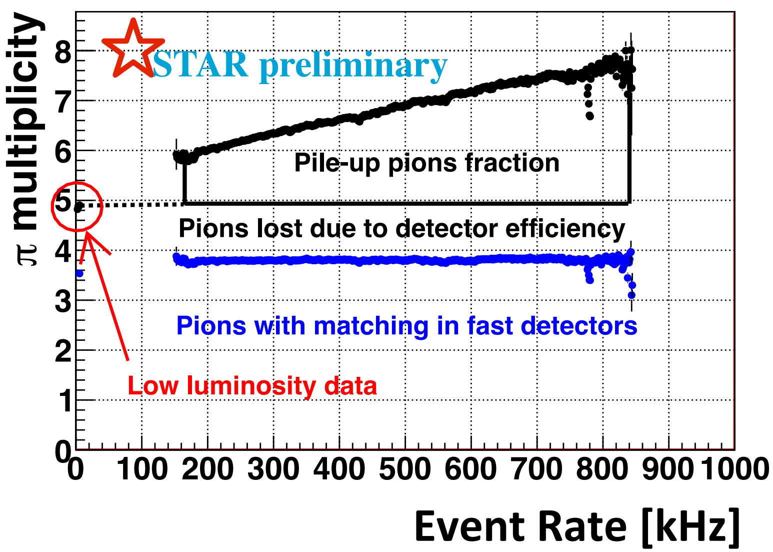
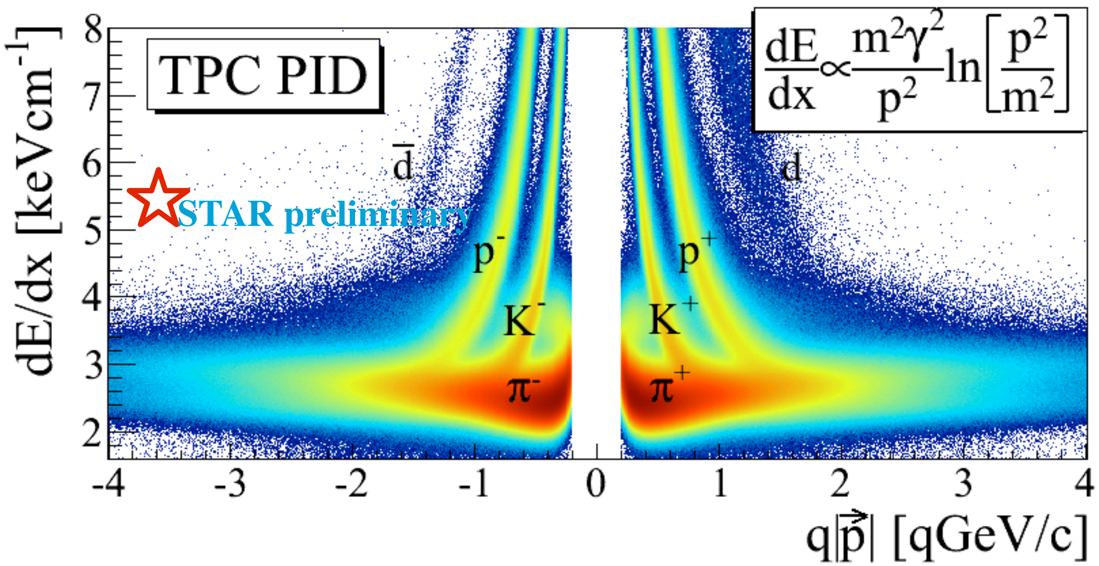


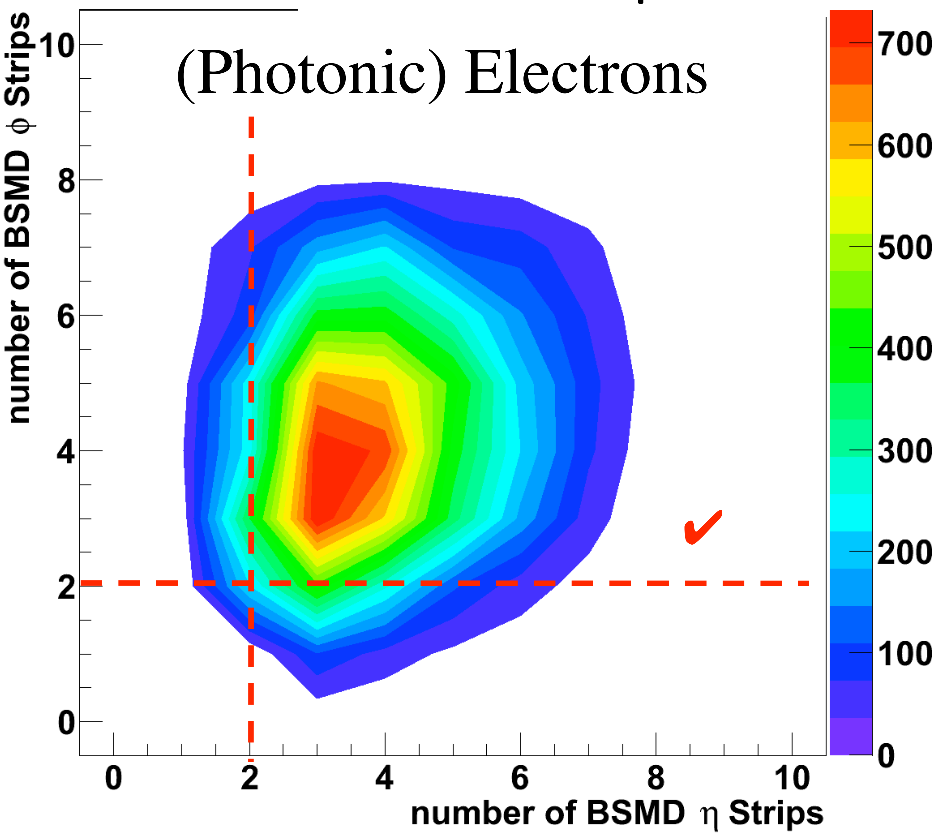


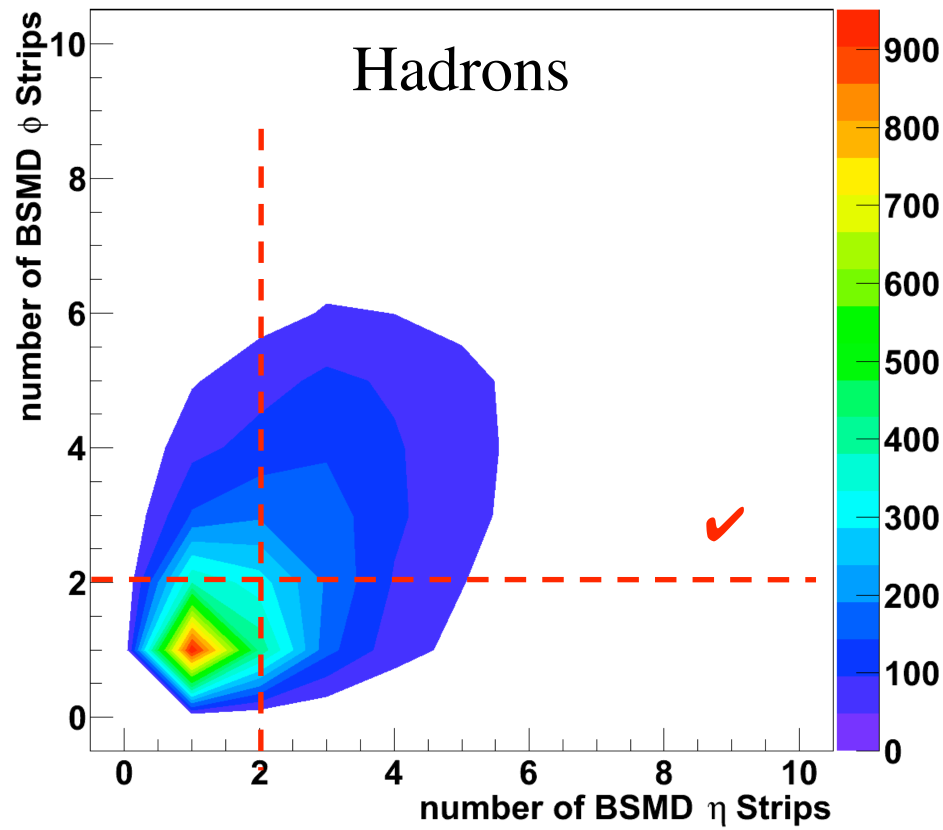




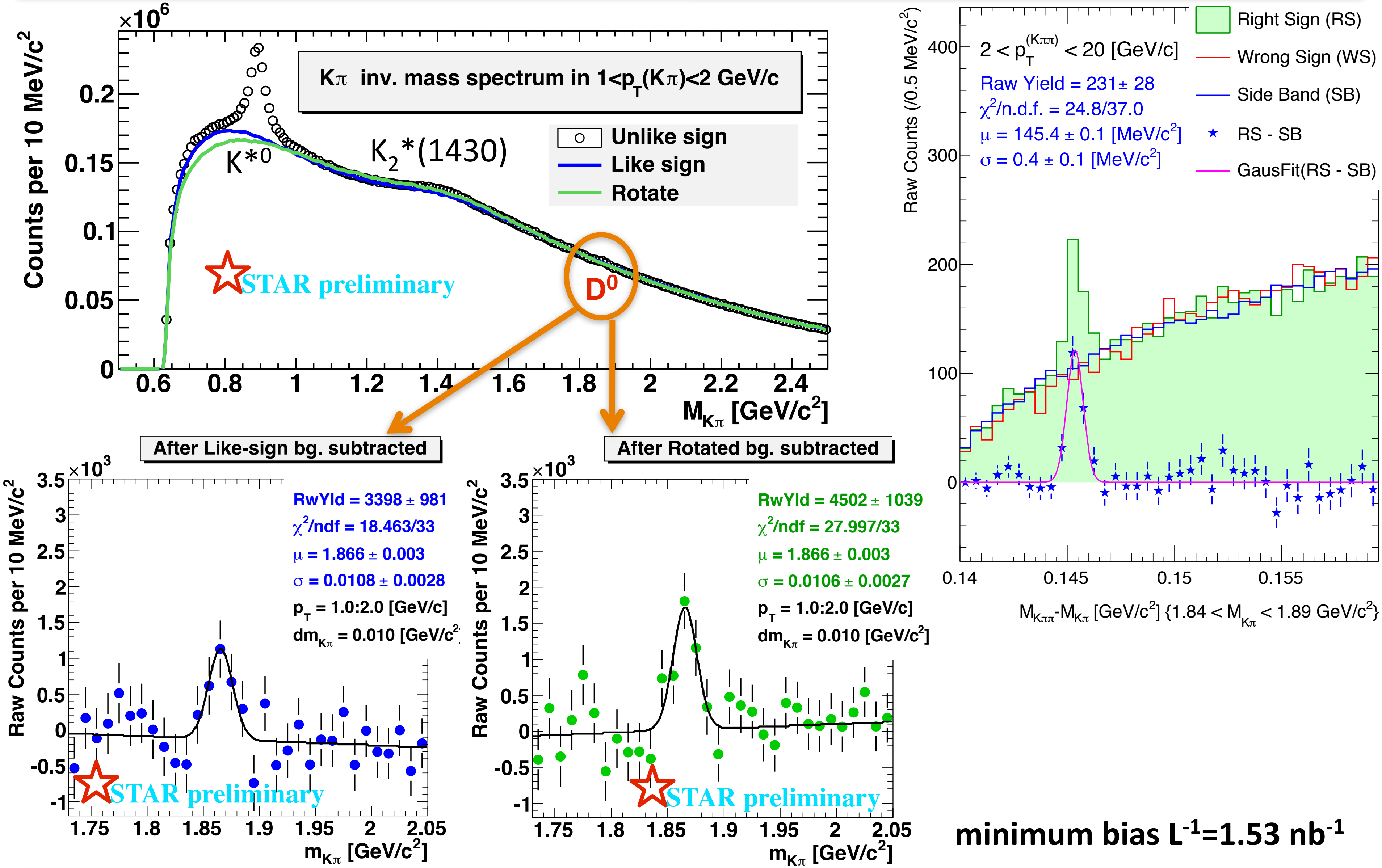
Electron showers are widely developed, firing several Barrel Shower Max Detector strips

Hadron showers are much less developed, firing mostly one or zero strip.



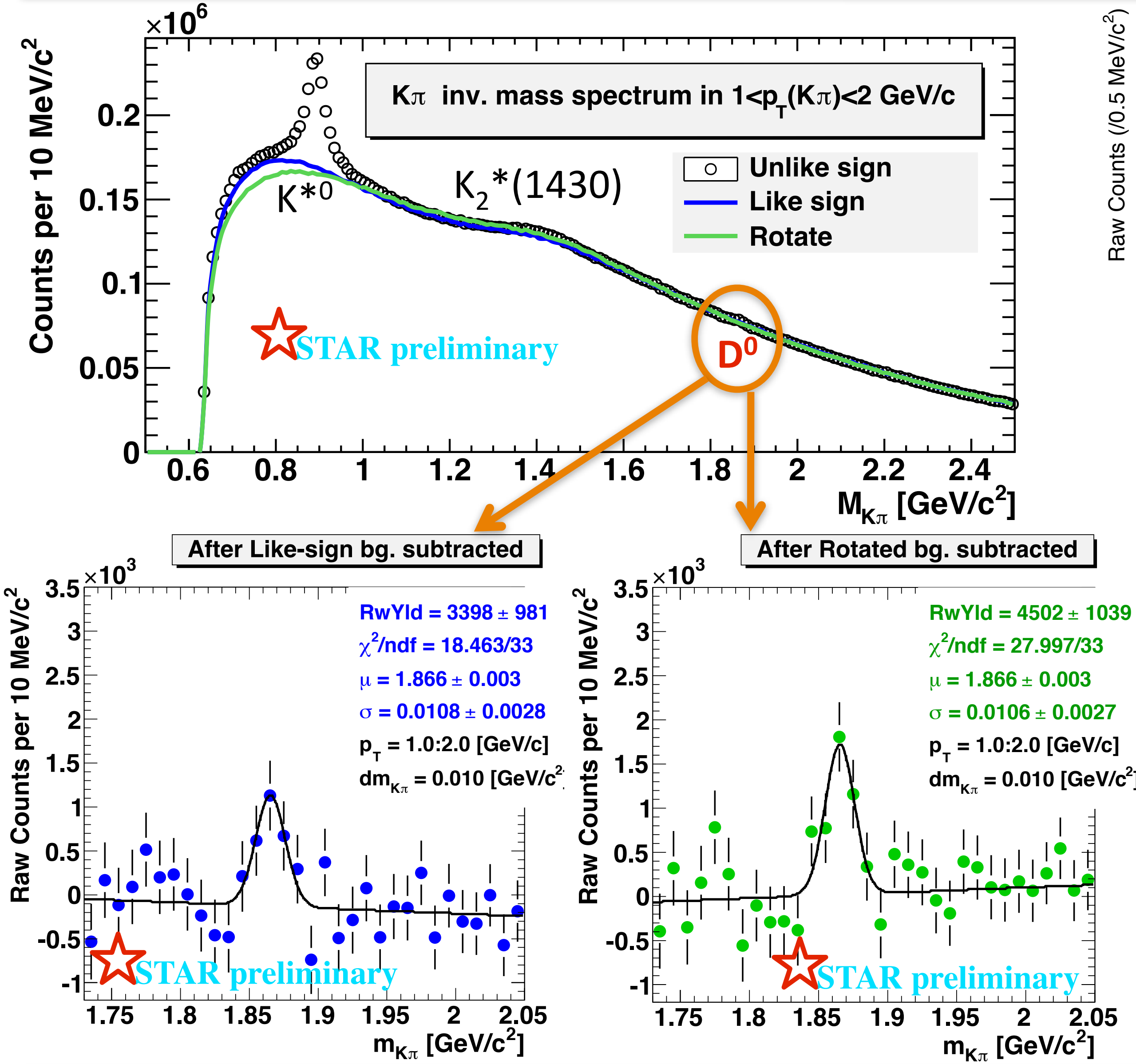


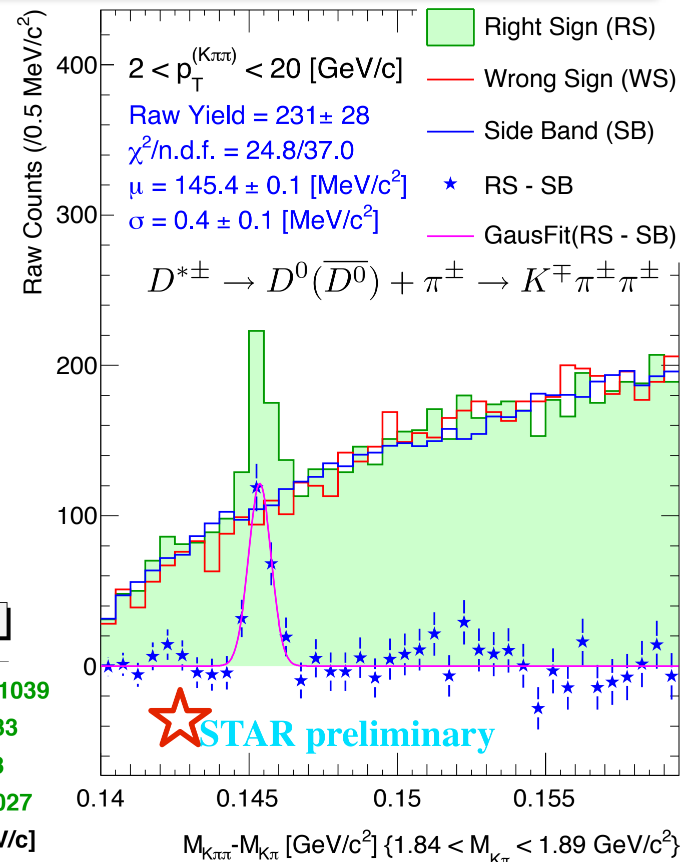
D^0 and D* Signal in p+p 500 GeV



minimum bias L^{-1}=1.53 nb^{-1}

D^0 and D* Signal in p+p 500 GeV





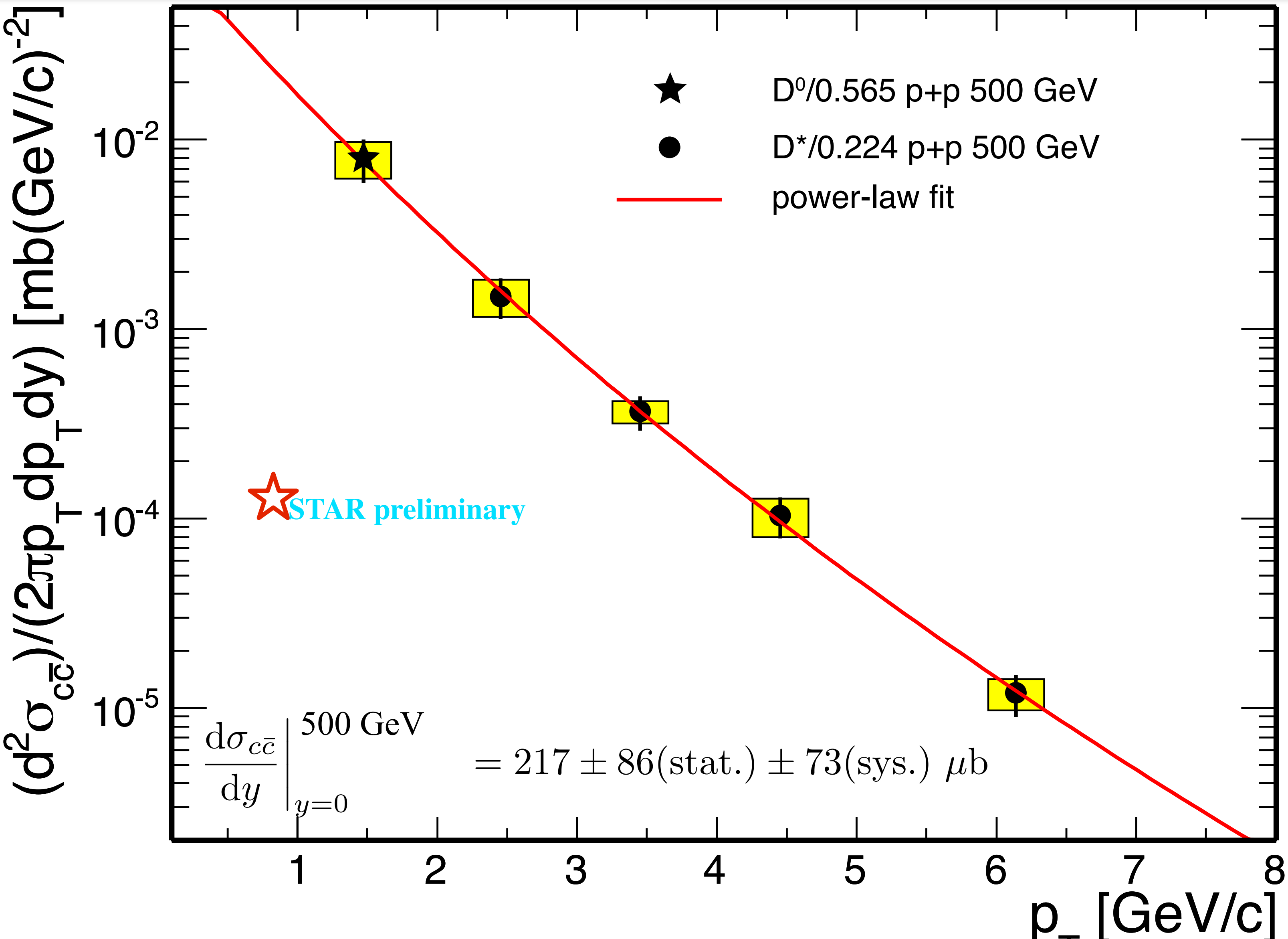
right sign : $1.83<M(K\pi)<1.9$ GeV/c²

wrong sign : $K^-\pi^+\pi^- + K^+\pi^-\pi^+$

side band : $1.7<M(K\pi)<1.8$ + $+1.92<M(K\pi)<2$ GeV/c²

minimum bias L^{-1}=1.53 nb^{-1}

D^0 and D* p_T Spectra in p+p 500 GeV



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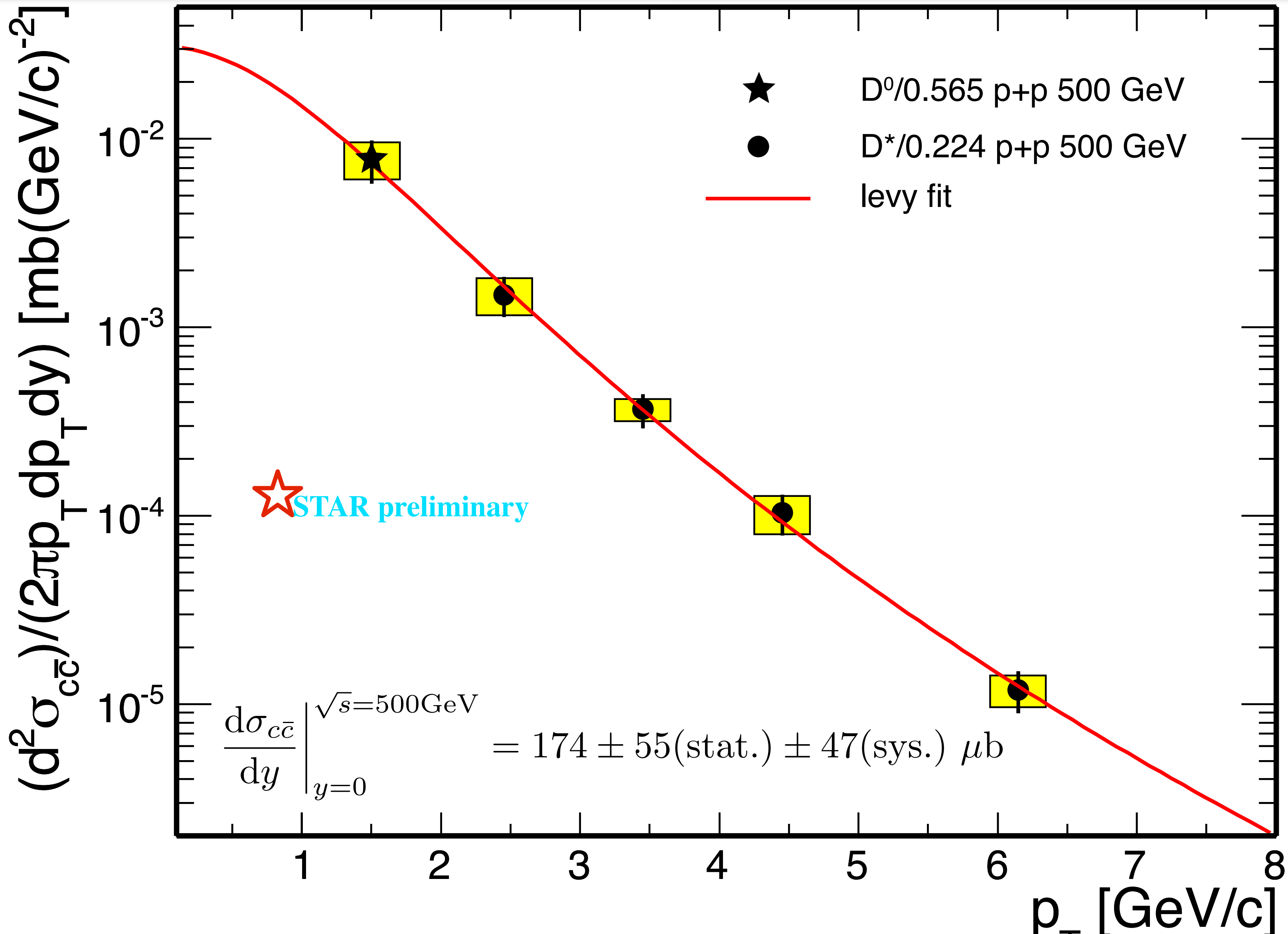

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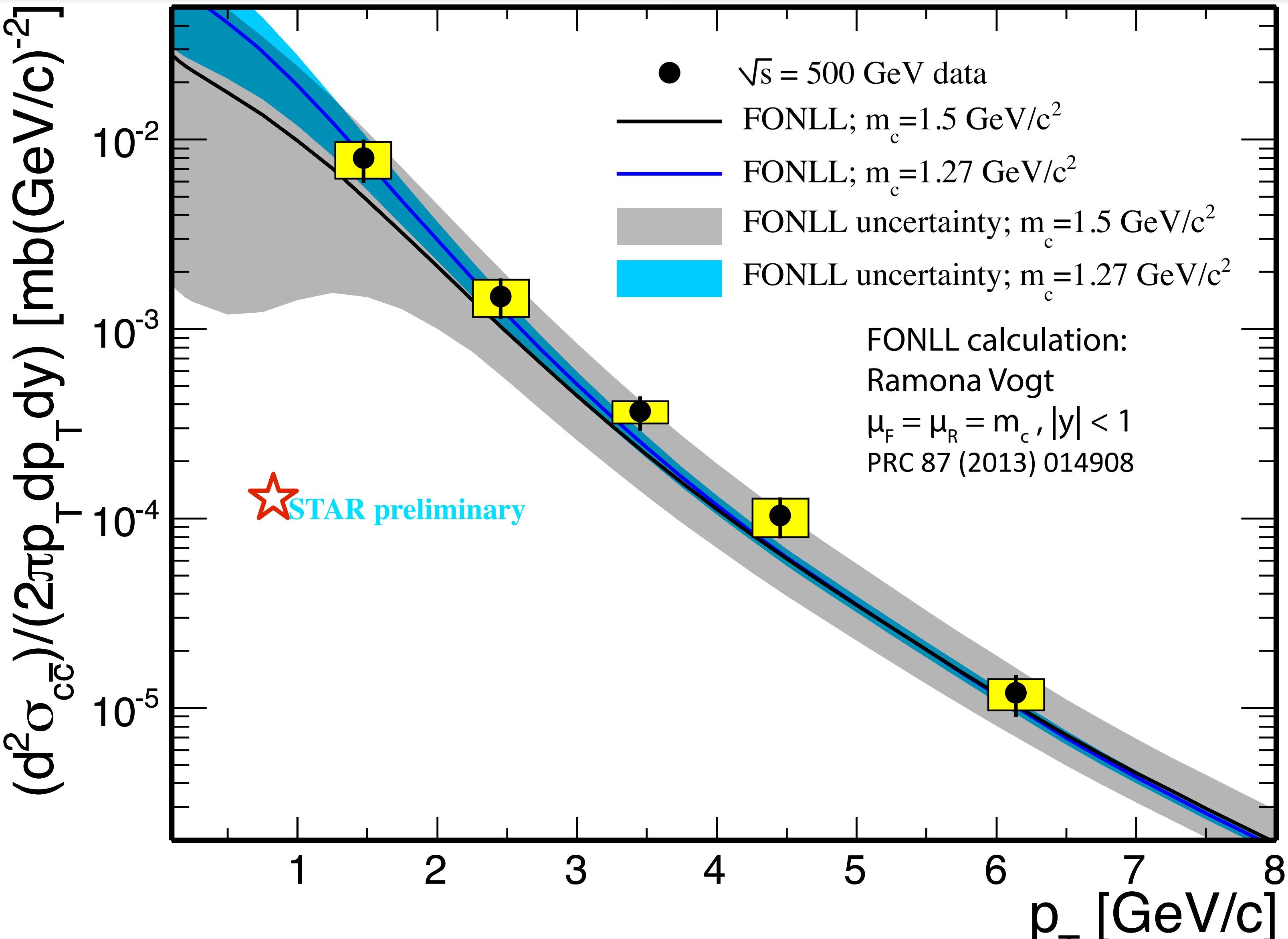
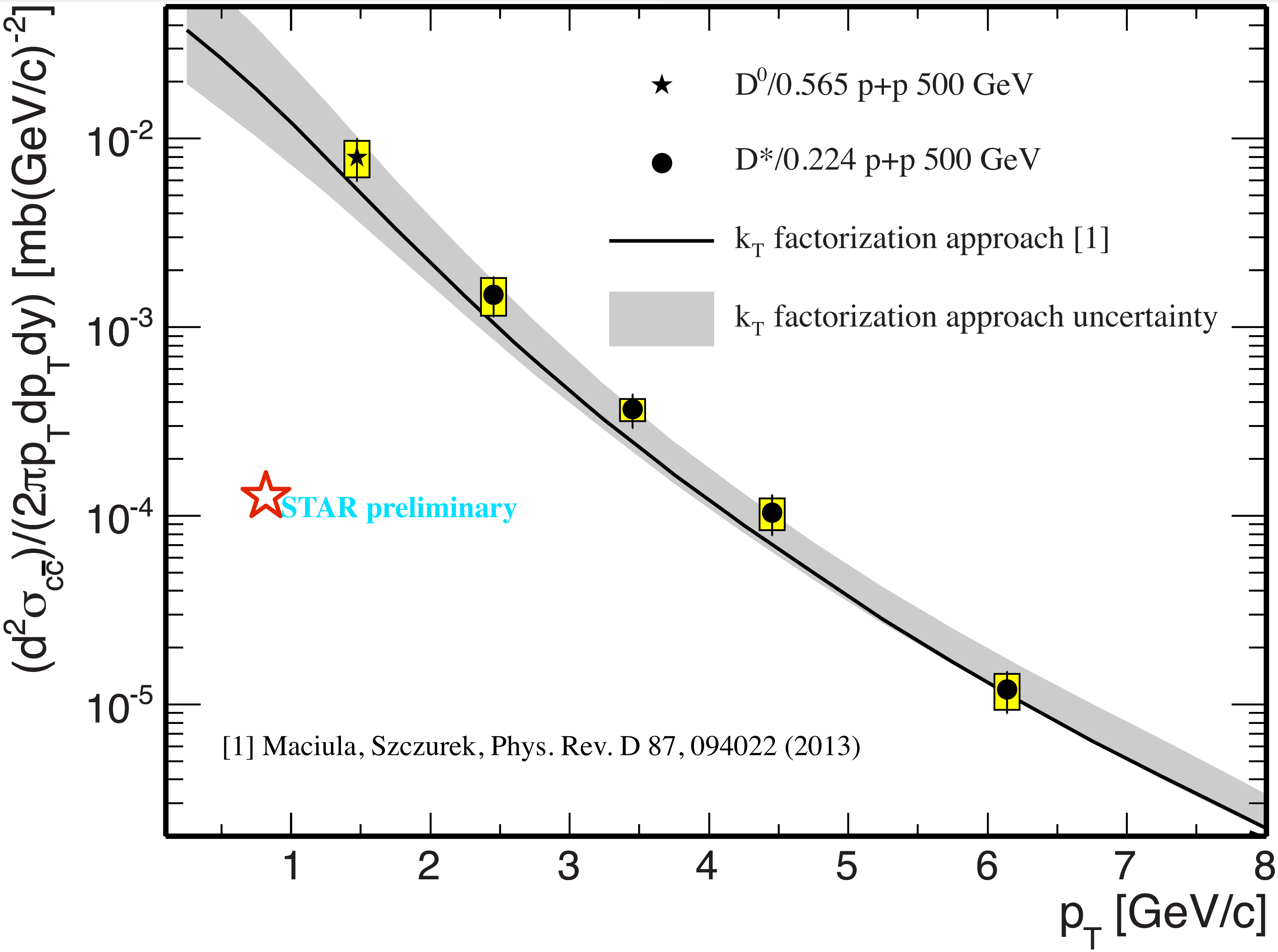
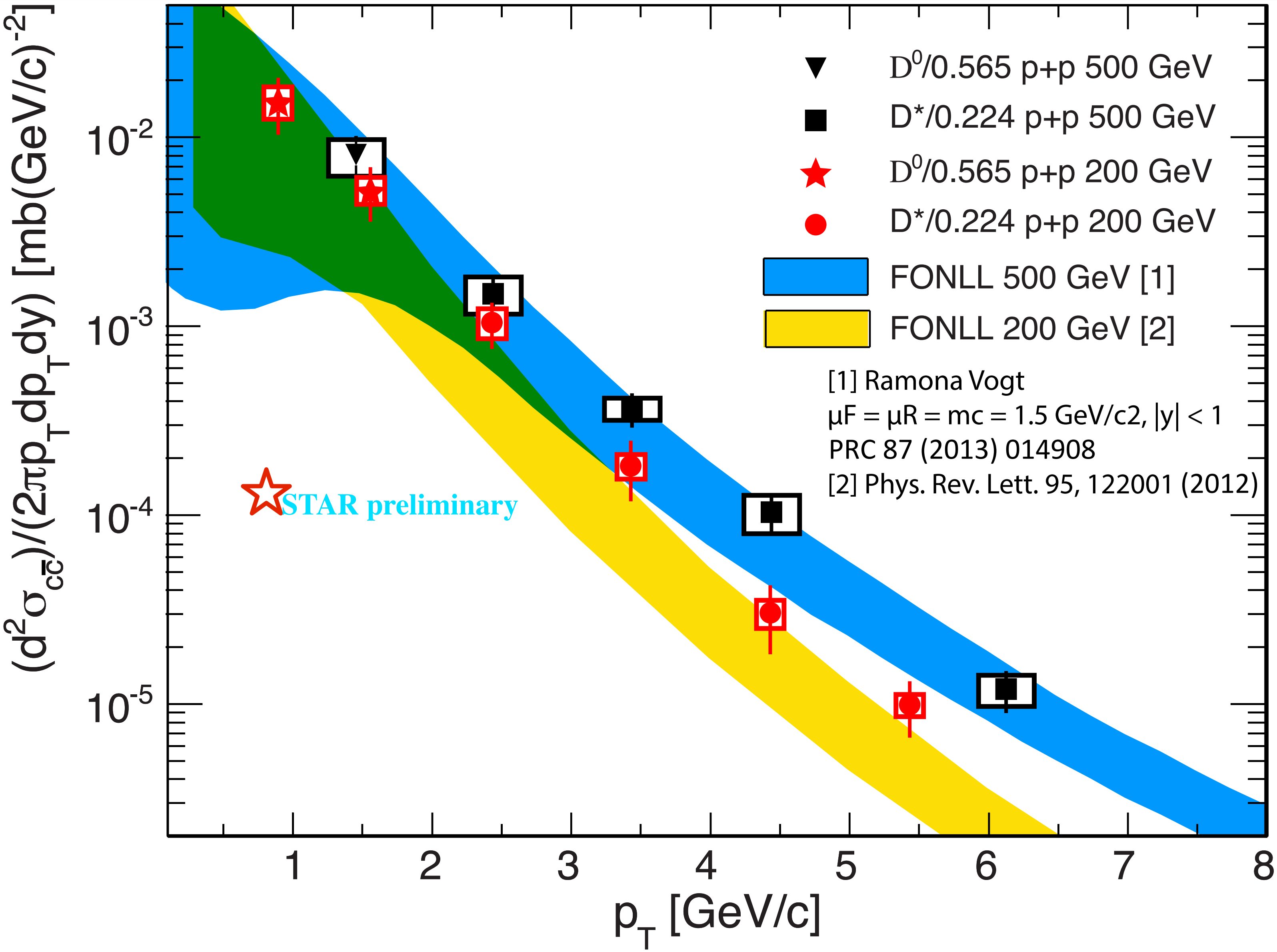


D^0 and D* p_T Spectra in p+p 500 GeV



D^0 and D* p_T Spectra in p+p 500 GeV



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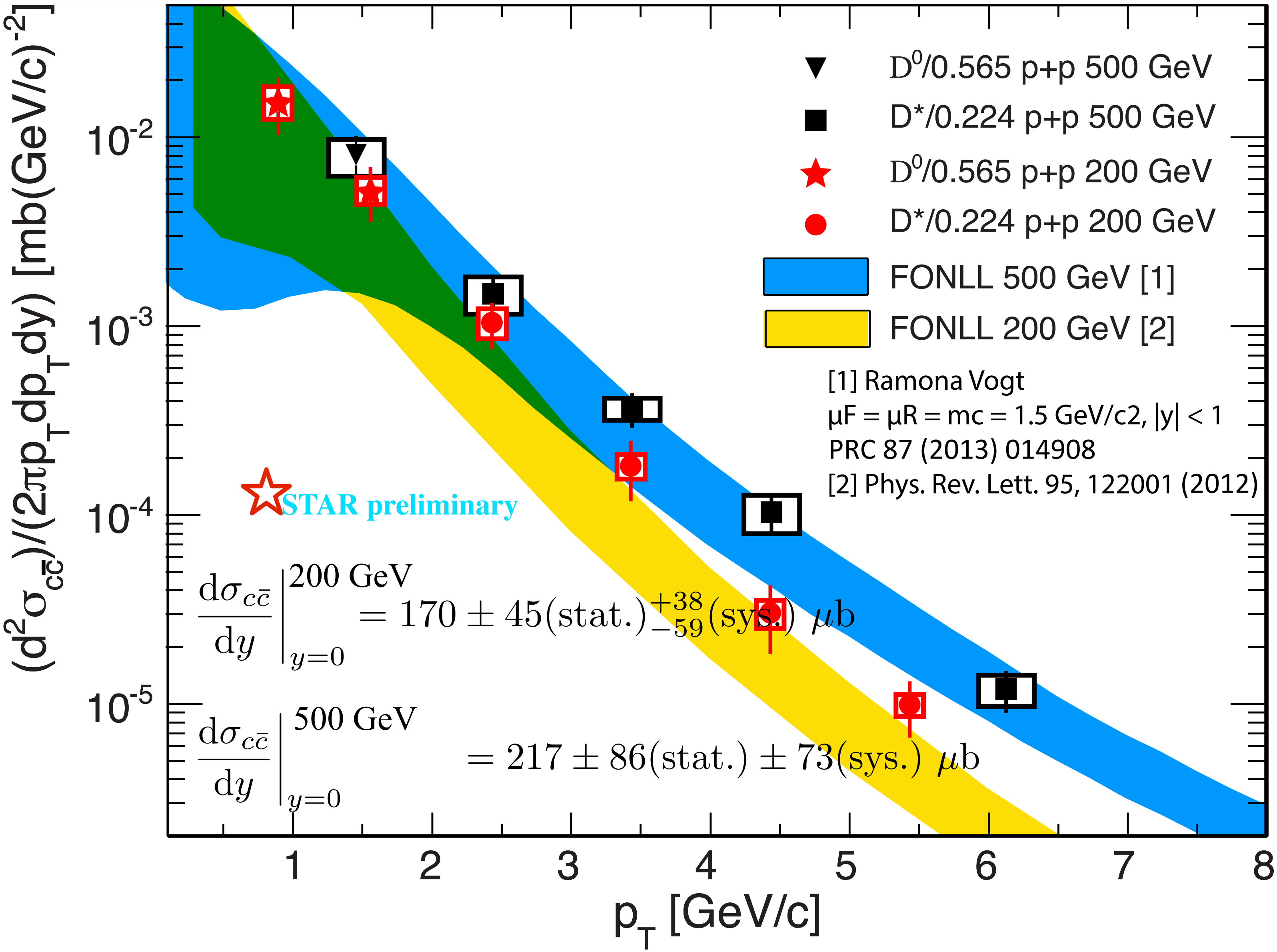
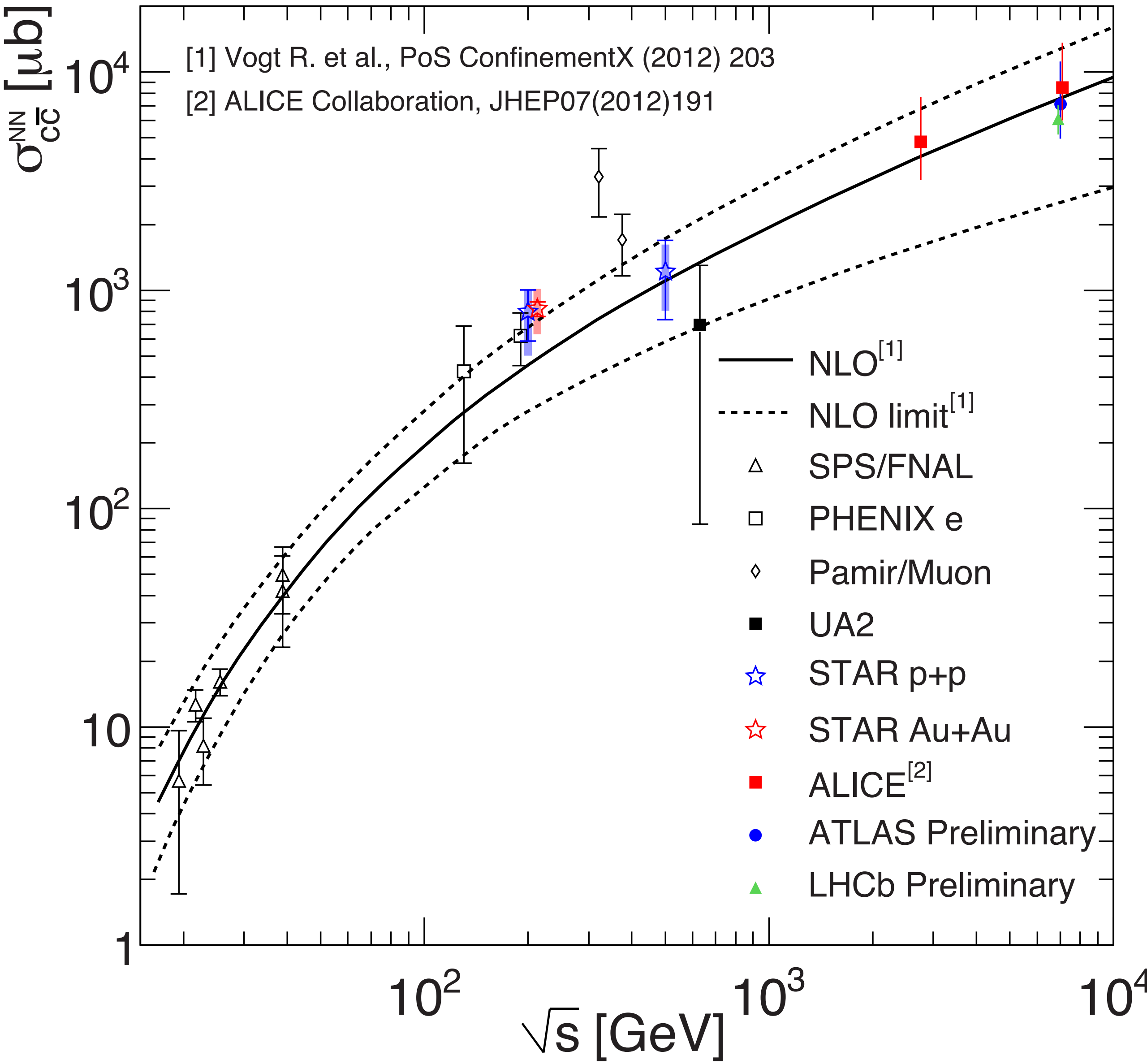


Total Charm Cross Section



$$\sigma_{c\bar{c}} = F \left. \frac{dN_{c\bar{c}}}{dy} \right|_{y=0}$$

$$F \equiv \text{mid } y \rightarrow \text{full } y$$

500 GeV, F = 5.6

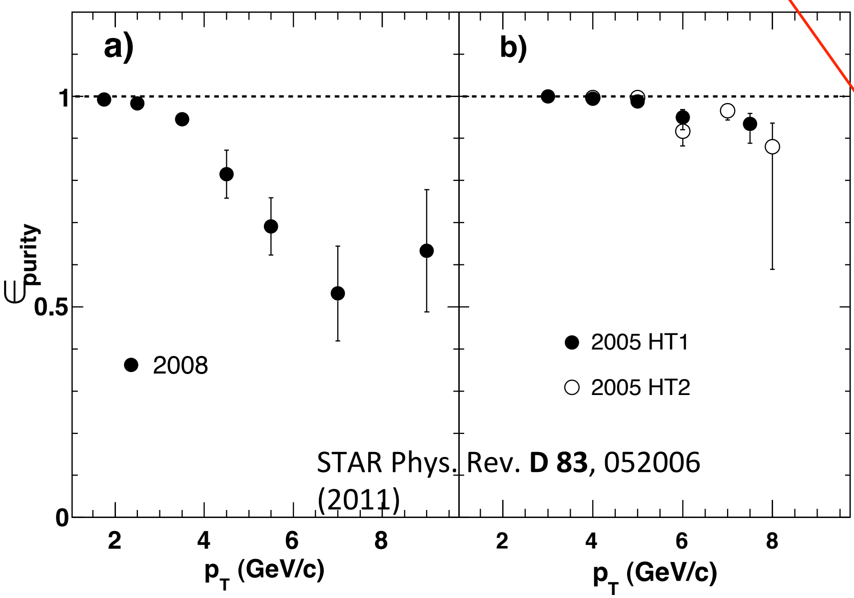
$$\sigma_{c\bar{c}} = 1215 \pm 482(\text{stat.}) \pm 409(\text{sys.})\ \mu b$$

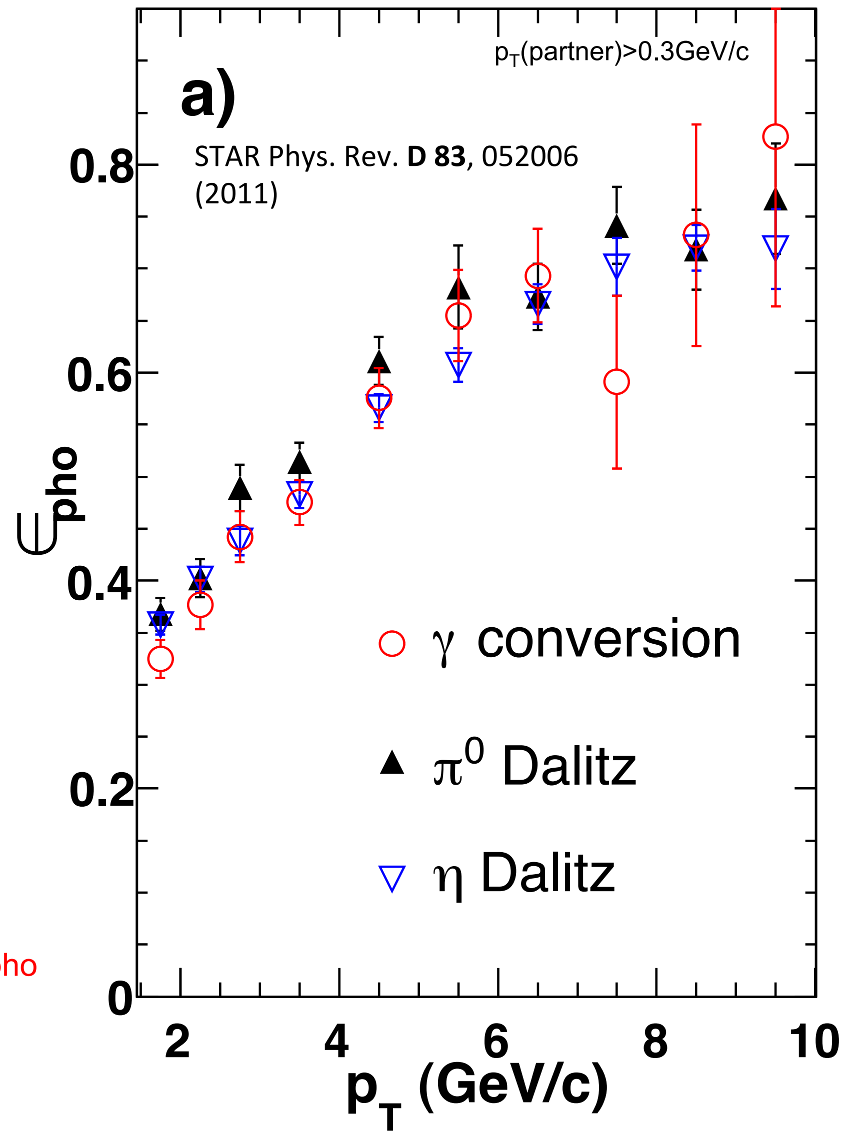
200 GeV, F = 4.7

$$\sigma_{c\bar{c}} = 797 \pm 210(\text{stat.}) {}^{+208}_{-295}(\text{sys.})\ \mu b$$

Non-Photonic Electrons in p+p collisions

$$N_{npe} = N(\text{inclusive})\varepsilon_{purity} - \frac{N(\text{photonic})}{\varepsilon_{pho}}$$





Photonic Electron Reconstruction Efficiency ε_{pho}

- Estimated from embedding
- Precision is critical to N_{npe}

Bottom contribution

Distributions of the azimuthal angle between NPE and hadrons normalized per NPE trigger

$$r_B \equiv \frac{N_{e_B}}{N_{e_B}+N_{e_D}} = \frac{N_{e_B}}{N_{\rm npe}}$$

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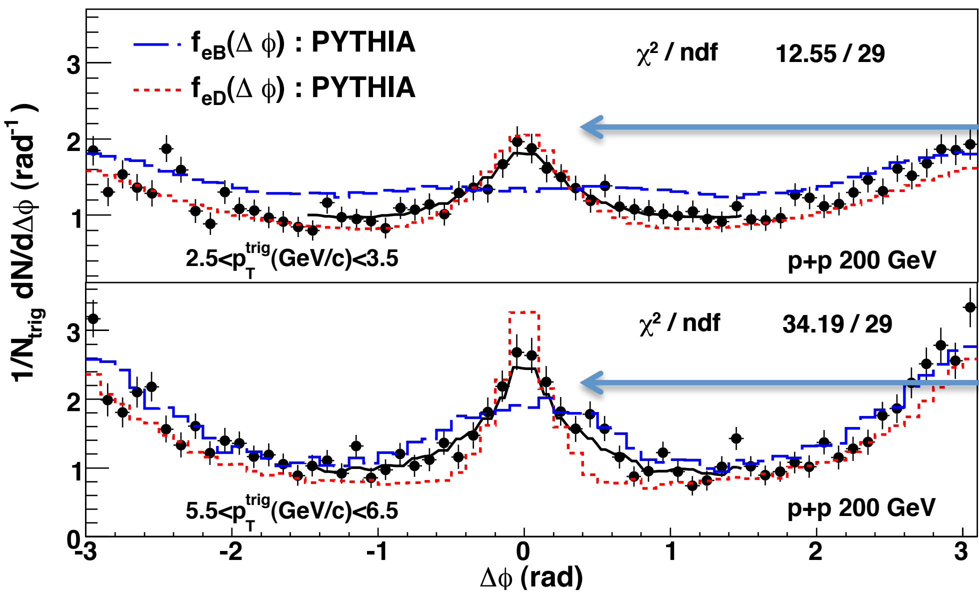

$$r_B f_{e_B}(\Delta\phi) + (1-r_B) f_{e_D}(\Delta\phi)$$

near side (|$\Delta\phi$|<1.5) fit, r_B as parameter

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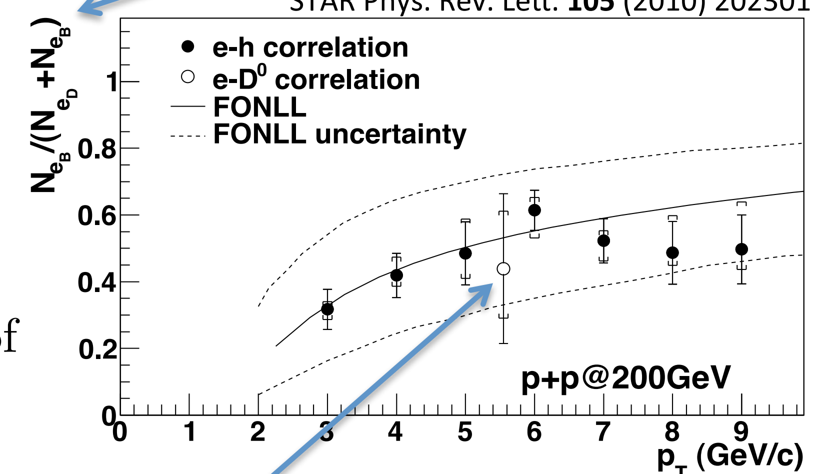
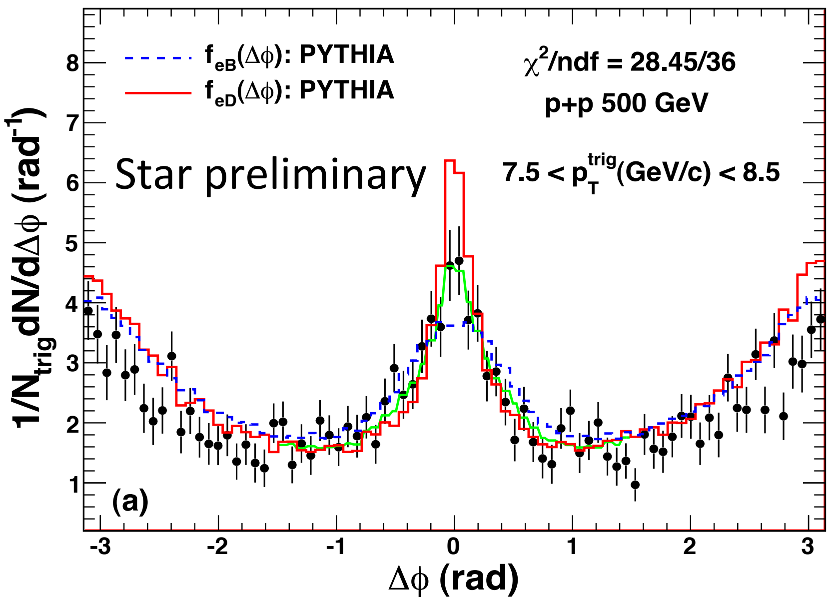


$f_{e_B}(\Delta\phi),\ f_{e_D}(\Delta\phi)$: Pythia 6.22 calculation of azimuthal correlations between electrons from B, D meson decay and charged hadrons

Independent measurement of r_B

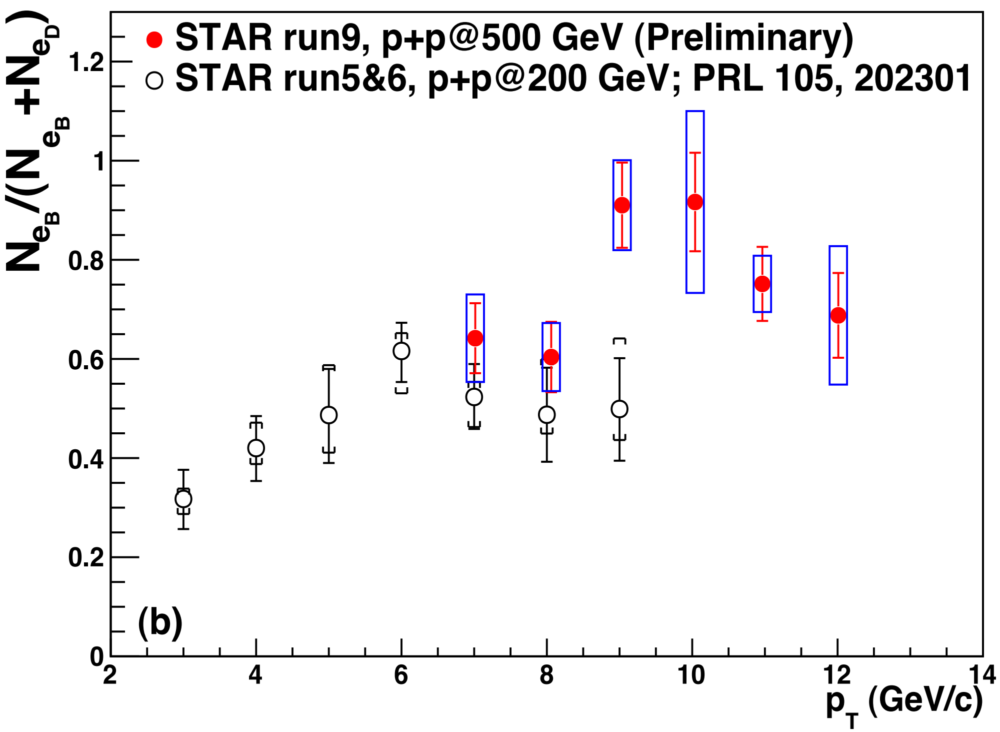
different mostly due to the decay kinematics

Bottom Contribution in p+p 500 GeV



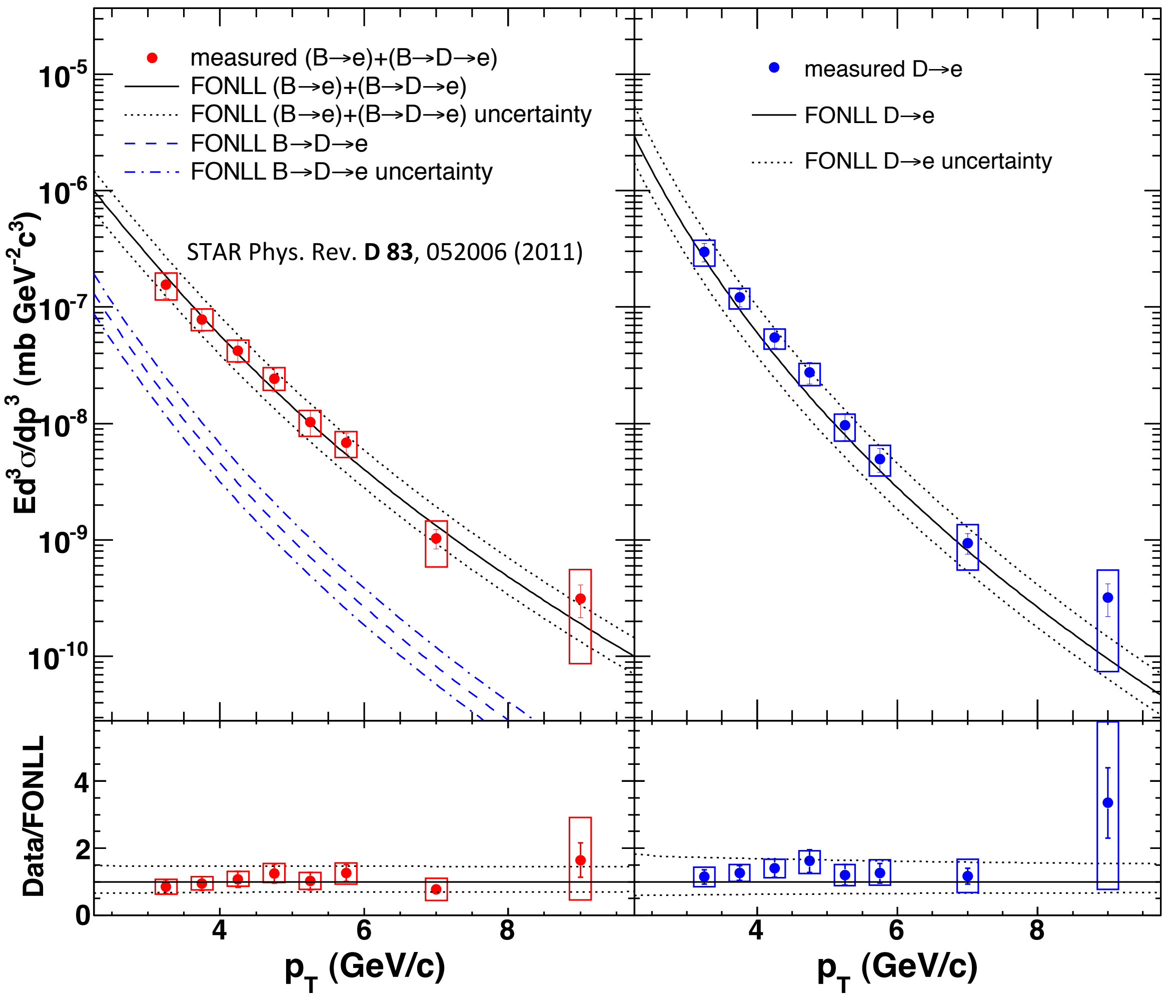
New measurement in AuAu 200 GeV
see talk of Prof. Zhang
Friday 17:30, Quarkonia/Heavy Flavor session

- ★ is above 60% at
  $8.5 < p^{NPE} < 12.5$ GeV/c
- ★ increases with trigger NPE p_T



Separate Measurement of B and D meson Spectra

$$E\frac{d^3\sigma^{(B\to e+B\to D\to e)}}{dp^3} = r_B\left(E\frac{d^3\sigma^{(e^++e^-)/2}}{dp^3} - E\frac{d^3\sigma^{(J/\psi,\Upsilon\to e+\mathrm{DrellYan})}}{dp^3}\right)$$



From the measured spectra, integrated cross sections at $3<p_T<10$ GeV/c are determined:

$$\left.\frac{d\sigma^{(B\to e+B\to D\to e)}}{dy_e}\right|_{y_e=0} = 4.0 \pm 0.5(\mathrm{stat}) \pm 1.1(\mathrm{syst})\mathrm{nb}$$

$$\left.\frac{d\sigma^{(D\to e)}}{dy_e}\right|_{y_e=0} = 6.2 \pm 0.7(\mathrm{stat}) \pm 1.5(\mathrm{syst})\mathrm{nb}$$

Extrapolation to full kinematic phase space based on two PYTHIA tunings:
1.34 μb and 1.83 μb
consistent with FONLL prediction

Summary

★ D^0 and D^* are measured in p+p 200 GeV up to 6 GeV/c and in p+p 500 GeV up to 6 GeV/c

➡ $\mathrm{d}^2\sigma^{c\bar{c}}/p_T\mathrm{d}p_T\mathrm{d}y$ consistent with

- FONLL / its upper limit
- k_T factorization approach

★ Non Photonic Electrons consistent with FONLL / its upper limit

★ Bottom contribution consistent with FONLL prediction

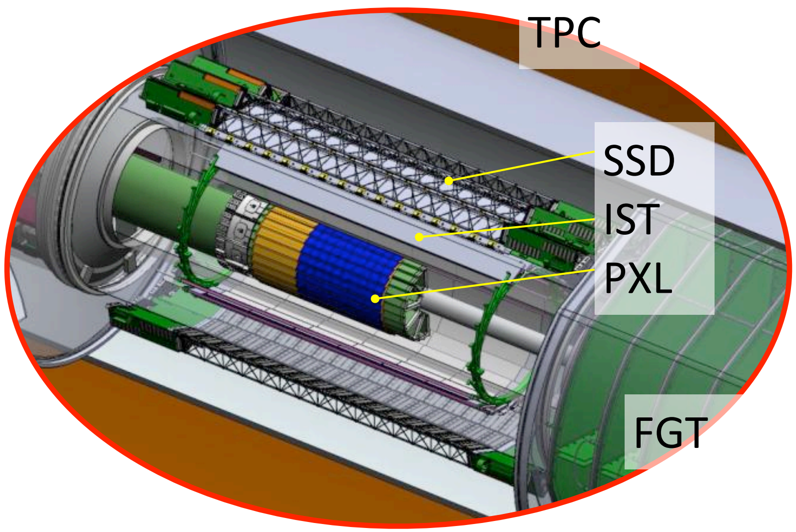
➡ systematically higher at 500 GeV than 200 GeV at $6.5 < p_T < 9.5$ GeV/c

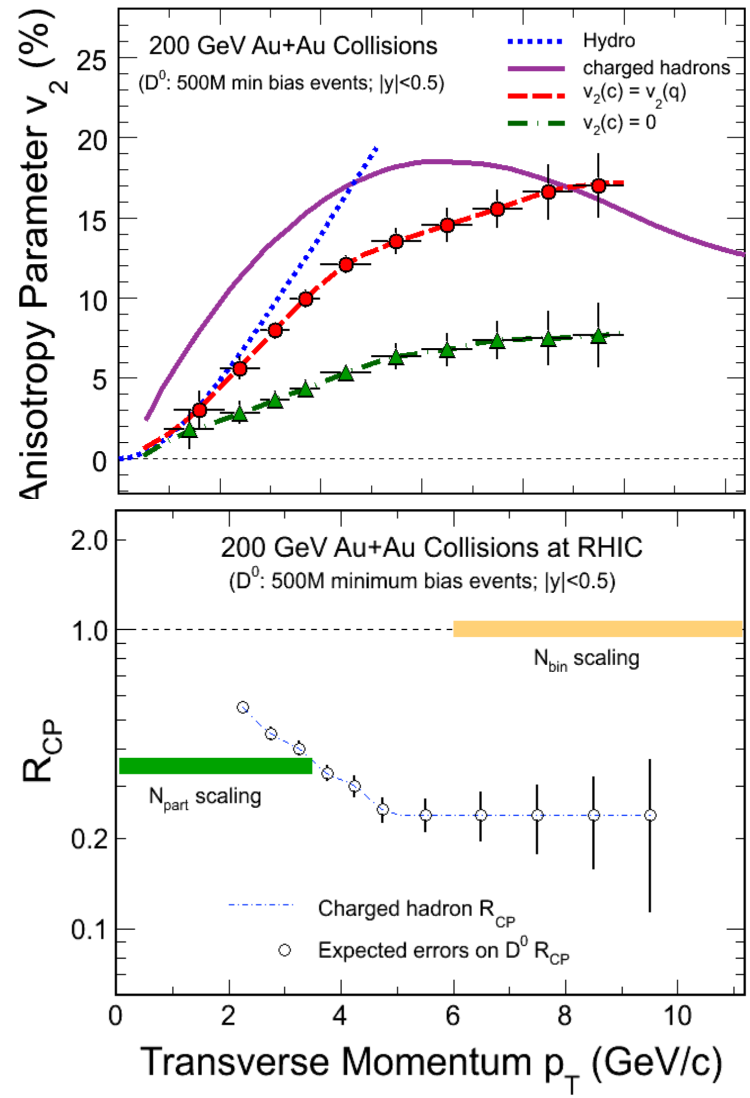
★ Further improvement with Heavy Flavor Tracker

➡ see talk of Dr. Hao Qiu, Friday 11:30, Plenary 11

Thank you

Backup Slides





STAR Heavy Flavor Tracker Project.

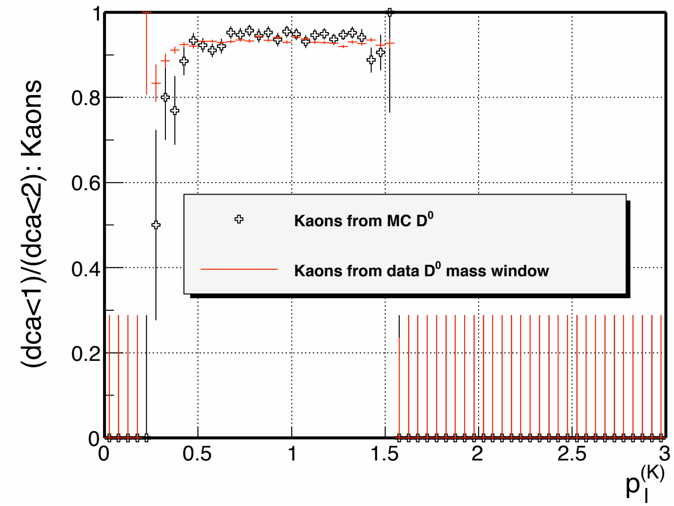
- ✓ Reconstruct secondary vertex.
- ✓ Dramatically improve the precision of measurements.
- ✓ Address physics related to heavy flavor.

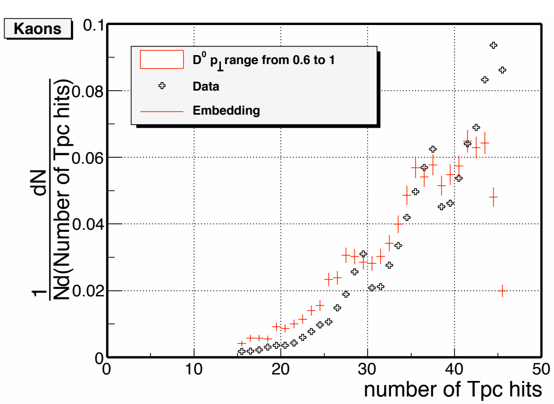
v_2 : thermalization

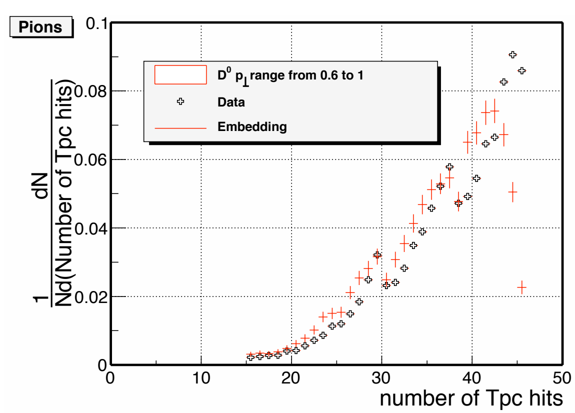
R_{CP}: charm quark energy loss mechanism.

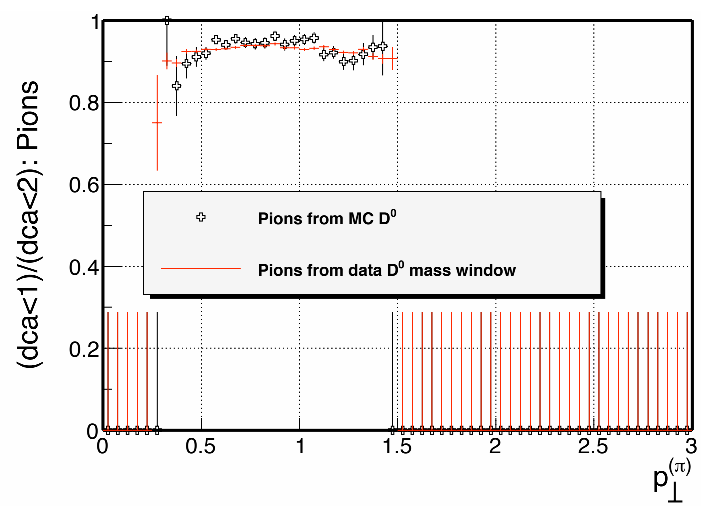
Systematic error study

1) Raw Counts – Difference between methods
2) nFitPoints - difference between MC(nFitPts>25)/MC(nFitPts>15) and Data(nFitPts>25)/Data(nFitPts>15)
3) DCA - difference between MC(dca<1)/MC(dca<2) and Data(dca<1)/Data(dca<2)

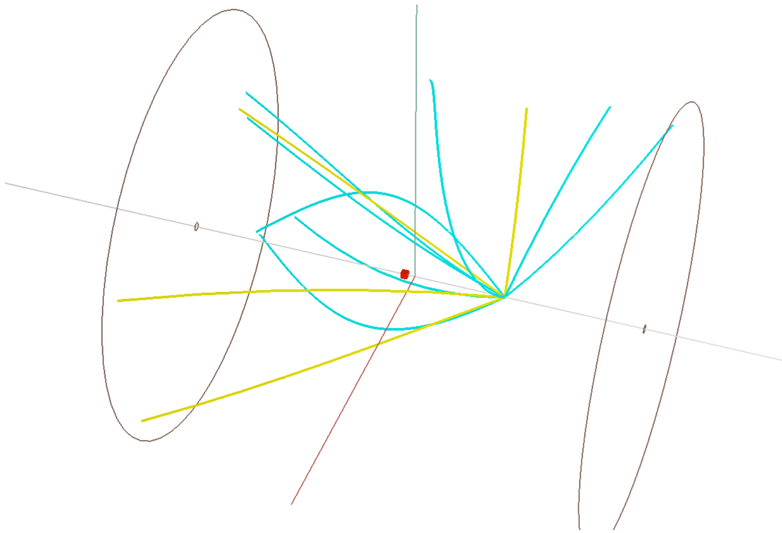


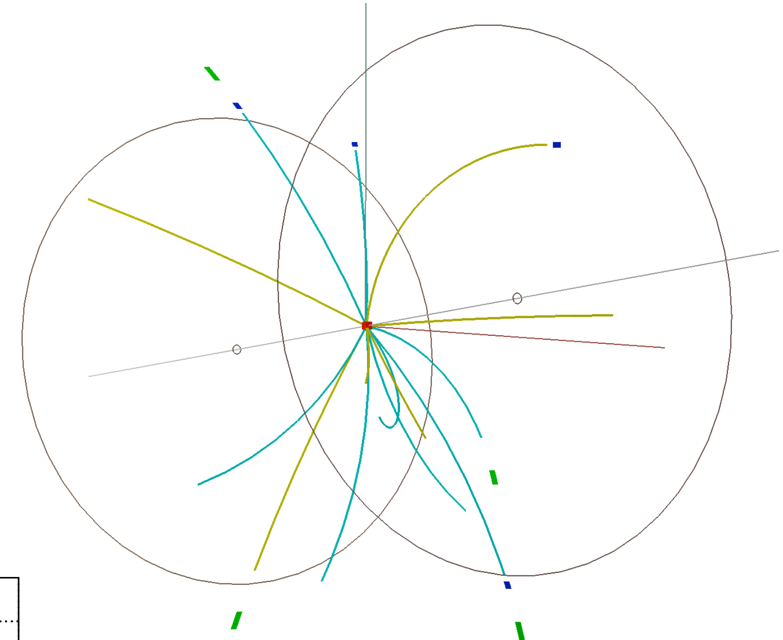


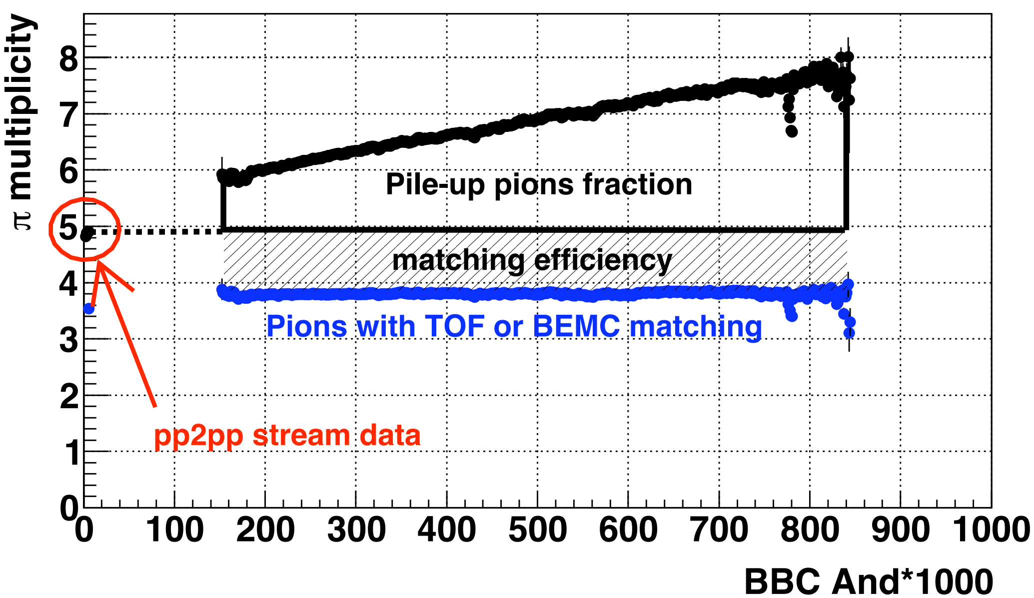




Pile-up removal







- pp collisions peak luminosity $L_{peak} = 5*10^{31}\ cm^{-2}s^{-1}$ in year 2009.
- EventRate = $L_{peak}*\sigma^{NSD}$(30 mb) = 1.5 MHz
- TPC readout ~ 80 μs => TPC sees tracks from 120 collisions. Pile-ups are removed by
  - |VpdVz - TpcVz| < 6cm cut
  - TPC PPV reconstruction algorithm