STAR Spin Related Future Upgrades

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for the STAR Collaboration

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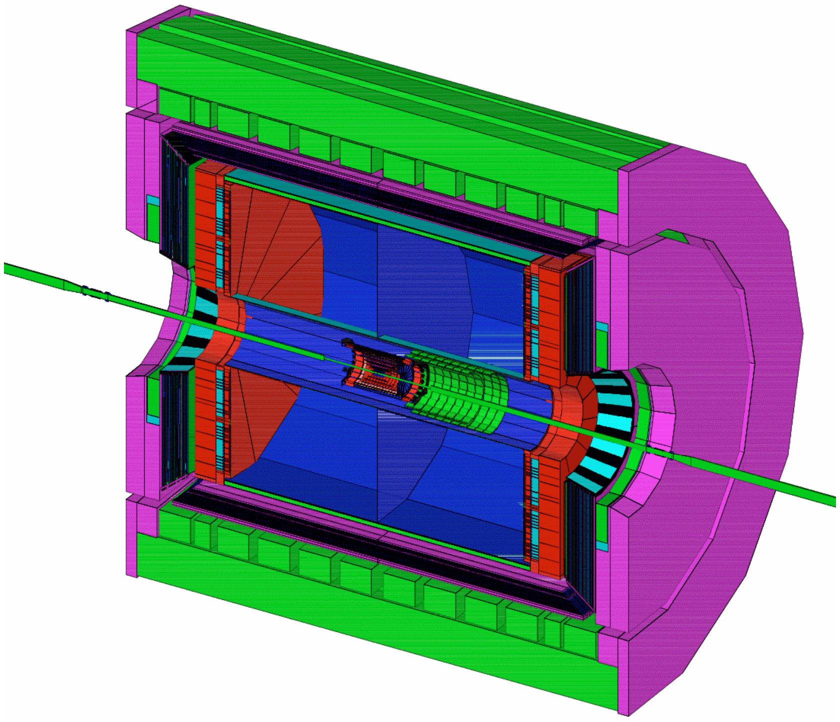
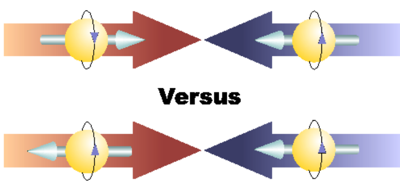
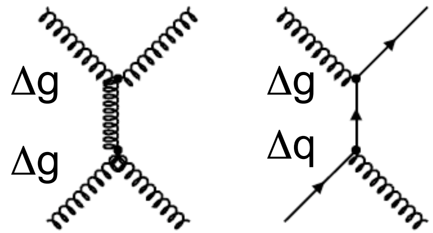
- STAR Spin Physics Program
- Current Capabilities
- Heavy Flavor Physics
- W Program
- Transverse Program
- Upgrades: Plans & Technologies
- Summary & Outlook



Introduction: STAR Spin Physics Program

- Δg via longitudinal spin asymmetry (A_{LL}) of inclusive jets, $\pi^{\pm}$, π^0





$$\vec{p}\vec{p} \rightarrow \pi^0 + X$$
$$\vec{p}\vec{p} \rightarrow \pi^{+/-} + X$$
$$\vec{p}\vec{p} \rightarrow jet + X$$

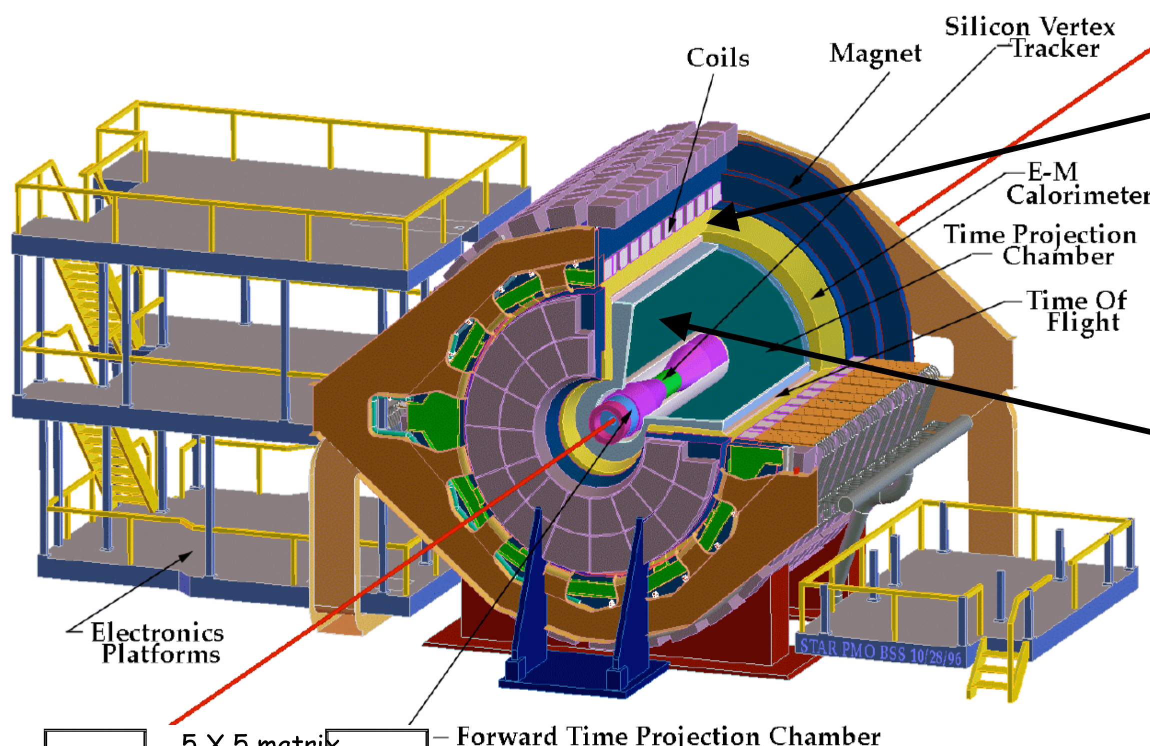
J.Kiryluk

- with higher luminosity: Δg via A_{LL} of di-Jets, γ-Jet coincidences
- transverse spin measurements: forward π^0 production — C. Gagliardi

Measurements requiring detector upgrades:

- Δg via longitudinal spin asymmetry of heavy flavor production
- flavor decomposition of the spin structure via W production in 500 GeV polarized p+p collisions
- "Jet" reconstruction in forward rapidity with transversely polarized beams, mid-rapidity - forward rapidity correlations

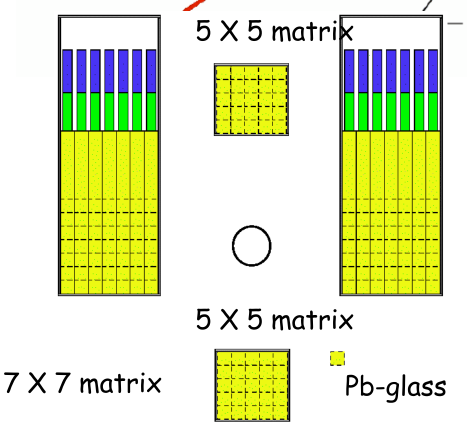
STAR Detector: Current Capabilities



EM Calorimeters:
BEMC & EEMC
$-1 < \eta < 2$
used also to trigger on high E_t events

large volume TPC:
highly efficient tracking
$-1 < \eta < 1$

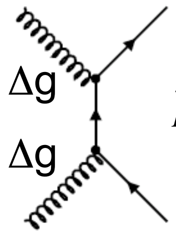
⇨ unique full jet reconstruction capability at RHIC



Forward π^0 detector: Lead-Glass calorimeters on both sides of the STAR Magnet: π^0 detection for $3 < \eta < 4$, $x_F > 0.2$

Heavy Flavor Physics

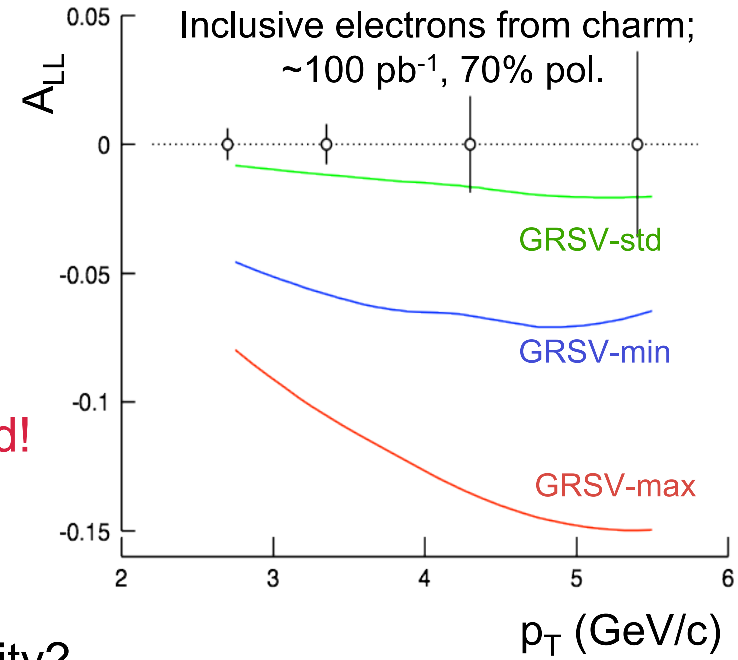
- Heavy flavor production in p+p collisions: gluon-gluon fusion



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

Advantages over jet measurements:
• one partonic subprocess dominates ⇨ contributions from quark helicities negligible

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

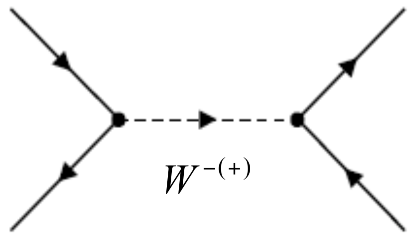
⇨ Precision vertexing needed!

- Heavy flavor in heavy-ion collisions:
  - does charm flow? ⇨ heavy quark collectivity?
  - what is the heavy quark energy loss in the medium?
  - does the J/Ψ melt?

Flavor Structure of the Proton Spin

- Flavor structure of the proton sea can be probed via $W^{\pm}$ production: flavor separation possible

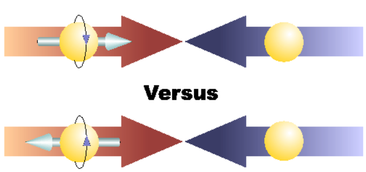
$$d + \bar{u} \rightarrow W^{-}$$
$$\bar{d} + u \rightarrow W^{+}$$



$$W^{-} \rightarrow e^{-} + \bar{\nu}_{e}$$
$$W^{+} \rightarrow e^{+} + \nu_{e}$$

experimental signature: high p_T lepton from W decay

- Study flavor-separated quark polarization via parity violating single spin asymmetries in polarized p+p collisions at 500 GeV



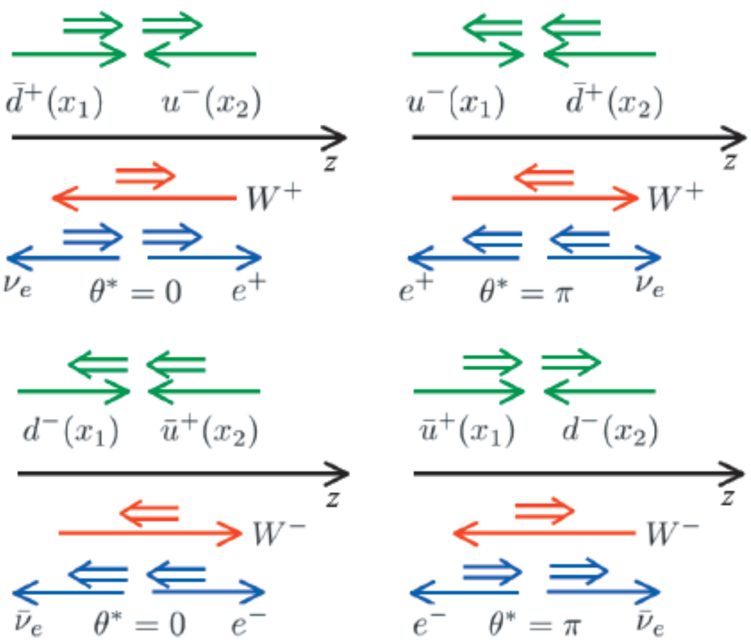
$$A_L^{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

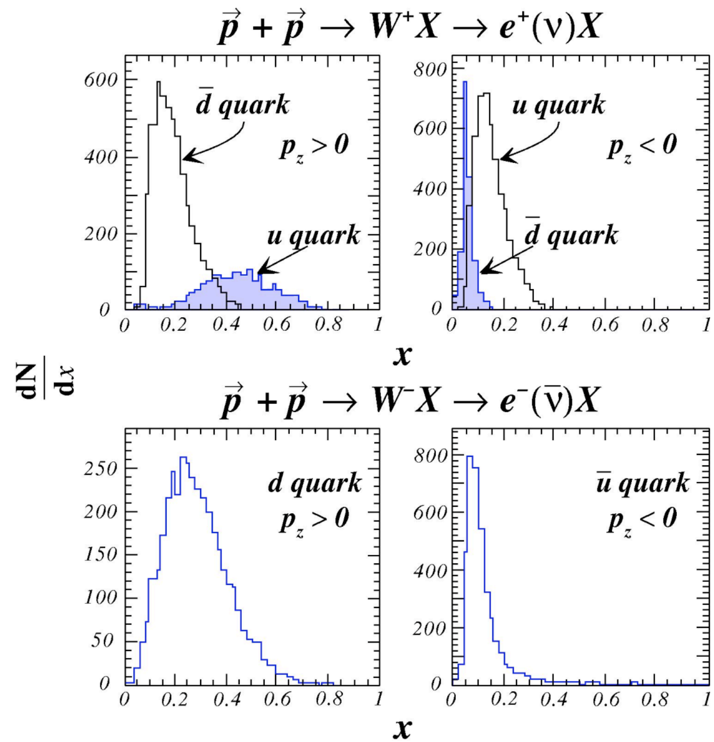
Simple ratio of PDFs in extreme kinematics:

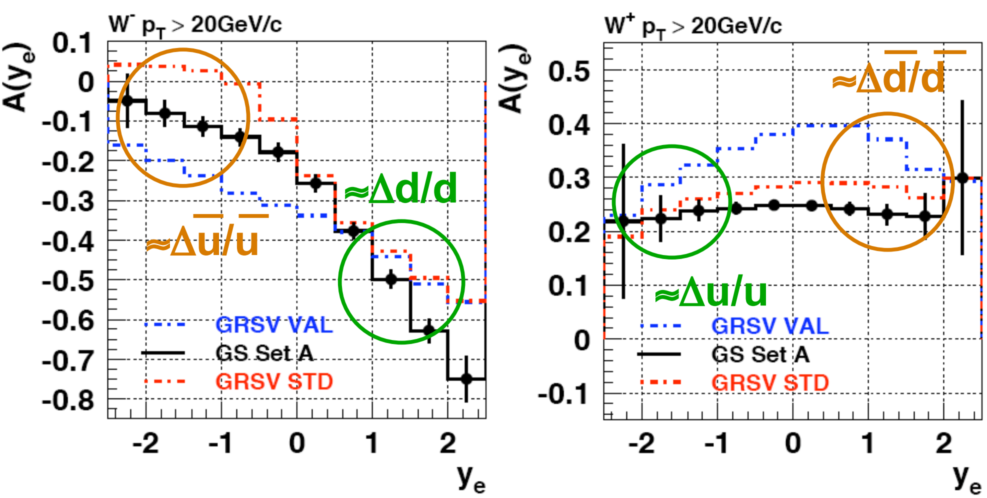
$$A_L(W^+) = \frac{\Delta u(x_1)\bar{d}(x_2) - \Delta\bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)} \Rightarrow$$

$$A_L(W^+, x_1 \gg x_2) \rightarrow \frac{\Delta u}{u}(x_1)$$
$$A_L(W^+, x_1 \ll x_2) \rightarrow -\frac{\Delta\bar{d}}{\bar{d}}(x_1)$$

W Production at RHIC





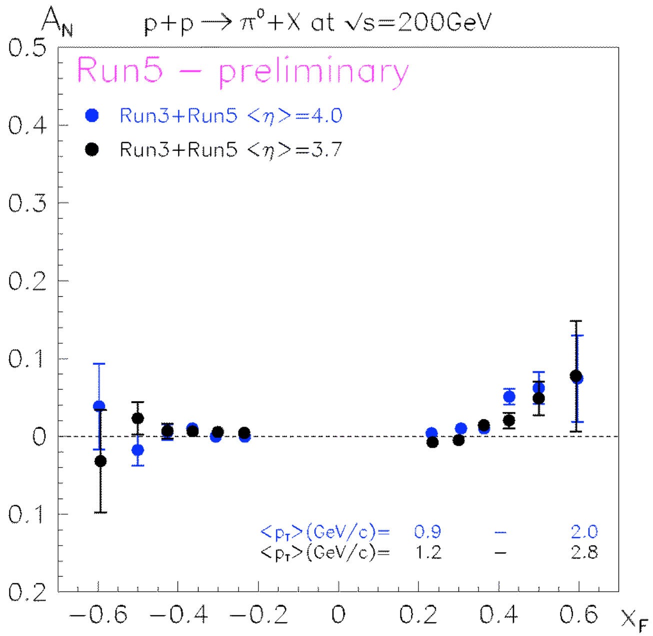


Single spin asymmetry as a function of lepton rapidity

⇨ charge sign identification of high p_T electrons at forward rapidity

Far Forward Neutral Meson Detection

- Transverse Spin Measurements



large transverse single spin asymmetries observed at forward rapidity

- Sivers: intrinsic transverse component, k_T, in initial state (orbital momentum) (before scattering)
- Collins: intrinsic transverse component, k_T, in final state (transversity) (after scattering)

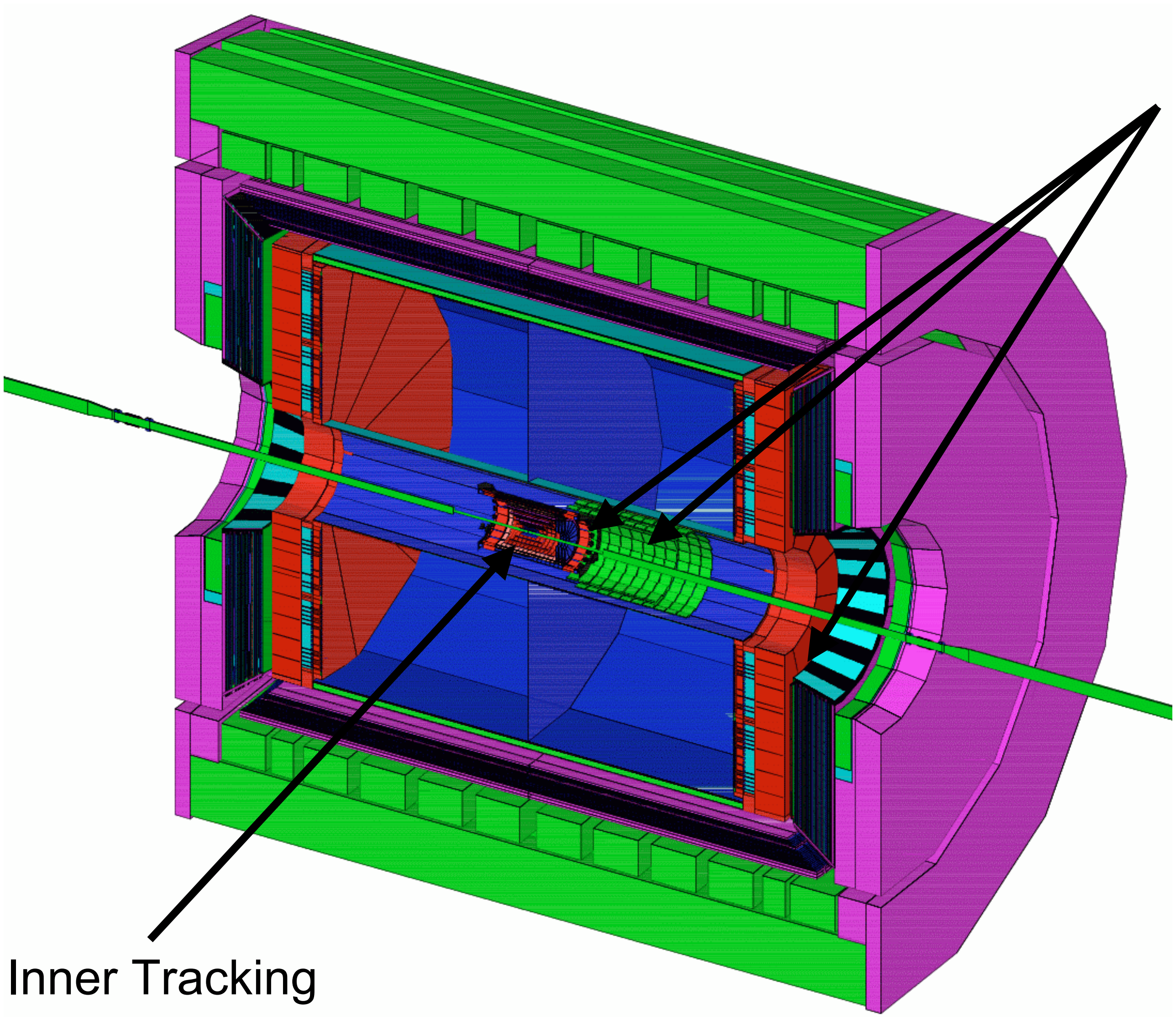
Distinguish via jet axis reconstruction: Sivers leads to asymmetry in jet production, Collins to asymmetry around thrust axis

⇨ large acceptance at forward rapidity to reconstruct jet axis

- Heavy-Ion, especially d+Au:
  - Measure the gluon density distribution in Au nucleus for $0.001 < x < 0.1$

  ⇨ is there a saturation (shadowing) of the gluon density at small x?

Planned Upgrades: Overview



Forward Tracking

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

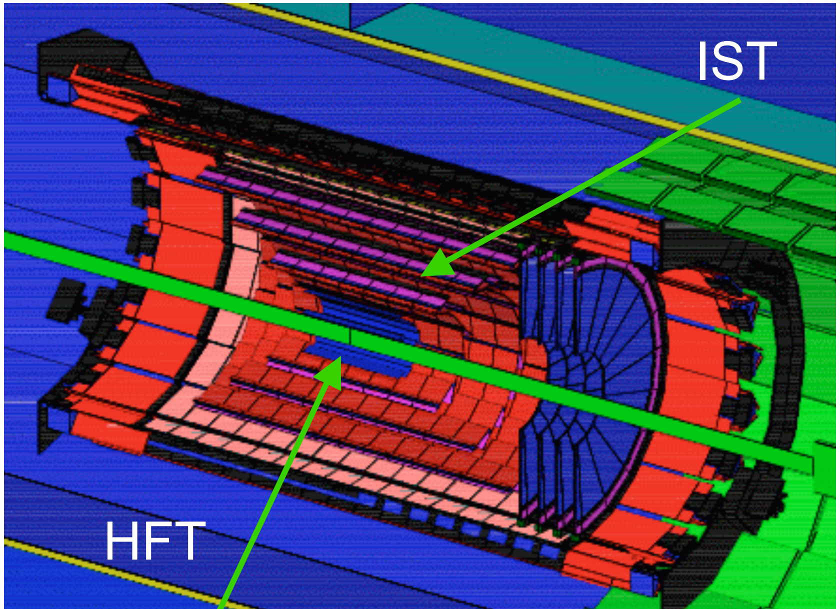
Forward Meson Spectrometer FMS

- large acceptance forward calorimeter, reconstruction of jet-like structures

Inner Tracking

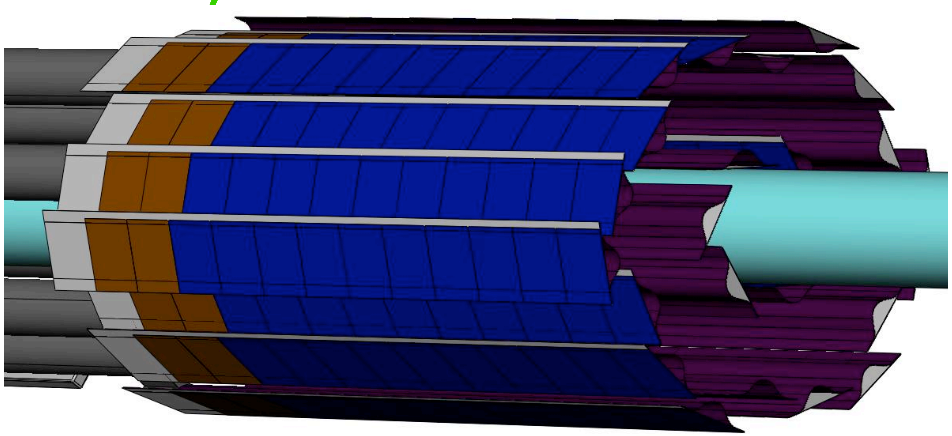
- precision vertexing for charm & bottom reconstruction

Heavy Flavor & Inner Tracking



Intermediate Silicon Tracker:

- 3 layers of 2x single sided Si (1 strip, 1 pad), 7, 12 & 17 cm radius
- fast tracker to resolve individual bunch crossings
- pointing accuracy to HFT < 150 μm
- replaces current SVT, and should not exceed its material budget of ~ 4.5% X_0
- Existing SSD will be used



Heavy Flavor Tracker:

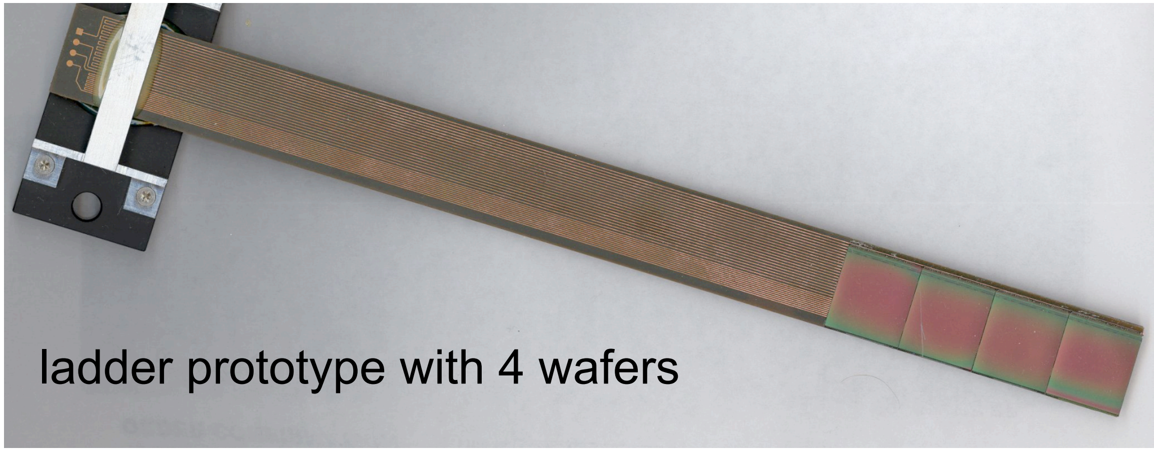
- 2 layers of Si-Pixel, 1.5 & 4.5 cm radius
- very low material budget: X_0 ~ 0.3% per ladder
- spatial resolution < 10 μm

Inner Tracker Technology Choices

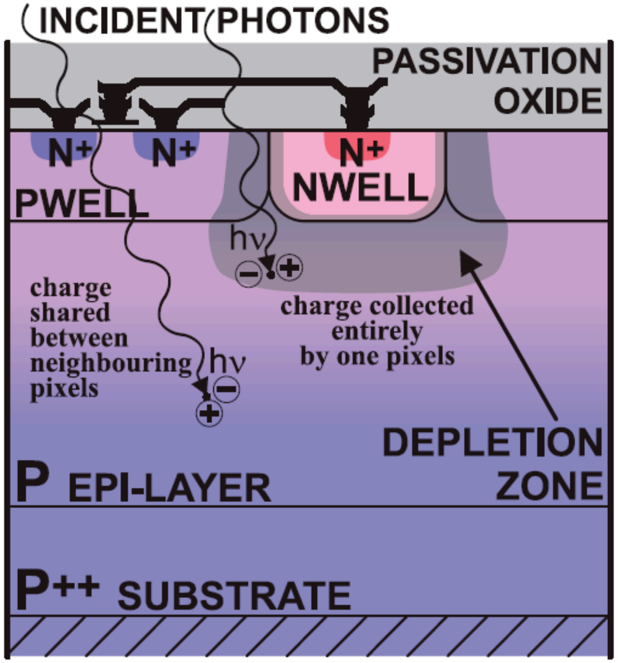
Heavy Flavor Tracker

- Active Pixel Sensor Technology

  silicon thinned to 50 μm



ladder prototype with 4 wafers

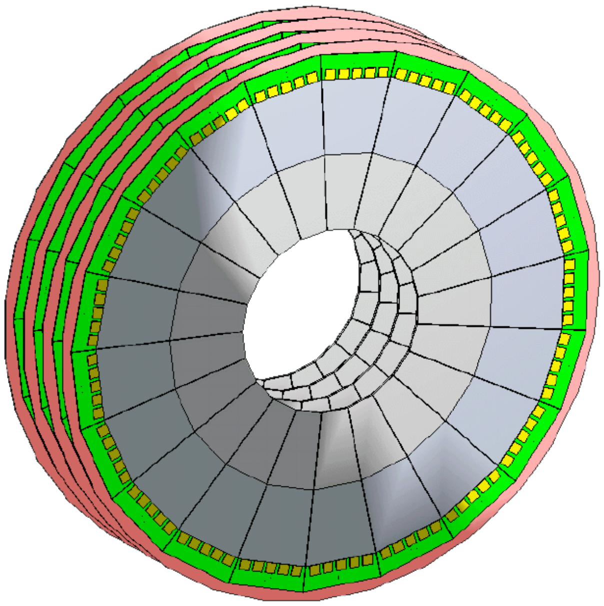


Intermediate Silicon Tracker

- Back-to-back single sided Si-Strip/Pad detectors
- Fast Readout based on APV25S1 front-end chip (developed by CMS)

⇨ Inner tracker a combination of new (APS) and proven (Si-strip, APV25) technology to achieve desired performance and reliability

Forward Tracking

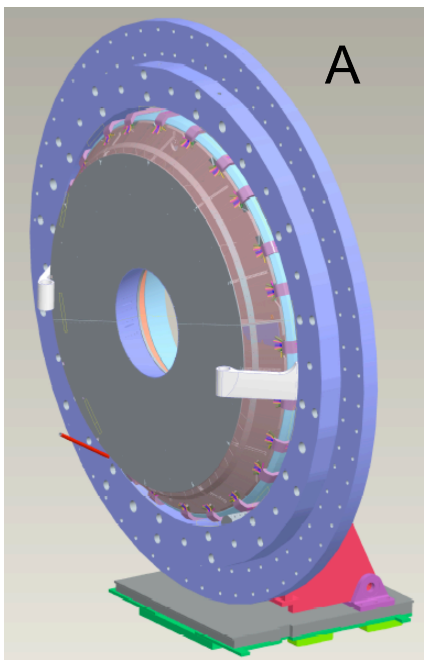


2 separate detectors:

Forward Silicon Tracker (FST):

• forward tracking close to the primary vertex, $1 < \eta < 2$

• 4 silicon disks, consisting of back-to-back strip sensors (same technology as IST)



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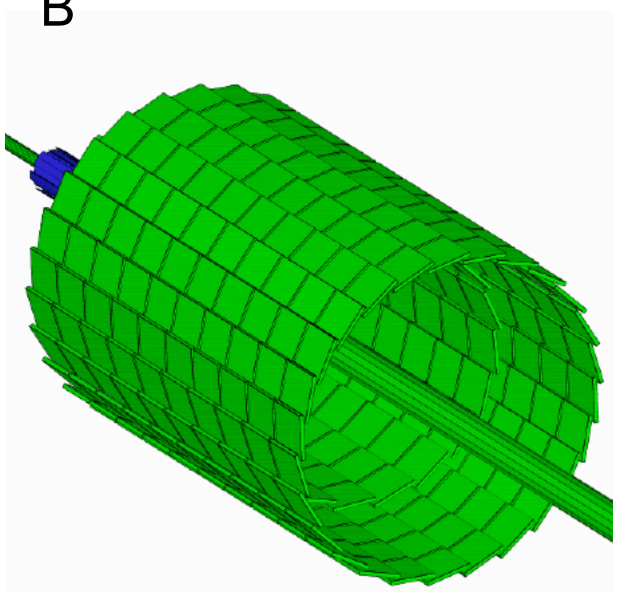


Forward GEM Tracker (FGT)

• large lever arm, tracking $1 < \eta < 2$

2 Options (resolution < 100 μm)

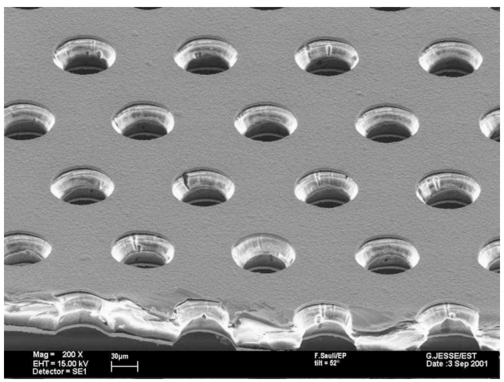
• A) large area tracker in front of EEMC, problem: TPC electronics

• B) GEM barrel (or disks)

Forward Tracking Technology

GEM technology a natural choice for large area forward trackers

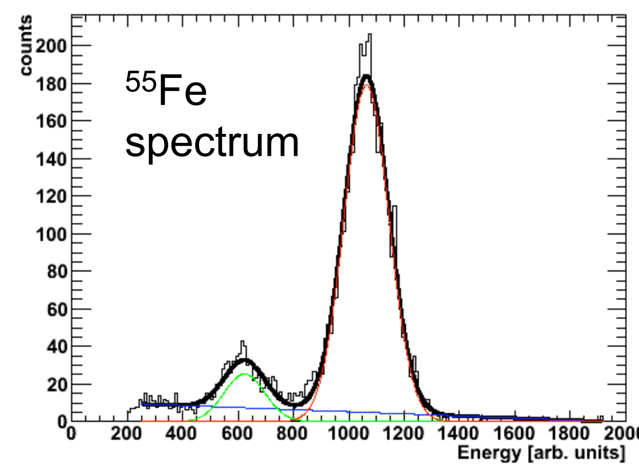
- Triple GEM trackers ~ 70 μm spatial resolution in high occupancy environment
- significantly cheaper than silicon per area
- fast detectors, low material budget ~ 0.7% X_0 per detector (2D readout)
- APV25 chip can be used (as for the IST and FST)



GEM: copper-clad insulator foil with a large number of small (~70 μm diameter) holes, voltage across the foil leads to charge amplification in the holes

Cooperation with company TechEtch to establish a commercial source of GEM foils

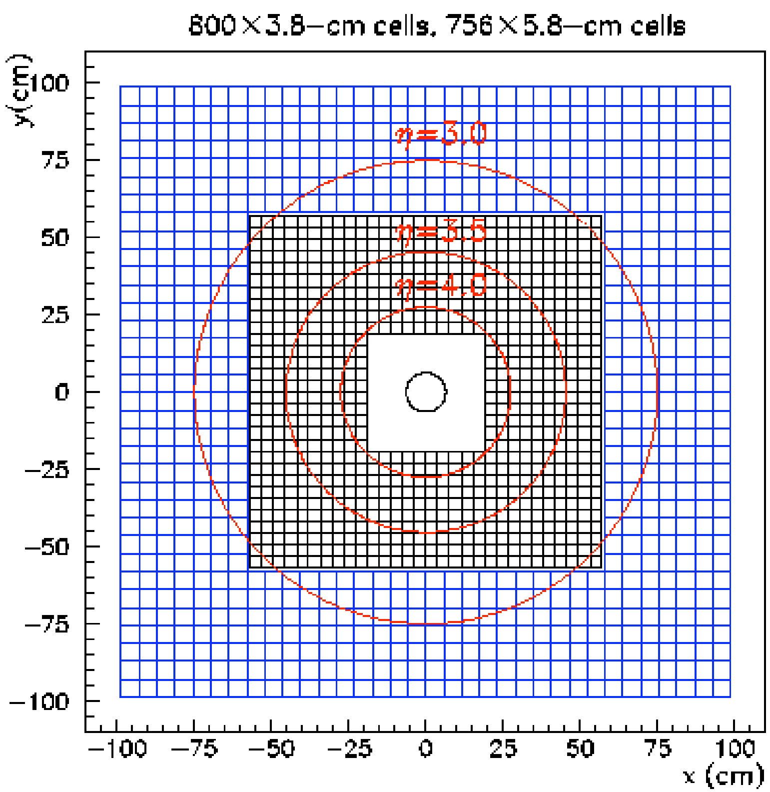
⇨ First promising results with test detector



Forward Meson Spectrometer

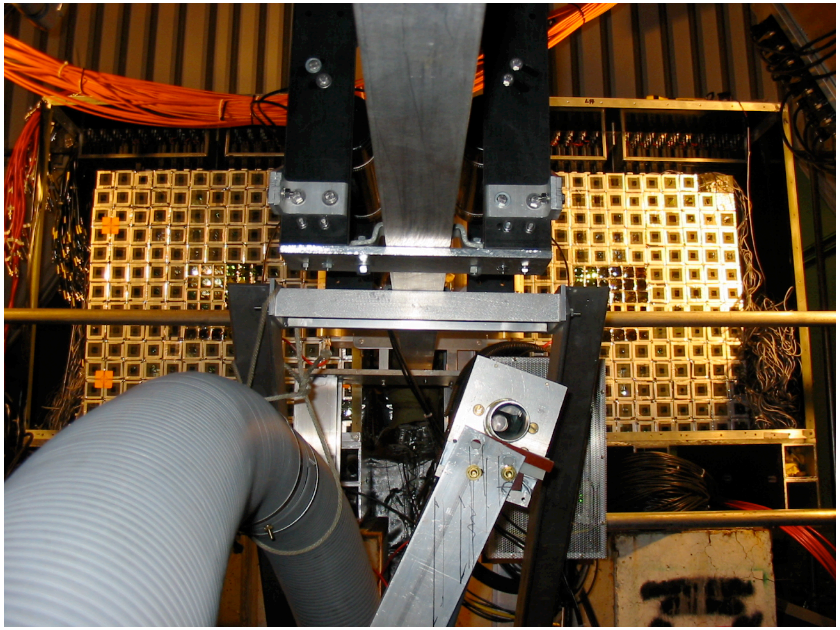
High resolution forward electromagnetic calorimeter

- full azimuthal coverage for π^0 and photons in the range of $2.5 < \eta < 4$
- use existing lead-glass calorimeter cells



FPD++: first part of the upgrade already installed and being commissioned:

⇨ first glimpse at FMS physics with this year's transverse p+p running



Summary & Outlook

- Rich spin physics program with polarized p+p collisions at 200 GeV and 500 GeV
- Several key measurements require upgrades of the STAR detector
  - accessing Δg via heavy quark production
  - flavor separation of proton spin structure via forward $W^{\pm}$ production
  - transverse spin physics with large acceptance in forward rapidity
- Upgrade requirements:
  - High resolution inner tracker: HFT and IST (silicon pixel & strips) 2009
  - Charge-sign resolution for high-p_T electrons in the forward direction: FST and FGT (silicon strips & GEM) 2011
  - Large acceptance forward calorimeter: FMS 2007

first results with upgraded FPD expected from current run!