Spin Physics at STAR

Not a lot of technical detail. This is a school, not a seminar!
Interested parties refer to: NIM A499 (2003)

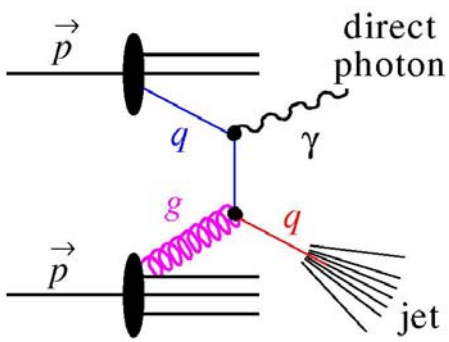
- What are we trying to learn (most critical items)?
- What physical processes do we need to study?
- What information must a suitable detector provide?
- What of the above can STAR do well?

Primary goal of RHIC spin physics program: to study in detail the spin structure of the nucleon.

- *map out the pol. gluon distribution function $\Delta g(x)$*
- *decompose $\Delta\Sigma(x)$ into its $q/\bar{q}$ and flavor components*

Note: experiments are sensitive to Δg at a particular value (or over some range) in x_{Bj} – to estimate integral ΔG, must obtain precise measurements over the *broadest reach in x.*

Basic technique: use polarized quarks as *probes* or *analyzers* of the spins of other, less well understood partons



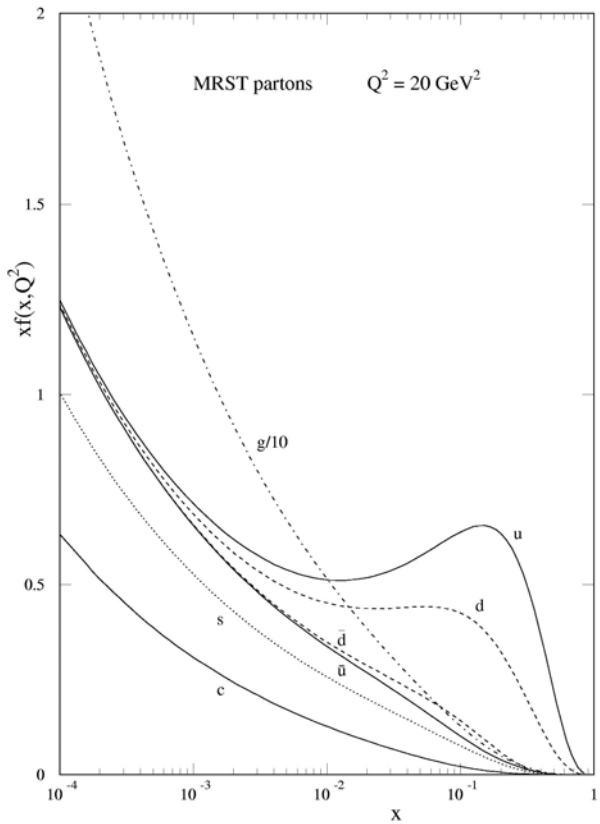
Quark - Gluon Compton Scattering

- ✓ Use γ as ~ unique signature of *qg* interaction
- ✓ Exploit large a_{LL} at *partonic* level (pQCD)
- ✓ Polarization of valence quarks large and well measured at xq ~ 0.2-0.4

Important asymmetries in both the roles *played by the two interacting partons, and in their values of* x*!*

Key point: to study either $\Delta g(x)$ *and* $\Delta\bar{q}(x)$, must use large-*x* quarks (because that's where they're polarized) interacting with low-*x* gluons or sea quarks (because that's where most of them live!).

→*To do this physics, <u>most</u> <u>useful</u> collisions will be highly asymmetric in the partonic c.m.*



Simplest experiment: put pol. protons on a table and shoot beam of pol. quarks at them!

Unfortunately, must surround our *q* beam with the rest of the proton. At high energies, not a problem (mostly non-interacting) … but we lost all information on x_q (and therefore on polarization of *q*)

Problem: how can we regain knowledge of x_q with a proton beam?

Homework: For 2 → 2 scattering of massless, collinear objects, show that

$$x_2 / x_1 = e^{-(\eta_3 + \eta_4)}$$

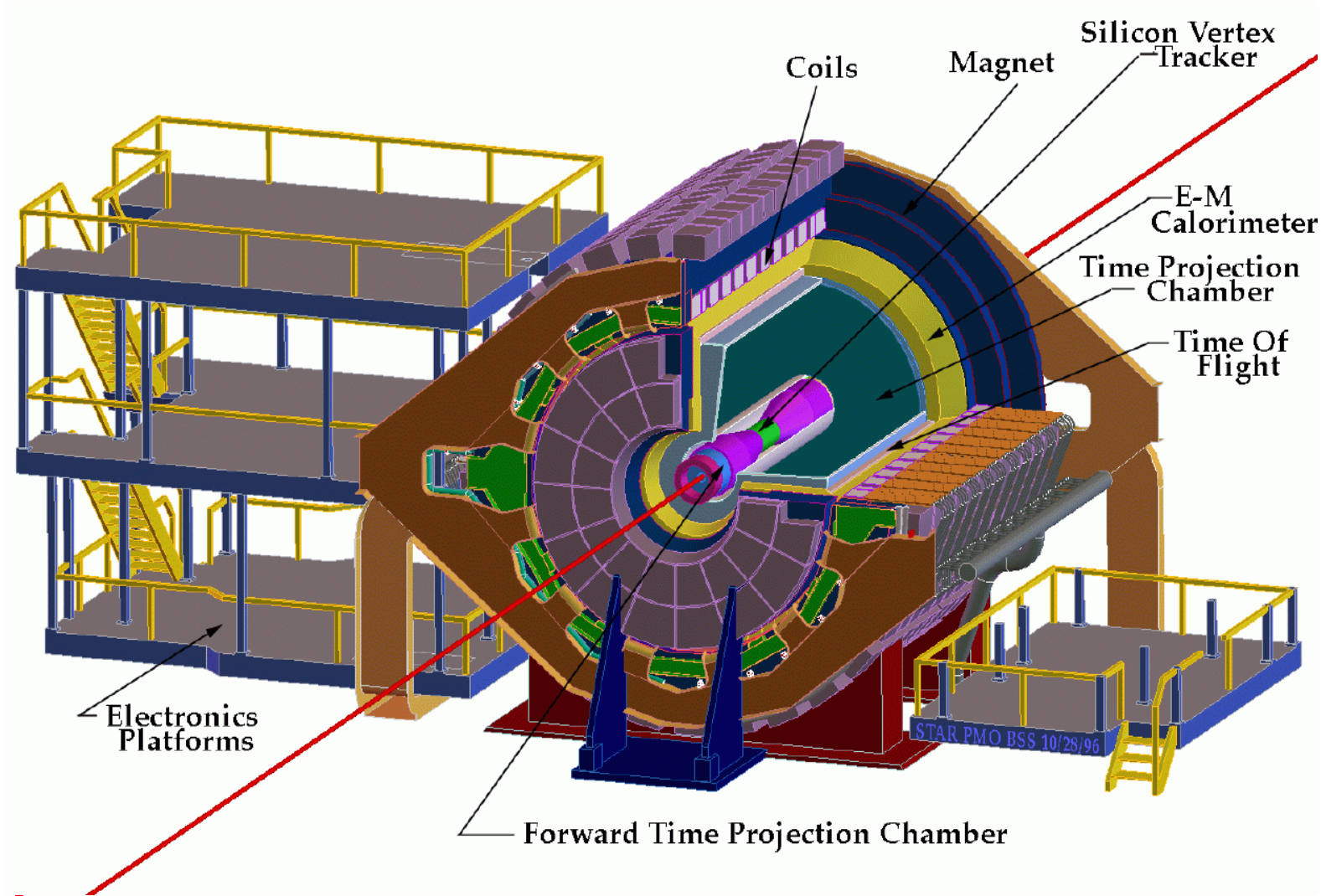
So: how should we design a real experiment?

- want to keep x_q large (~0.2-0.4) → lots of quarks, highly polarized (pDIS)
- want to vary x_{gluon} over as large a range as possible, esp. extending reach to low x → potentially sizable contributions to the integral ΔG

  e.g., for $x_g = 0.01$, $x_q = 0.2$, need $\eta_3 + \eta_4 = 3$
- would like to also detect the "away-side" jet in, *e.g.*, $p + p \rightarrow \gamma +$ jet
  → knowledge of jet thrust axis sufficient to determine above ratio
- need to measure E (or p) for only one of the final-state partons
  → provides sufficient information to convert $x_i \rightarrow p_i$

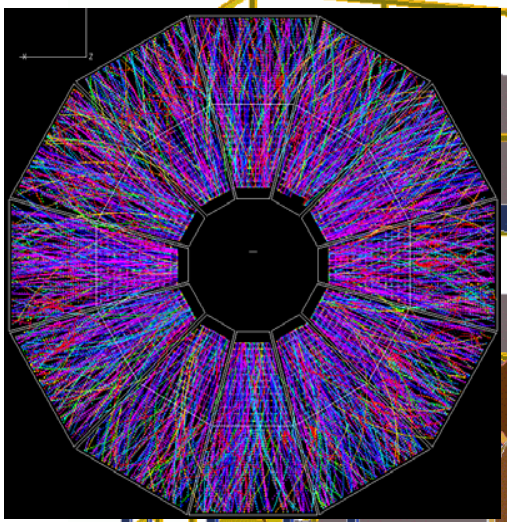
Bottom line: to probe the spins of low-*x* partons most precisely, would like to detect *both* outgoing particles/jets → requires good tracking (for charged particles) and good e.m. calorimetry (for γ's and $e^{\pm}$) over large range in pseudorapidity η

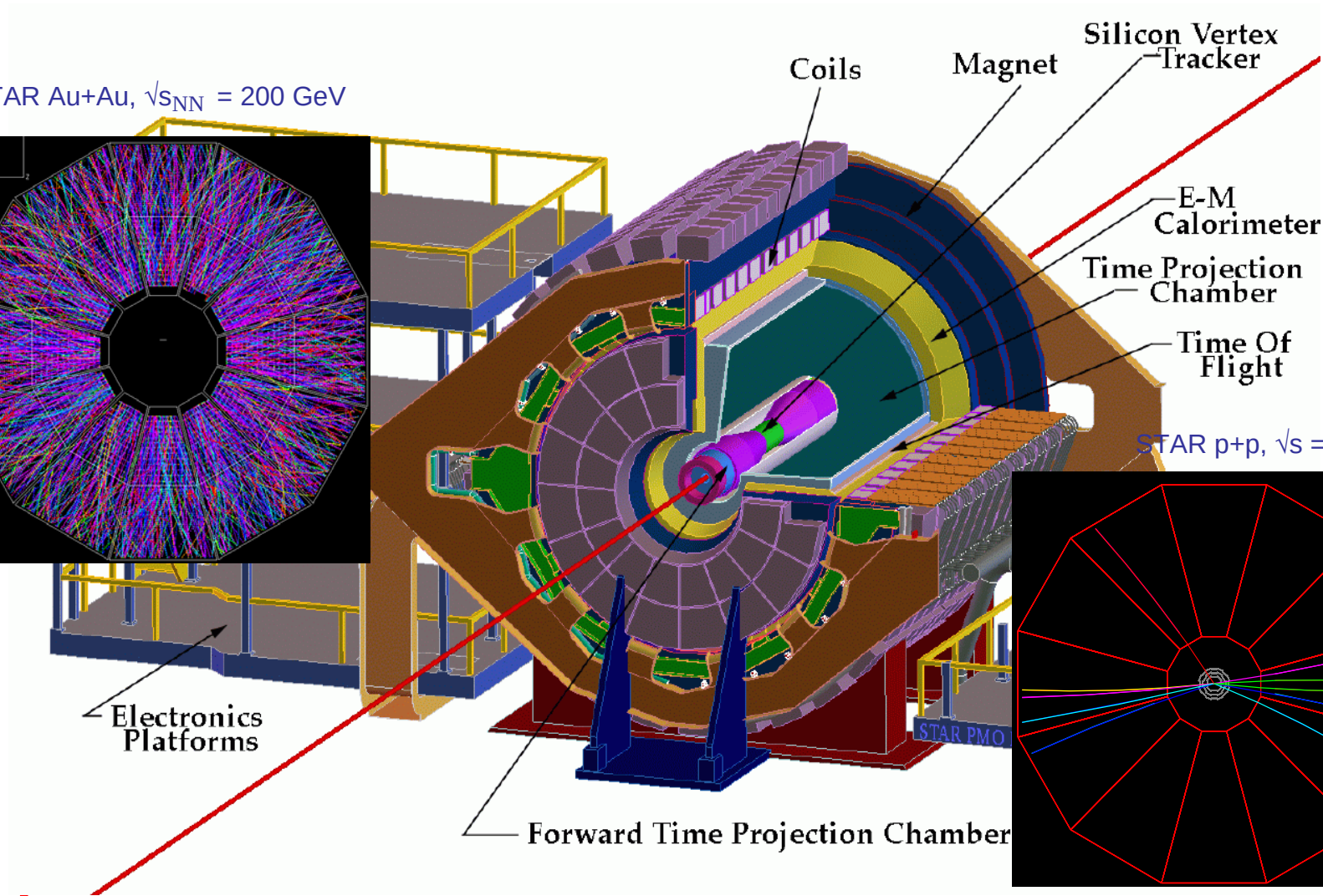
STAR: A First Look



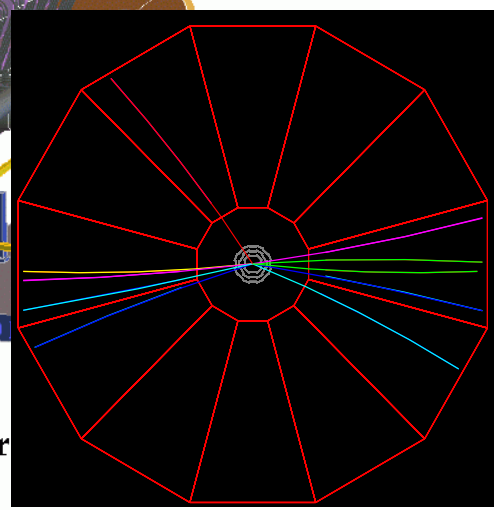
STAR: A First Look

STAR Au+Au, $\sqrt{s_{NN}}$ = 200 GeV

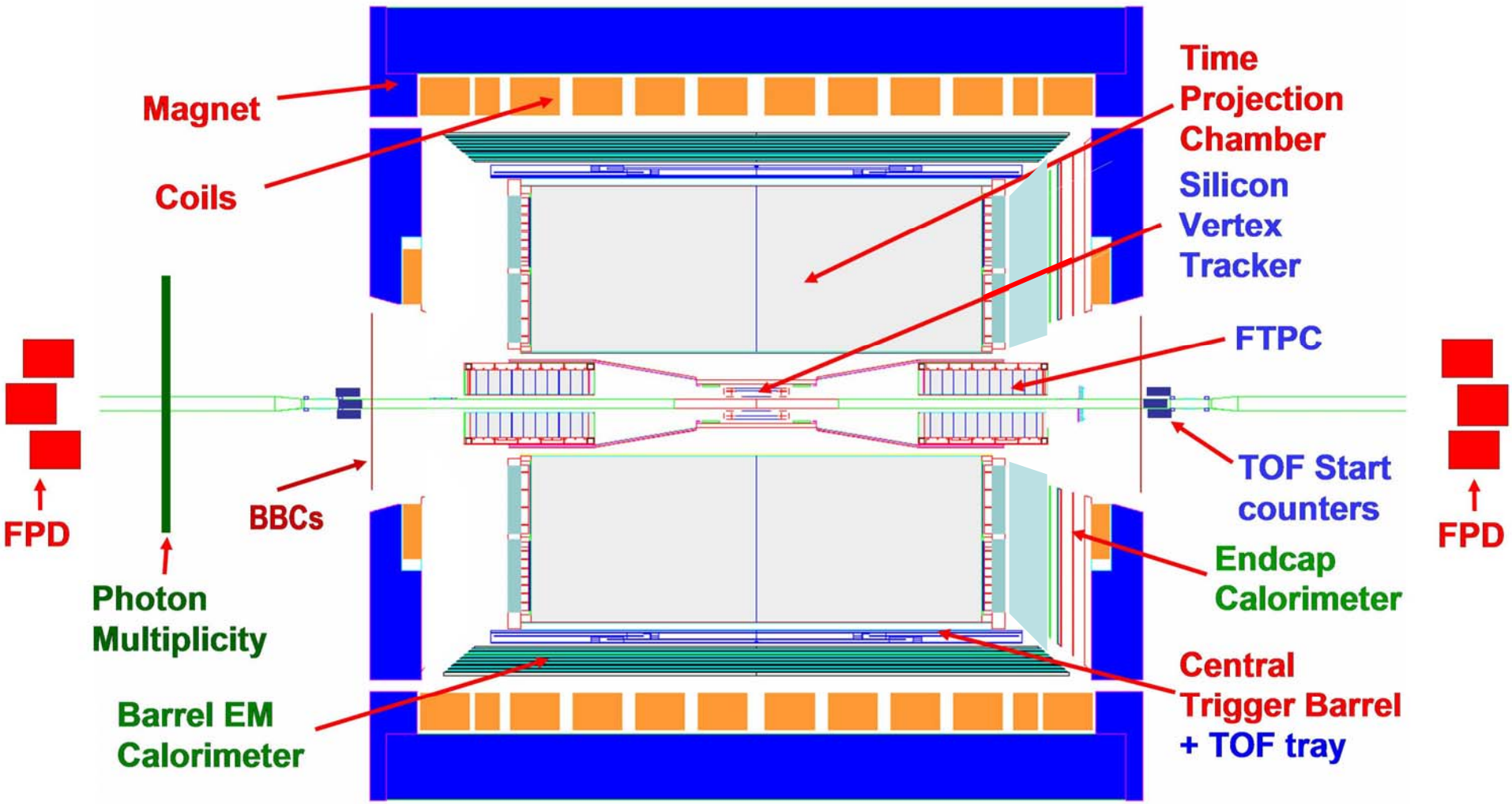




STAR p+p, $\sqrt{s}$ = 200 GeV



Schematic layout of STAR (2004 run)



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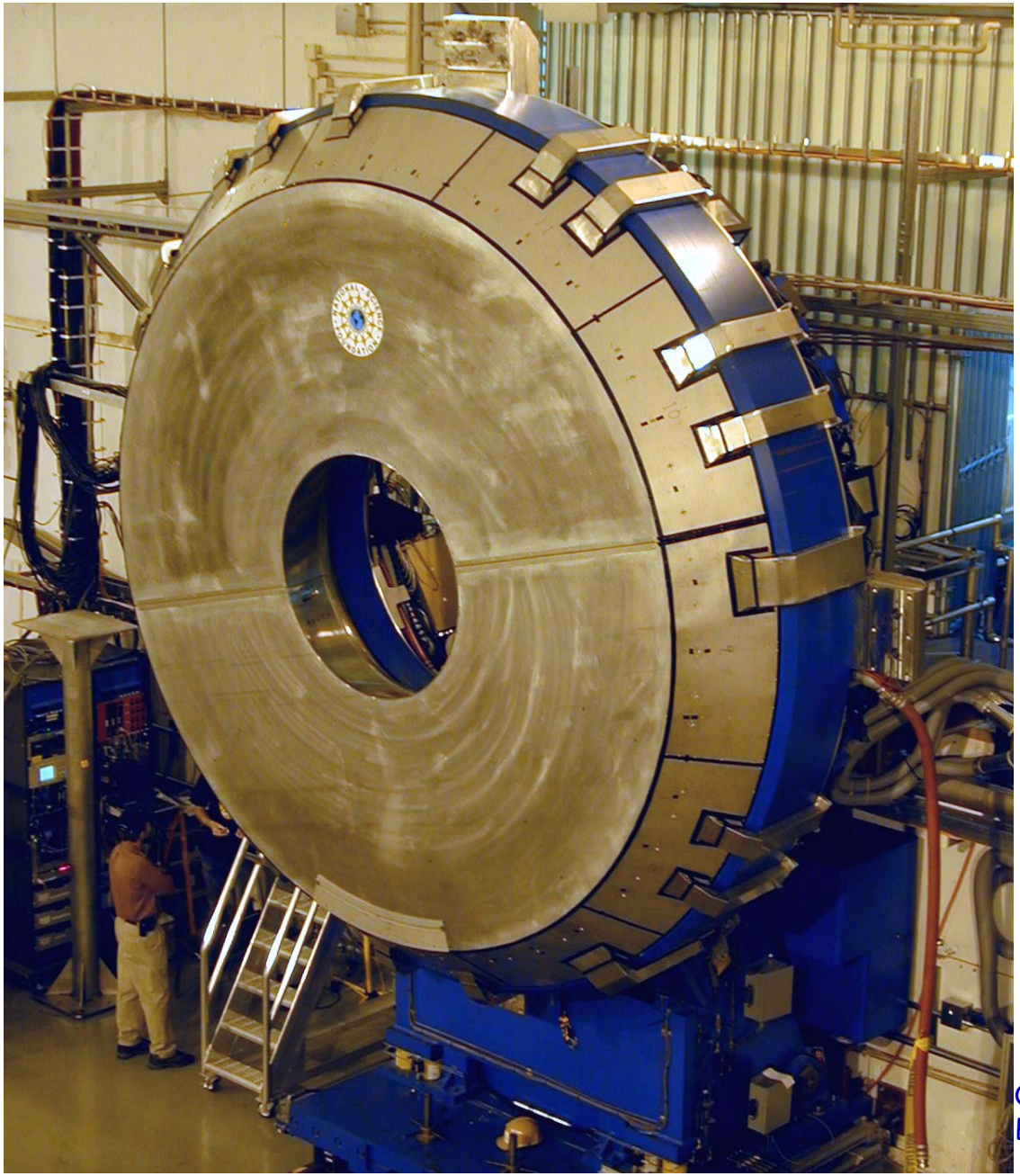
STAR Endcap EMC ⇒ Accepts Asymmetric Parton Collisions

October 20, 2003

All closed up!



Responsible institutions:
Indiana U., ANL, JINR Dubna, Texas A&M U., Kent State U., BNL, Valparaiso U.

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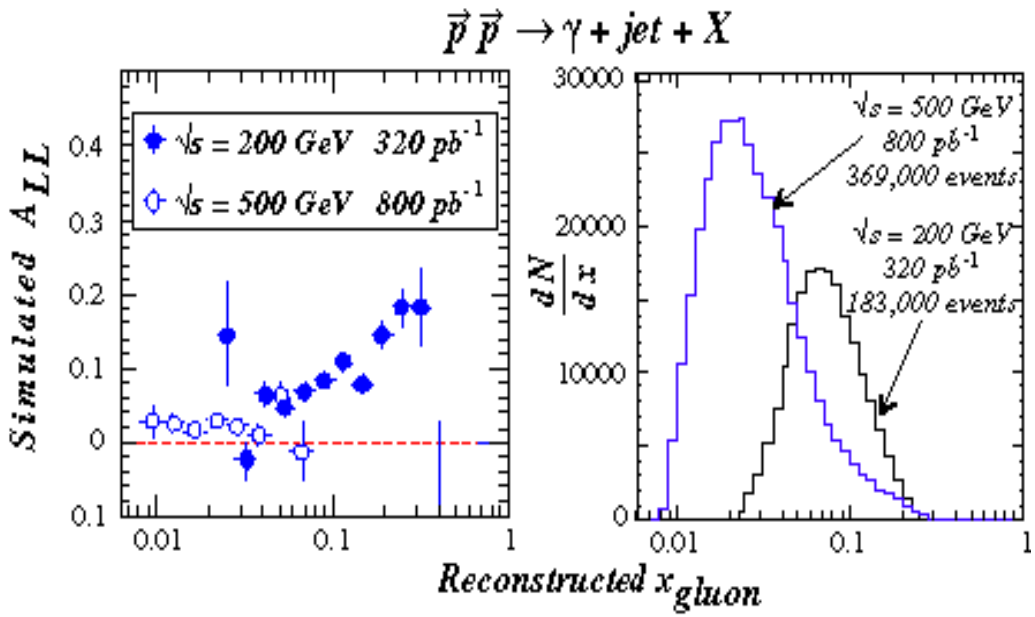
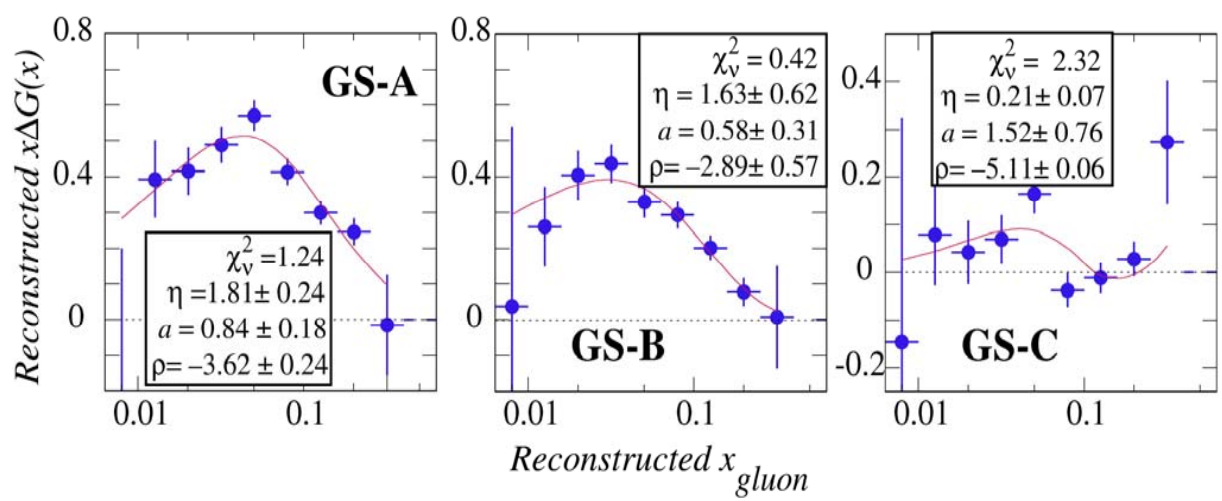
How well can we do?



- ***Detect γ-jet coincidences in polarized proton collisions at $\sqrt{s}$ = 200 and 500 GeV***
- ***Measure two-spin asymmetry in production rates between equal vs. opposite helicities, as function of η(jet), $\eta(\gamma)$, $p_T(\gamma)$***
- ***Assuming 2-body parton kinematics, can infer initial x values of gluon and quark***

- ***Next-Leading-Order (NLO) pQCD analyses of data, with DIS database, can extract $\Delta g(x)$ for Q^2 ~ 100 GeV^2***
- ***LO pQCD analysis of simulations at right ⇒***



GS-A,B,C models of $x\Delta G(x)$ from Gehrmann and Stirling, PR **D53**, 6100 (1996).

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