The STAR Tracking Upgrade

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for the STAR Collaboration

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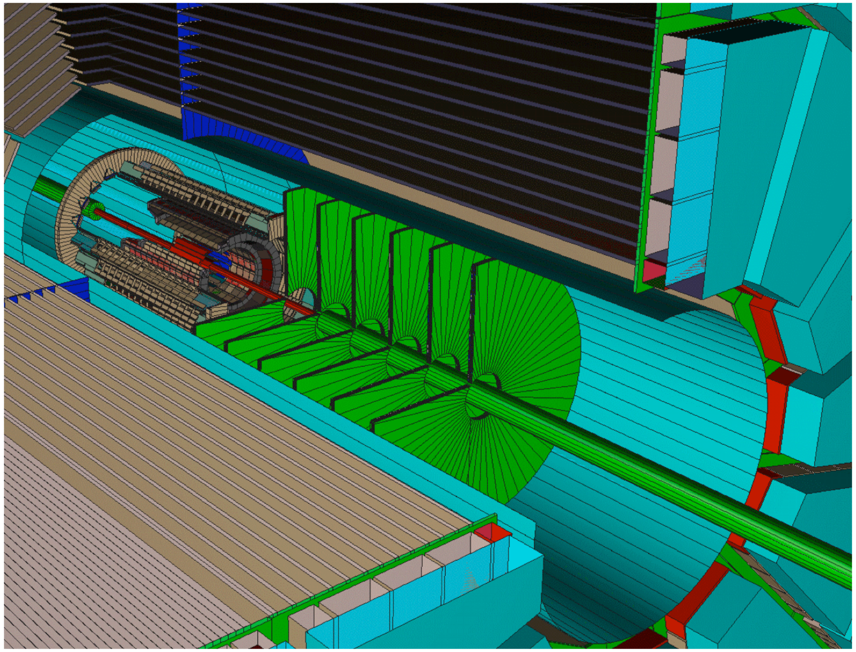
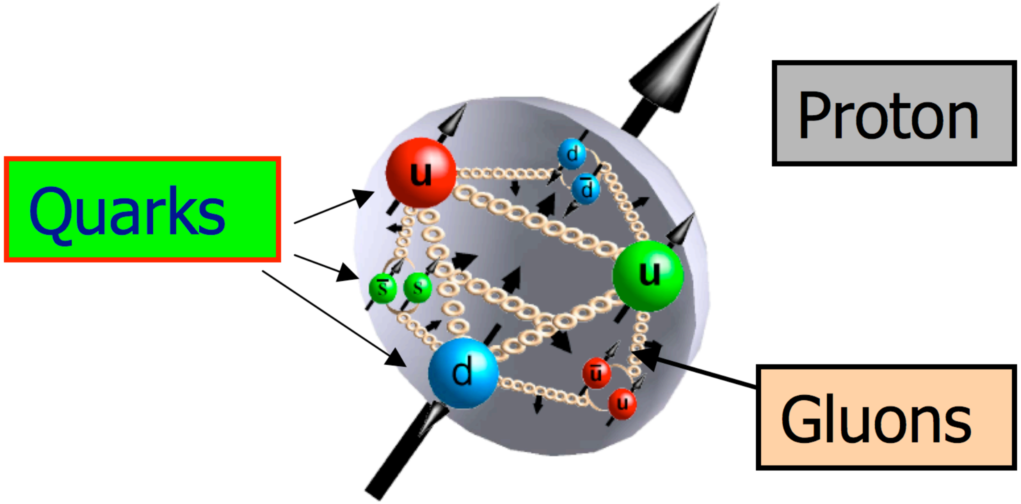
- Physics Objectives
- Future Detector Requirements
- Inner Tracker Upgrade
- Forward Tracker Upgrade
- Summary & Outlook



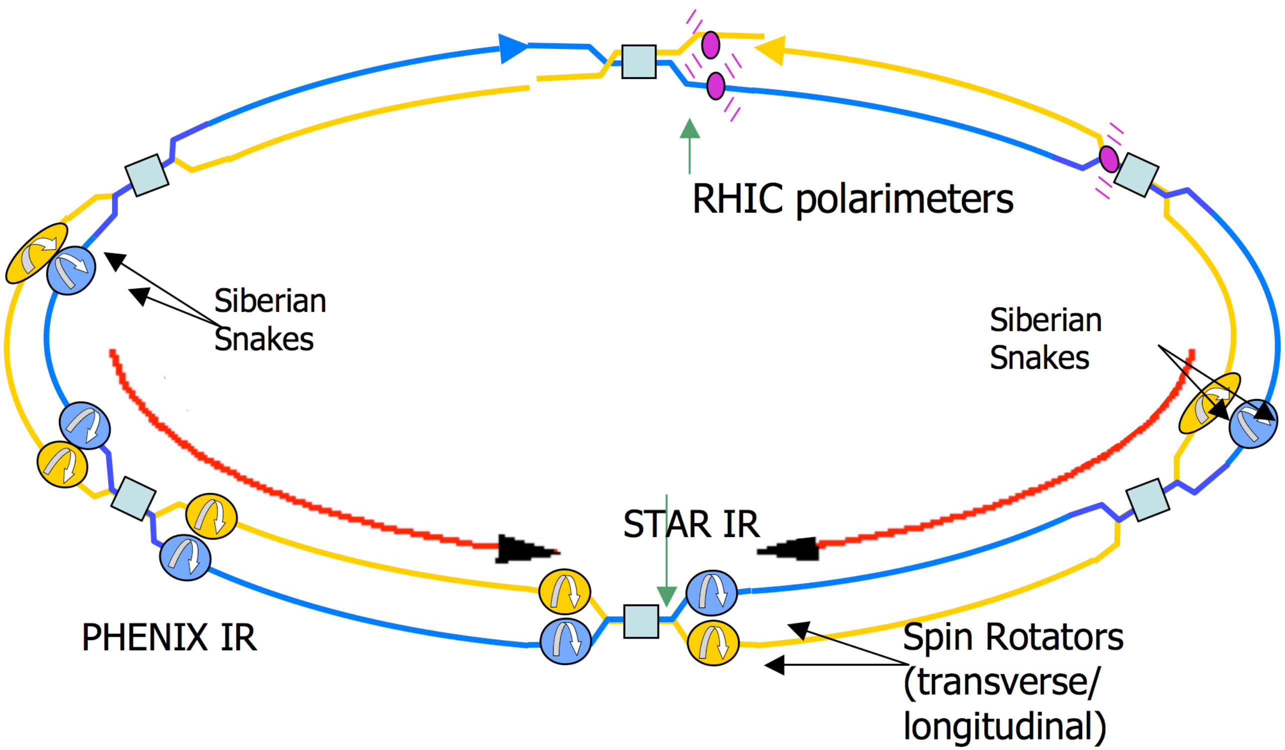
Fundamental Questions in QCD

- What are the properties of the medium created in HI collisions at RHIC?
- How is the spin of the proton made up?



$$J_{PROTON} = \frac{1}{2} = \langle S_q \rangle + \langle S_G \rangle + \langle L_q \rangle + \langle L_g \rangle$$

RHIC: A Tool to study QCD



RHIC: Relativistic Heavy Ion Collider

- Heavy Ion Collisions with a variety of species at up to 200 GeV/N
- Polarized Proton Collisions at up to 500 GeV

Heavy Flavor in Heavy Ion Collisions

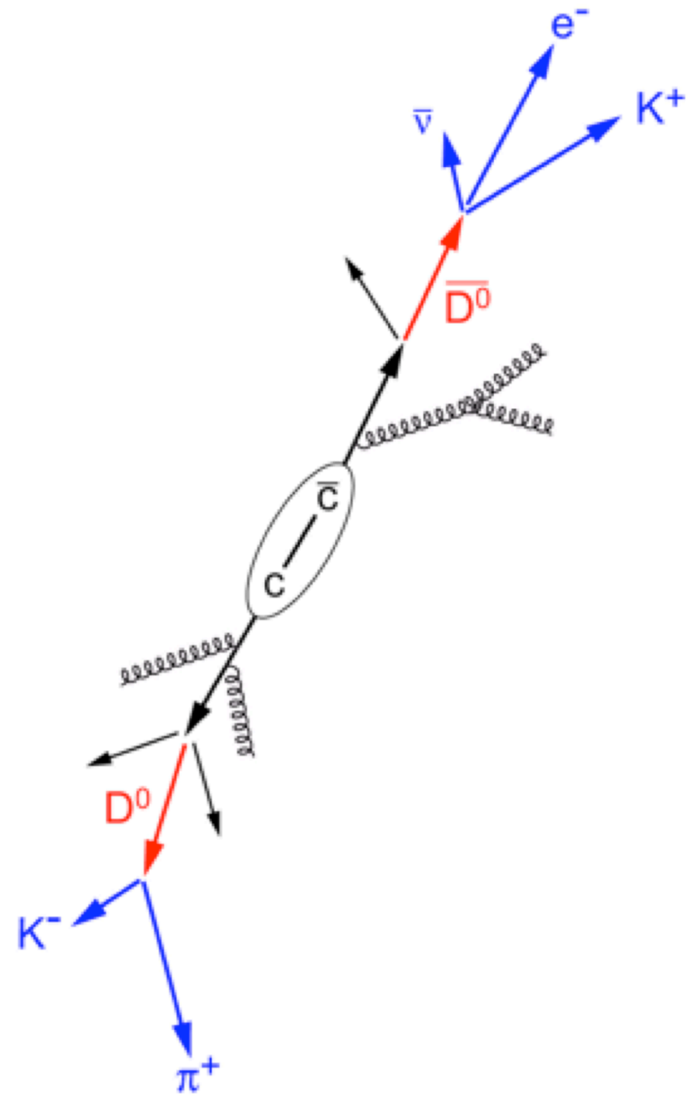
- Mesons and baryons containing light quarks (u,d,s) show strong elliptic flow
- Heavy quark mass dominated by intrinsic mass: c and b quarks are also heavy in a QGP

⇨ Heavy quark flow needs frequent interactions among all quarks

⇨ If c, b quarks flow light quarks very likely to be thermalized

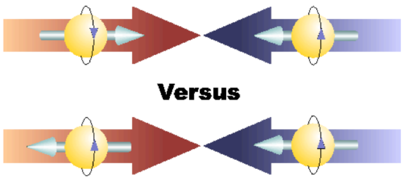
⇨ Heavy flavor a good probe of the medium created at RHIC
  - Energy loss in the medium
  - Spectra
  - …

⇨ Direct observation of mesons containing heavy quarks crucial



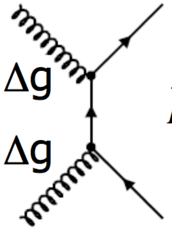
Heavy Flavor in Spin Physics

Use polarized p+p collisions to access the helicity distribution of the gluons in the proton
⇨ Measure double spin asymmetries for a variety of channels (Currently jets, neutral and charged pions)



Heavy flavor production in p+p collisions: gluon-gluon fusion

- one partonic subprocess dominates ⇨ contributions from quark helicities negligible



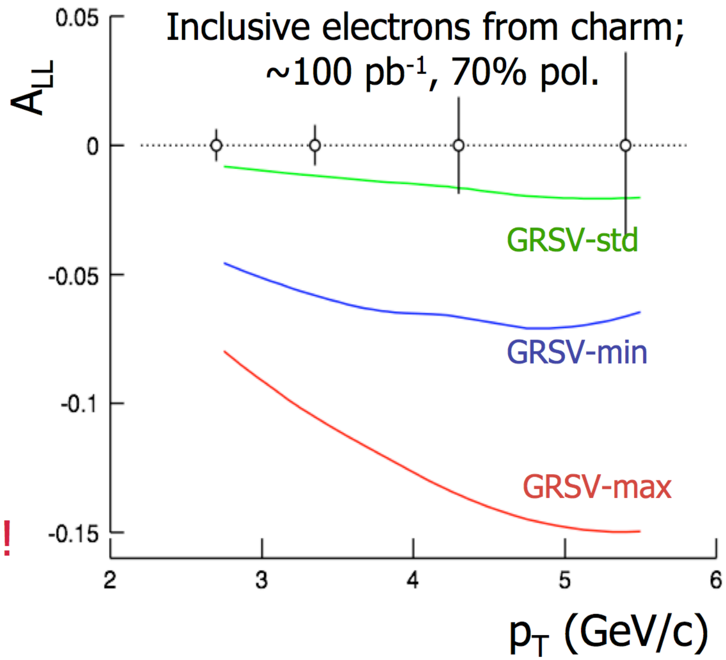
$$\vec{p}\,\vec{p} \rightarrow c\bar{c}X,\ b\bar{b}X$$

clean theoretical connection from the experimentally accessible spin asymmetry to Δg

the challenge:
directly identify charm & bottom mesons

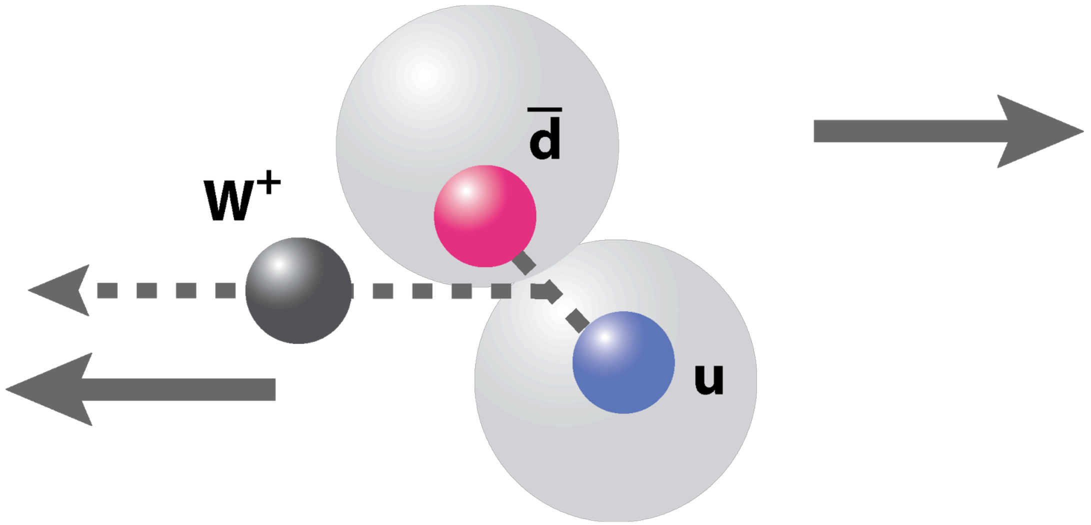
- D^0 cτ ~ 123 μm
- B^0 cτ ~ 460 μm

⇨ Precision vertexing needed!



Accessing Quark Helicities with W Bosons

- Maximal Party-Violation in Weak Interaction: Inherent spin sensitivity of W production



- Charge of the Boson provides flavor tagging:

$$d + \overline{u} \rightarrow W^-$$
$$\overline{d} + u \rightarrow W^+$$

RHIC: 500 GeV CME in p+p collisions
⇨ the quark is usually a valence quark (large x)

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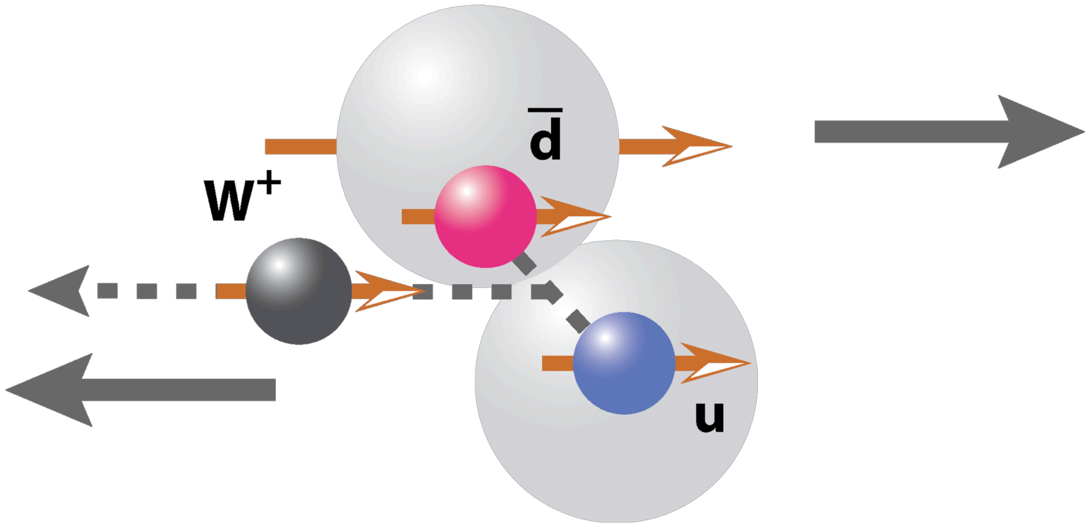

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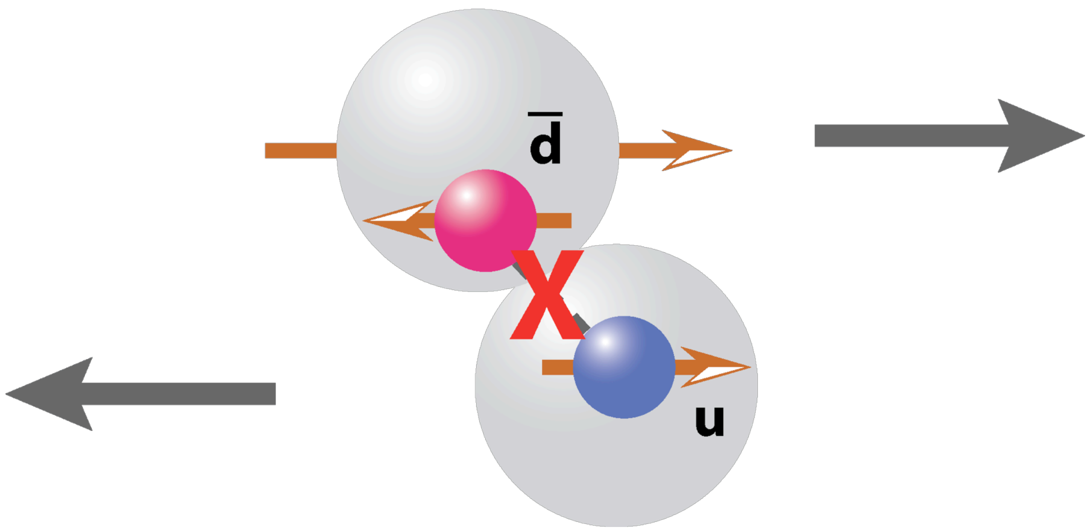

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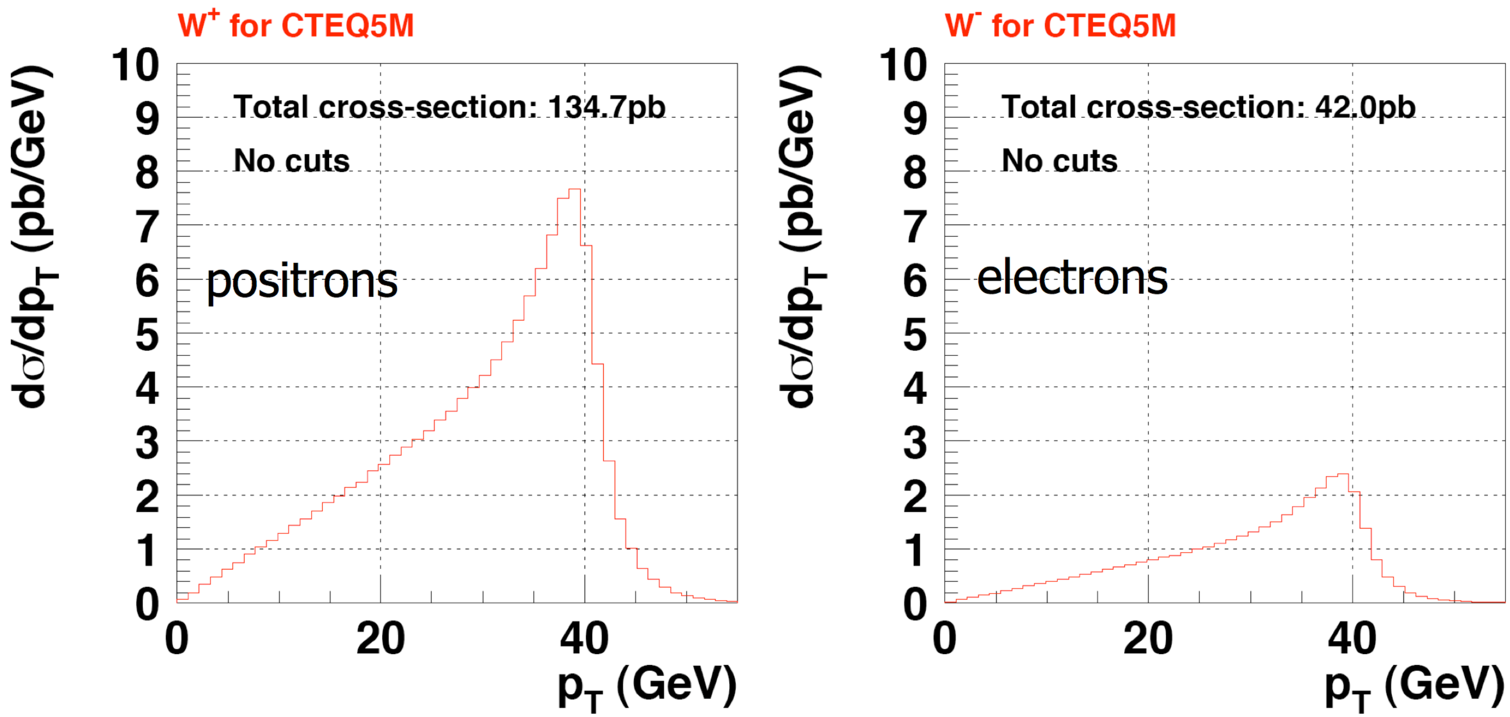
W Bosons: Making the Measurement

- Identification of W in STAR via

$$W^- \rightarrow e^- + \bar{\nu}_e$$
$$W^+ \rightarrow e^+ + \nu_e$$

(BR 10.7%) ⇨ Signature: High p_T lepton

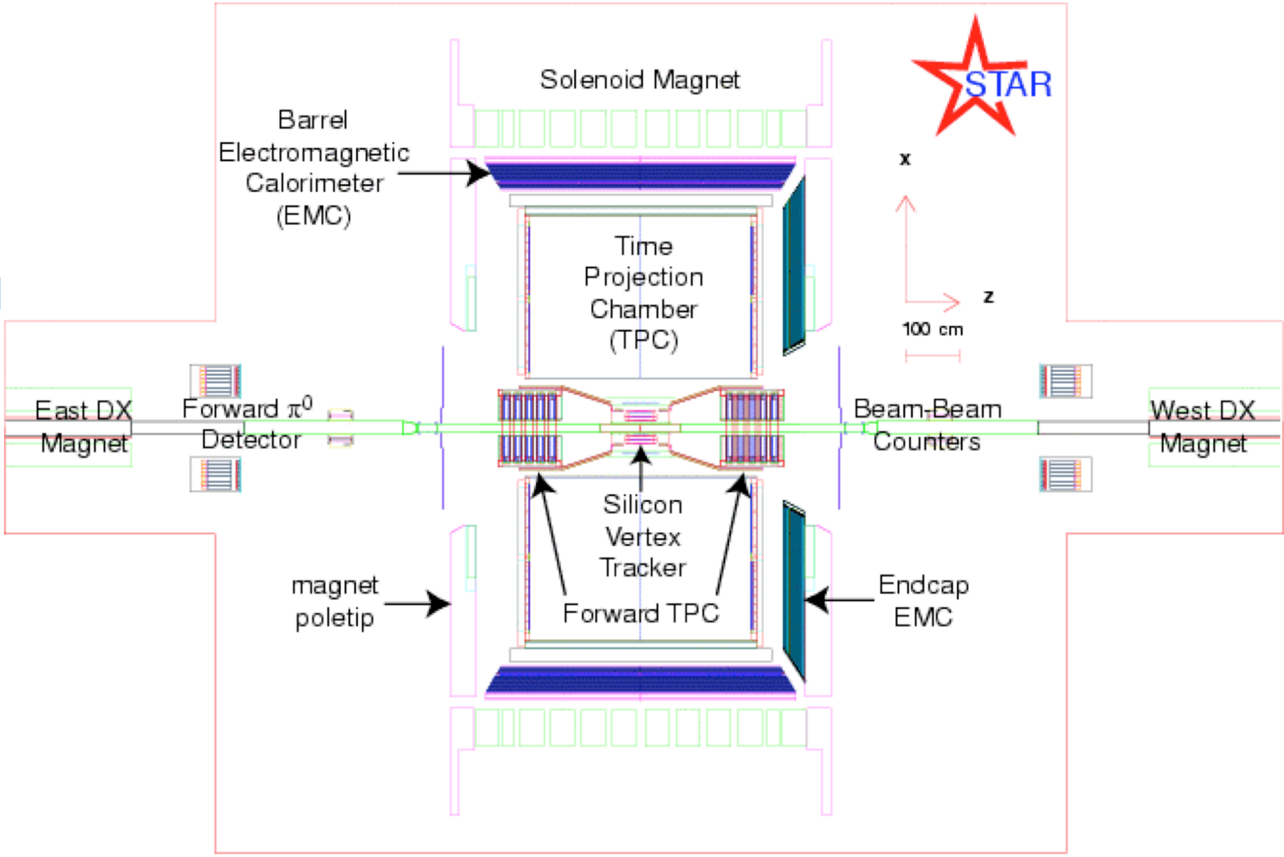


⇨ identification of high p_T electrons (including charge sign) at forward rapidity!

STAR: Current Capabilities

Tracking

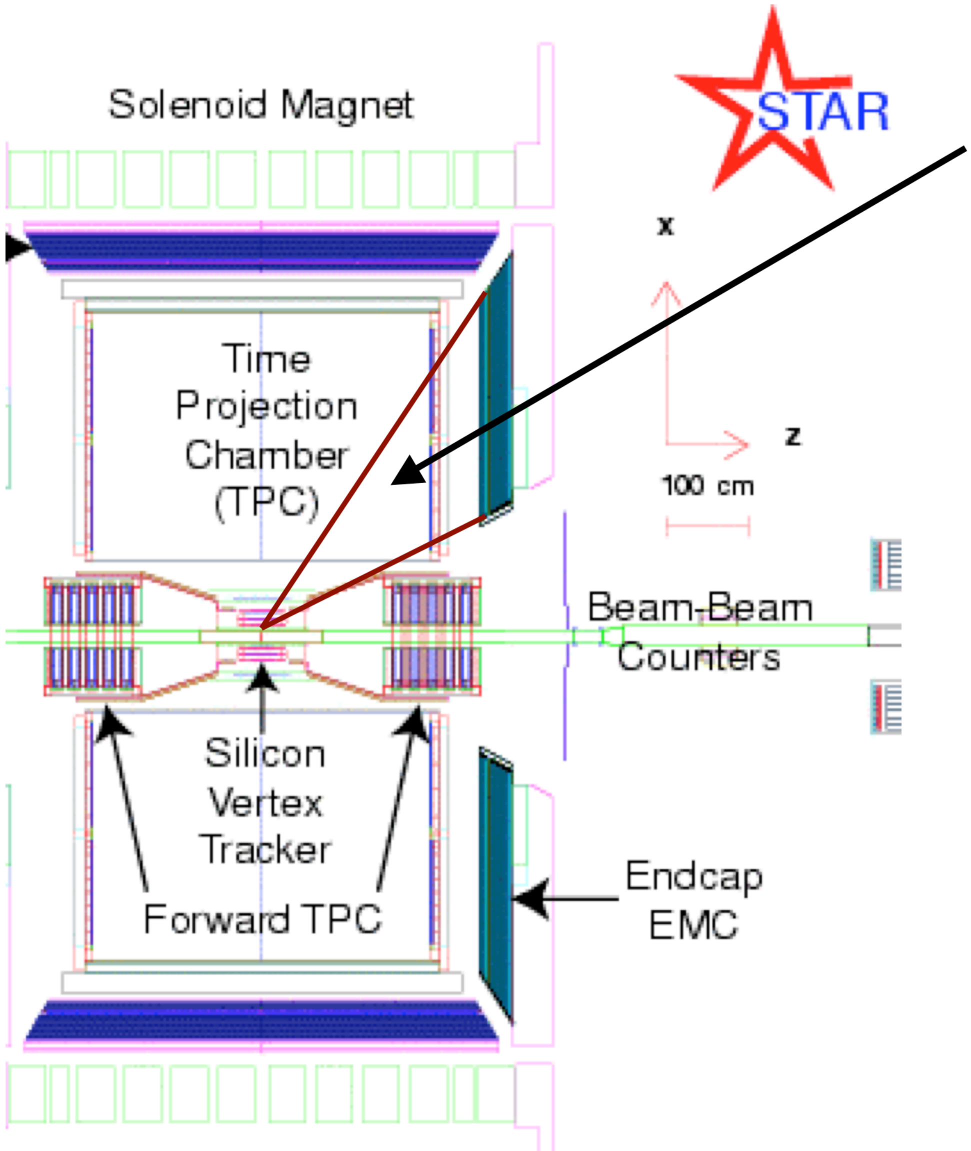
- Large-volume TPC
  - $|\eta| < 1.3$
  - particle ID via dE/dx
- SVT/SSD
  - Silicon trackers: improved vertex reconstruction, displaced vertices for strange particle decays
- Forward TPC
  - $2.5 < |\eta| < 4.0$



Calorimetry

- Barrel EMC / Endcap EMC
  - $-1.0 < \eta < 2.0$
- Forward Meson Spectrometer FMS
  - $2.5 < |\eta| < 4.0$

Requirements on Forward Tracking



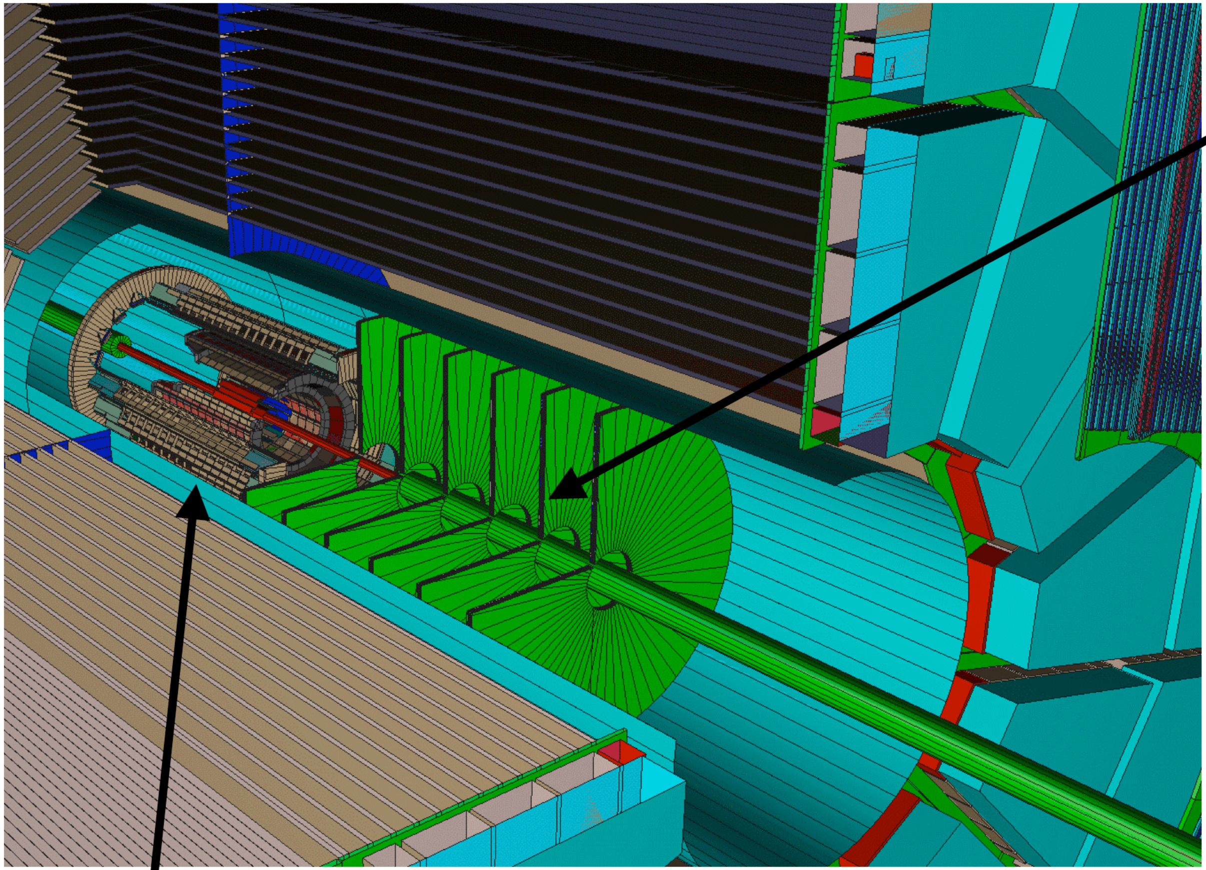
High resolution tracking needed to cover the acceptance of the Endcap EMC

Requirements:

- Spatial resolution ~ 80 µm or better
- High rate capability
- Fast detectors to reject pileup from earlier and later bunch crossings
- Low cost for large areas and low material budget

⇨ GEM Technology

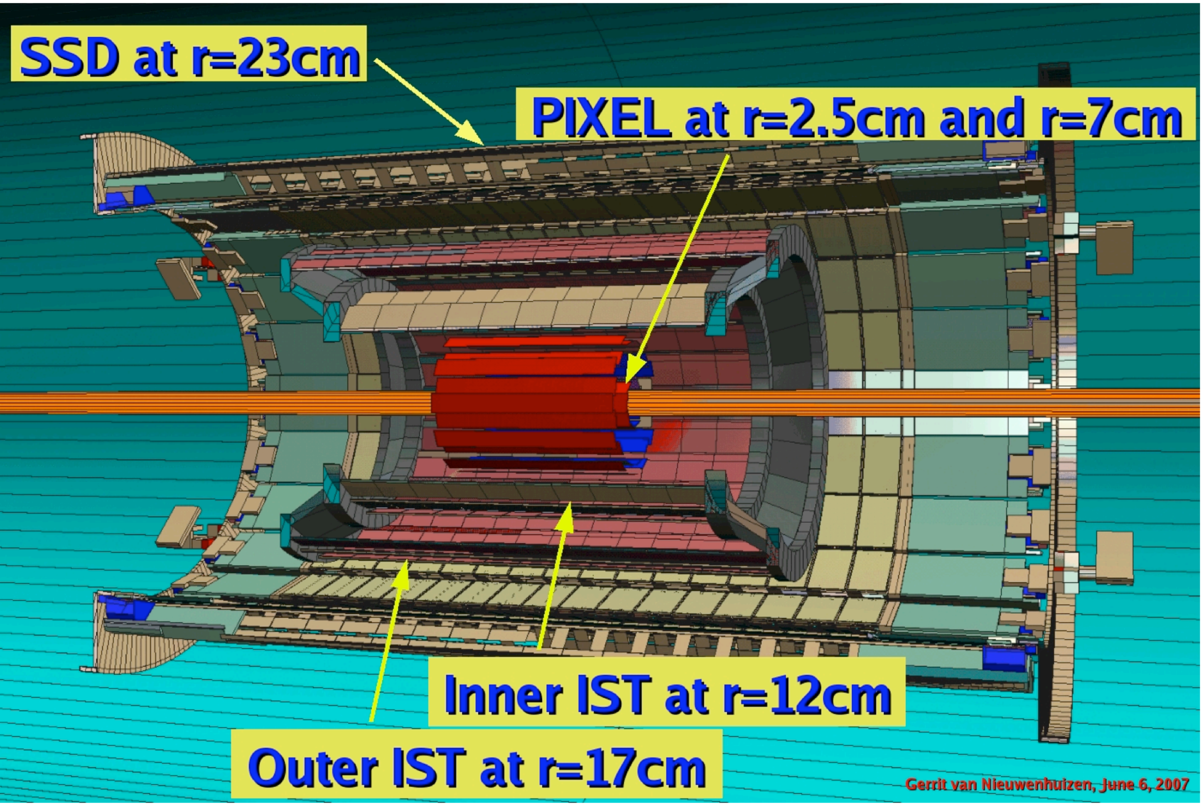
Planned Upgrades: Overview



Forward Tracking
- charge sign identification for high momentum electrons from $W^{\pm}$ decay (energy determined with endcap EMC)
- GEM technology

Inner Tracking
- precision vertexing for charm & bottom reconstruction
- Silicon pixel and strip technology

The Heavy Flavor Tracker



A new inner vertex detector:

- 30 µm active Si pixels
- total thickness of ladders (incl. cables & support): 0.28% X_0
- 100 M pixels

Intermediate pointing detector:

- 2 layers of conventional Si-strip technology
- strips in z and r-ϕ direction
- ~200 µm pointing precision to PIXEL

- existing SSD will be re-used (double sided Si-strips)

⇨ overall pointing precision to vertex ~ 40 µm

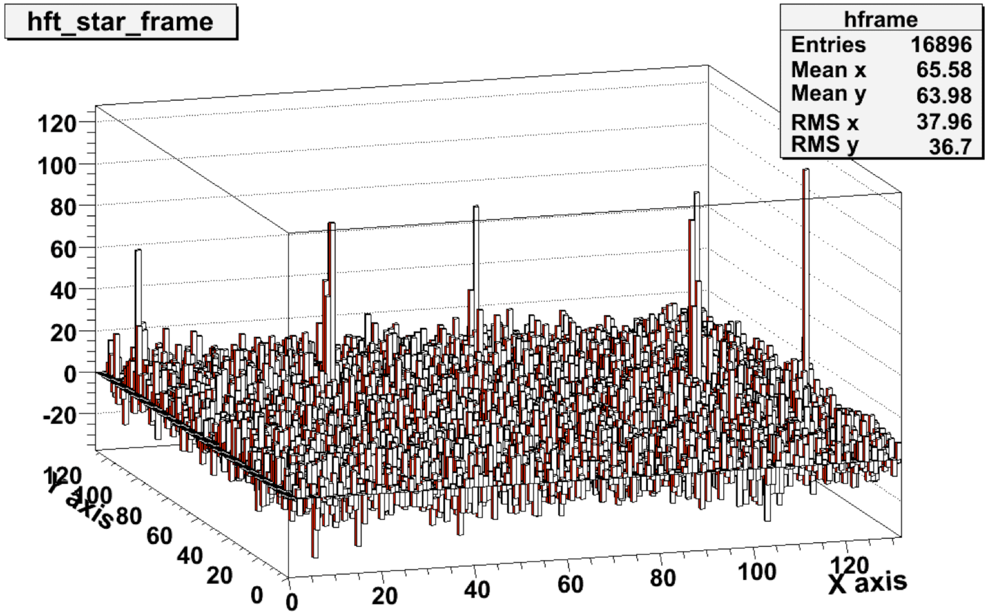
⇨ direct reconstruction of open charm

PIXEL Technology Test in STAR

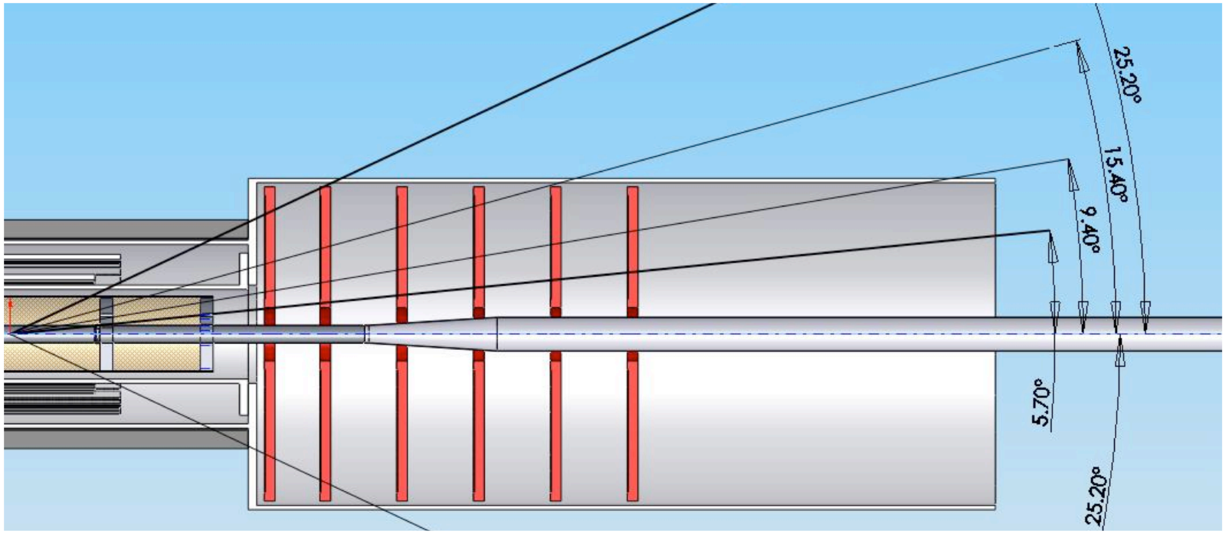
- Active Pixel Sensors developed at Strasbourg by M. Winter et al.
- A small prototype of the Active Pixels was installed in STAR for the 2007 Au+Au run
- ~ 5 cm distance from the beam, ~145 cm from IP, looking at IP

- Hits on a 4 x 4 mm wafer

⇨ **it worked!**

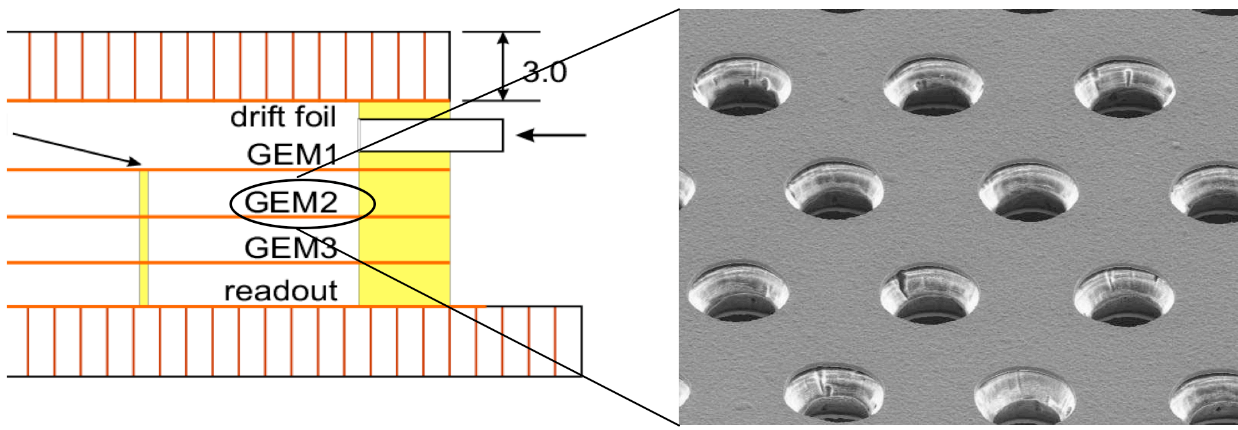


The Forward GEM Tracker

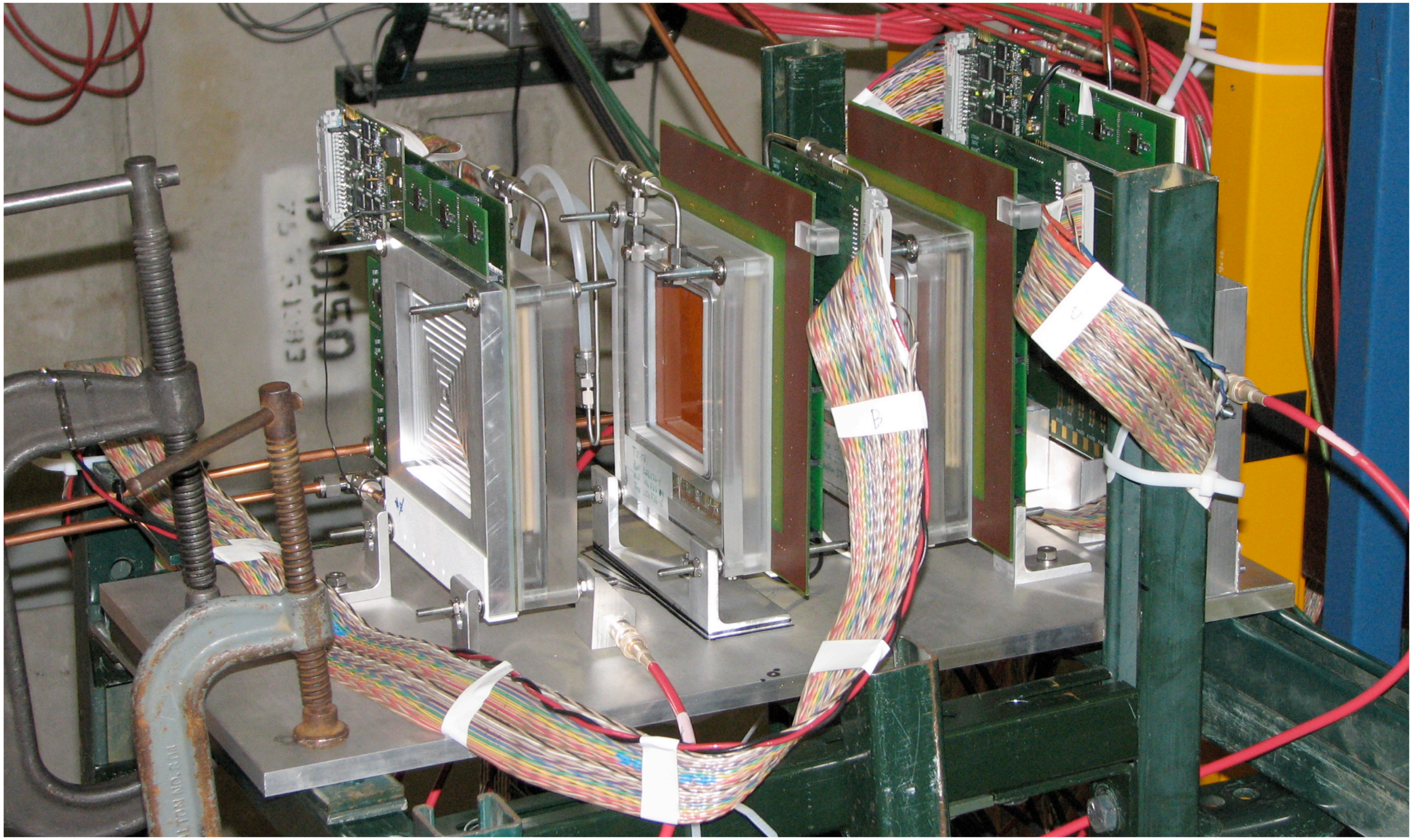


- 6 triple GEM disks, ~ 40 cm radius
- each disk consists of 4 detectors

- 3 GEM foils to reach high gain with high stability
- 2D readout board: each detector layer provides a space point

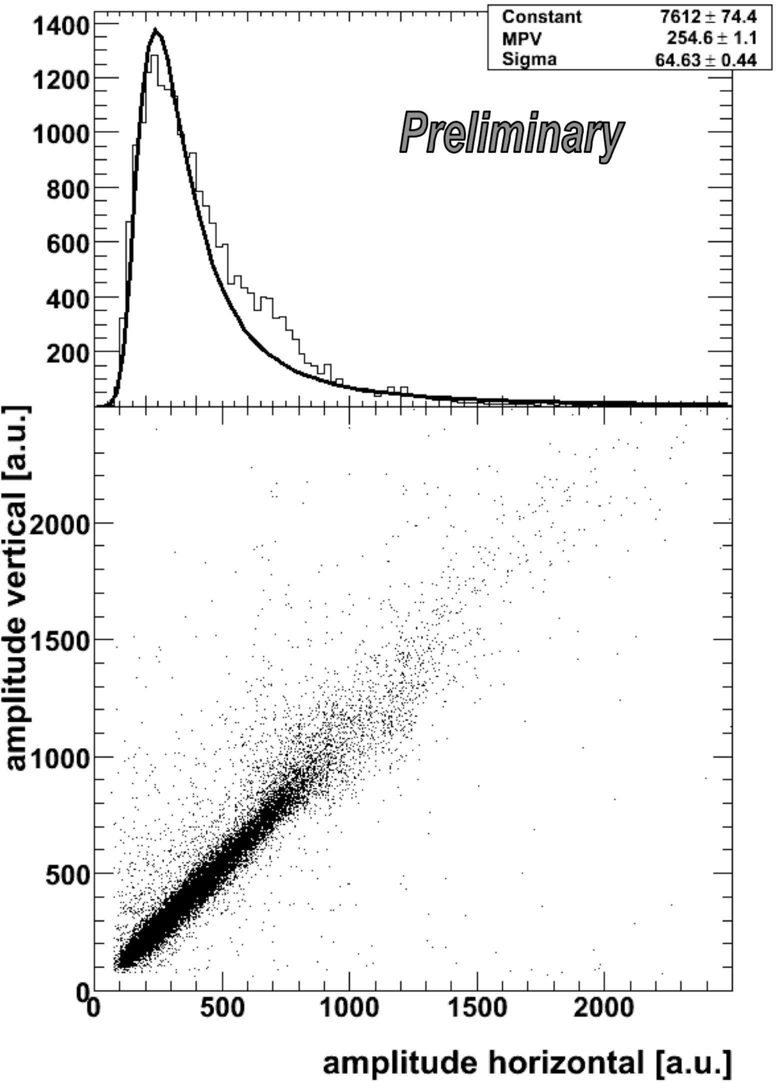


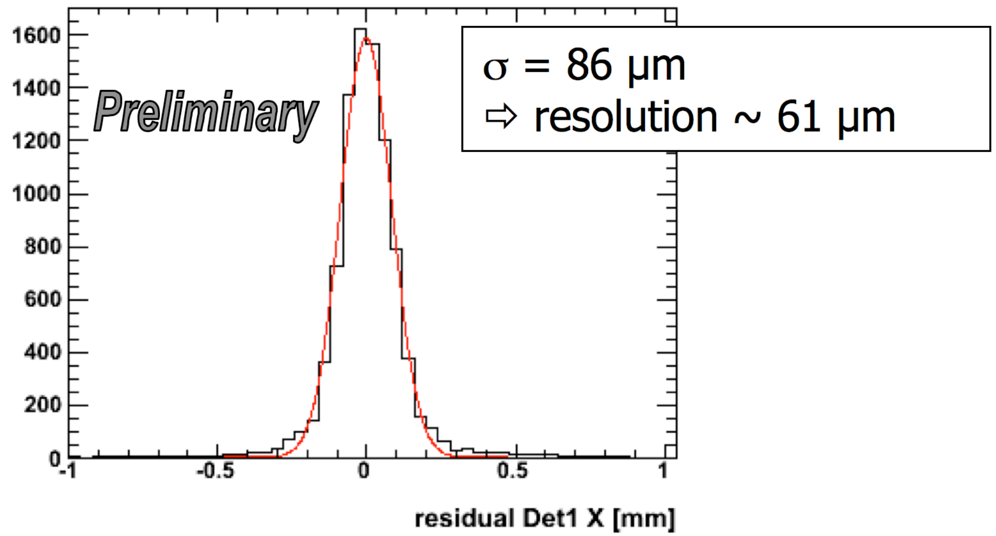
Prototype Test at FNAL



- Test triple GEMs using Tech-Etch GEM foils in beam conditions
- Detector readout with APV25S1 front-end chip

Fermilab Test: First Results





- Test detectors have 635 μm readout pitch, final design will use 400 μm, leading to better spatial resolution
- Nice charge sharing between readout coordinates of 2D readout board
- Efficiencies well above 90% reached
- Spatial resolution as good as ~ 60 μm reached

Summary & Outlook

- STAR has a rich physics program both in heavy ion collisions and in polarized p+p collisions
- Several key measurements require upgrades of the STAR tracking system
  - Investigation of heavy flavor properties in the medium created in Au+Au collisions
  - Accessing Δg via heavy quark production
  - Flavor separation of proton spin structure via forward $W^{\pm}$ production
- Plans for an integrated STAR tracker:
  - High resolution Heavy Flavor Tracker HFT (silicon pixel & strips)
    - completion projected for 2011
  - Charge-sign resolution for high-p_T electrons in the forward direction: Forward GEM Tracker FGT
    - Total Project Cost below $2M, allows accelerated construction and installation in Summer 2009