Future Avenues to Access Transversity

Polarized proton beams in RHIC

$\Rightarrow$ ***longitudinal polarization*** $\rightarrow$ { measure ΔG via $\vec{p} + \vec{p} \rightarrow \gamma$ + jet + X.
measure Δq_{val} and $\Delta \bar{q}_{sea}$ via $\vec{p} + p \rightarrow W^{\pm}$ + X
and $\vec{p} + \vec{p} \rightarrow l^{+}l^{-}$ + X.

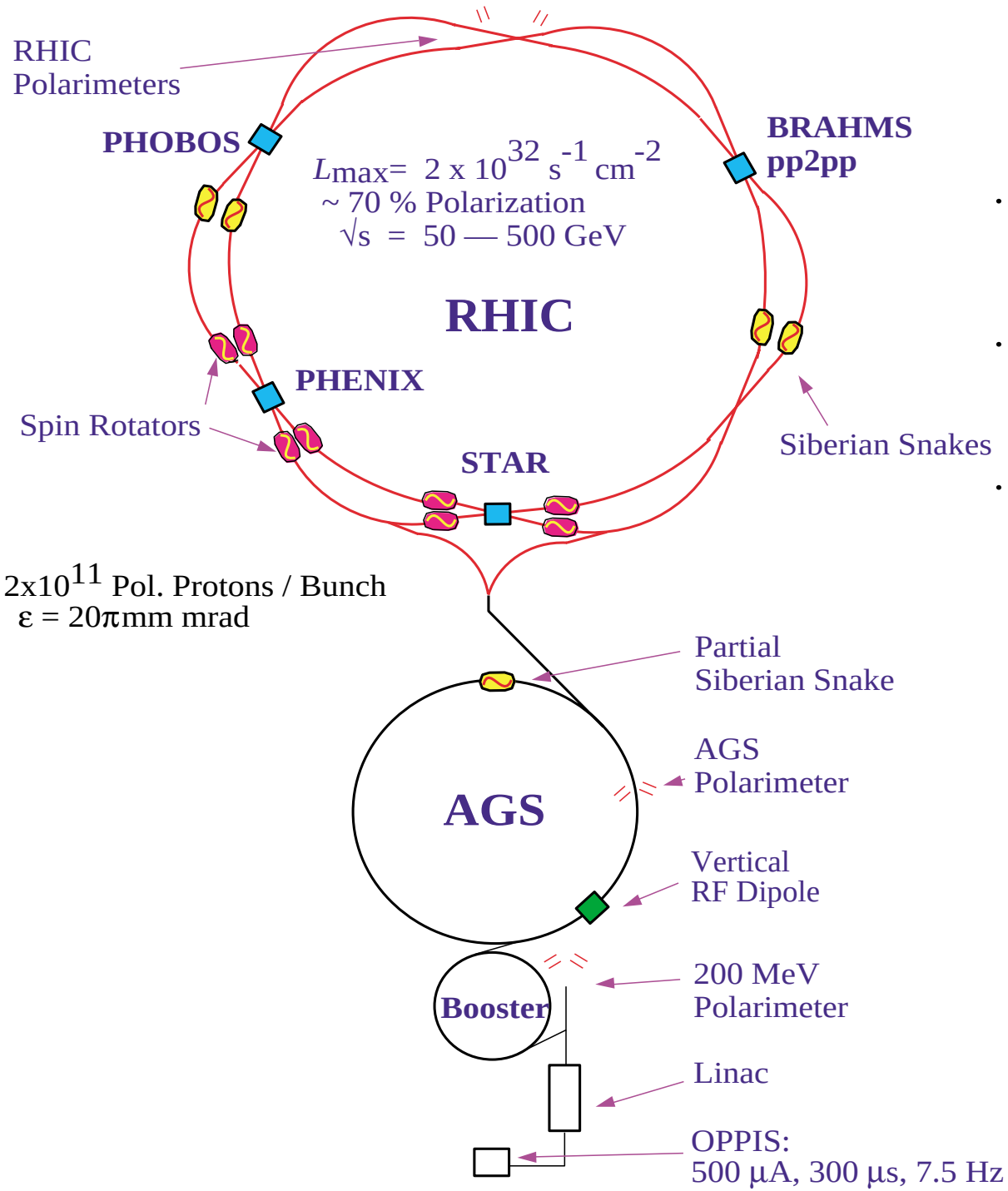
$\Rightarrow$ ***transverse polarization*** $\rightarrow$ measurements of transversity (δq)?

OUTLINE

- A description of RHIC and the FY2001-2002 run.
- Experimental motivation to measure transverse single spin asymmetries
  $\Rightarrow$ understanding spin asymmetry systematic errors in a collider.
- Beyond the upcoming run.
- Outlook

L.C. Bland
BNL

Polarized Proton Collisions at RHIC

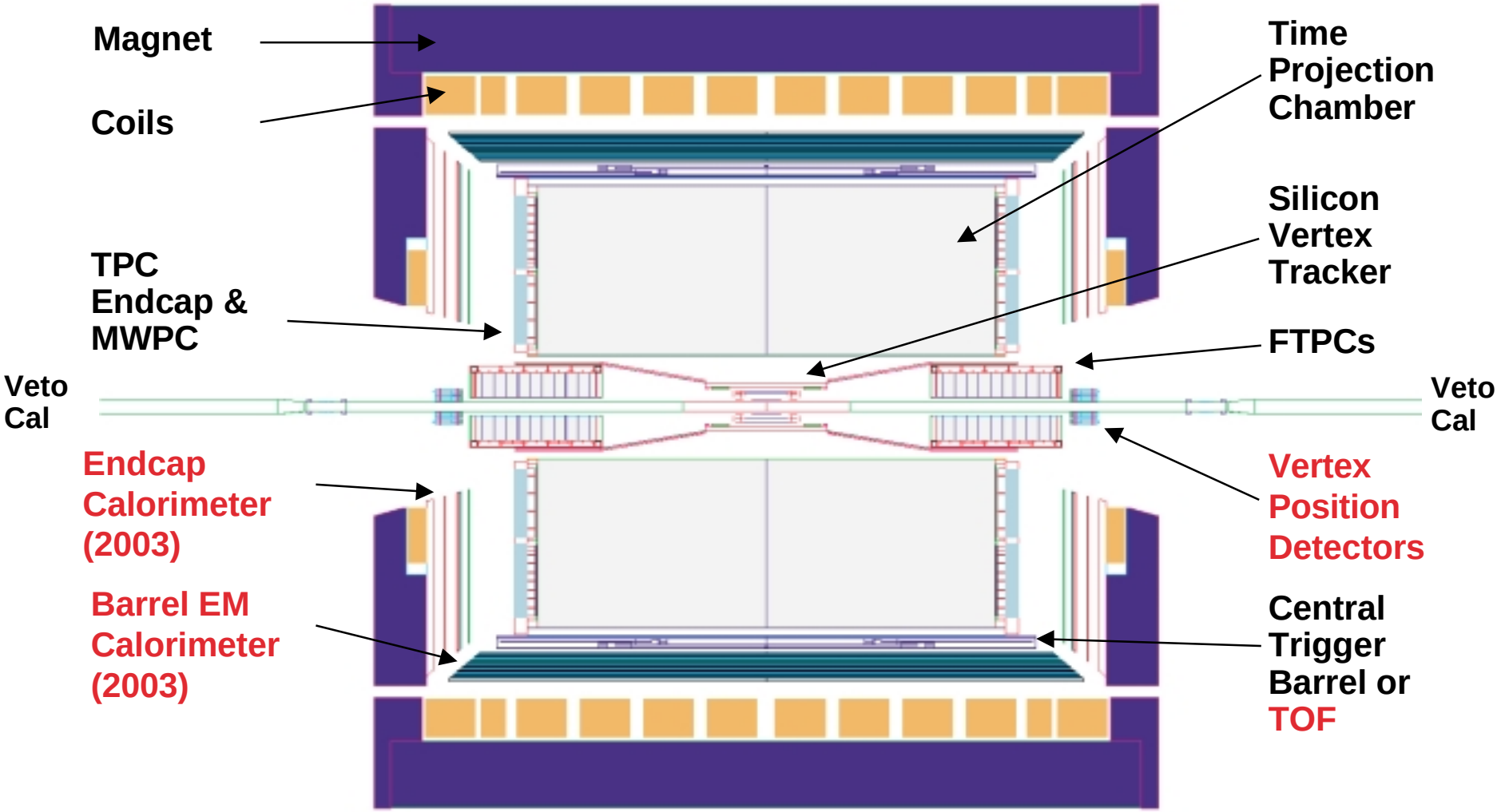


- Two siberian snakes in each ring
  ⇒ stable spin direction is vertical
- No spin rotators for FY2001-02 run.
- Produce longitudinal polarization in FY2001-02 run by turning off one snake at top of ramp...

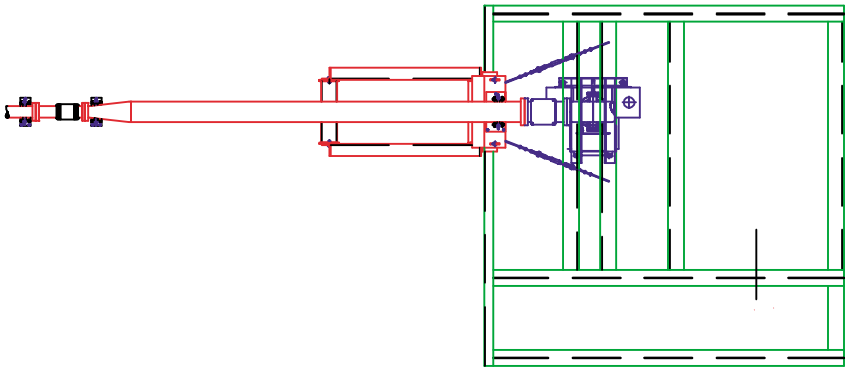
  ⇒ stable spin direction in bend plane.

  ⇒ special energies result in longitudinal polarization at all interaction points.

STAR from the Inside - Out



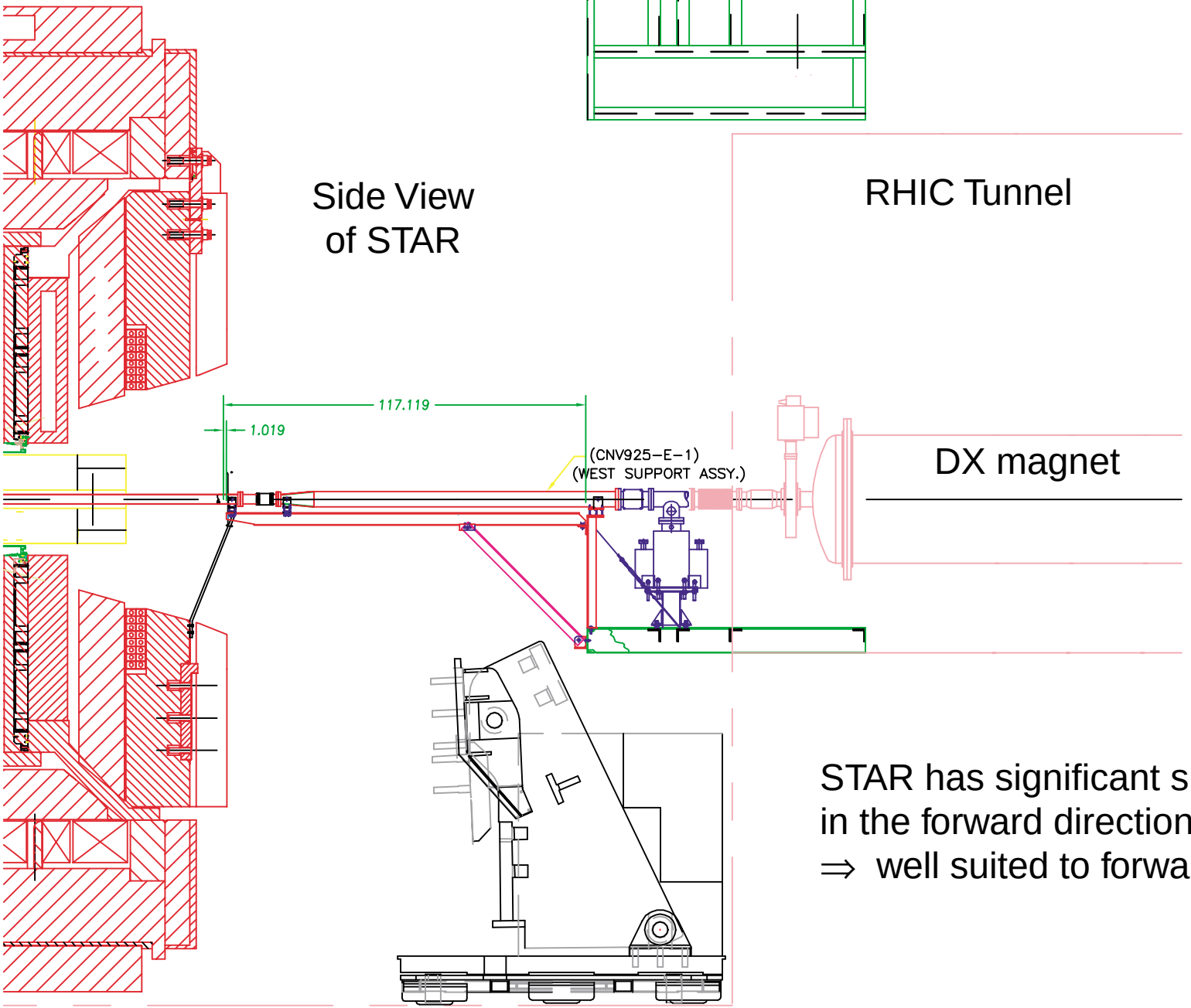
Items in red are not fully implemented for FY2001-2002 run.
Expected completion dates are shown in parentheses.



Top View
of Tunnel Platform
Extension

Side View
of STAR

RHIC Tunnel



DX magnet

STAR has significant space available
in the forward direction.
⇒ well suited to forward particle detection.

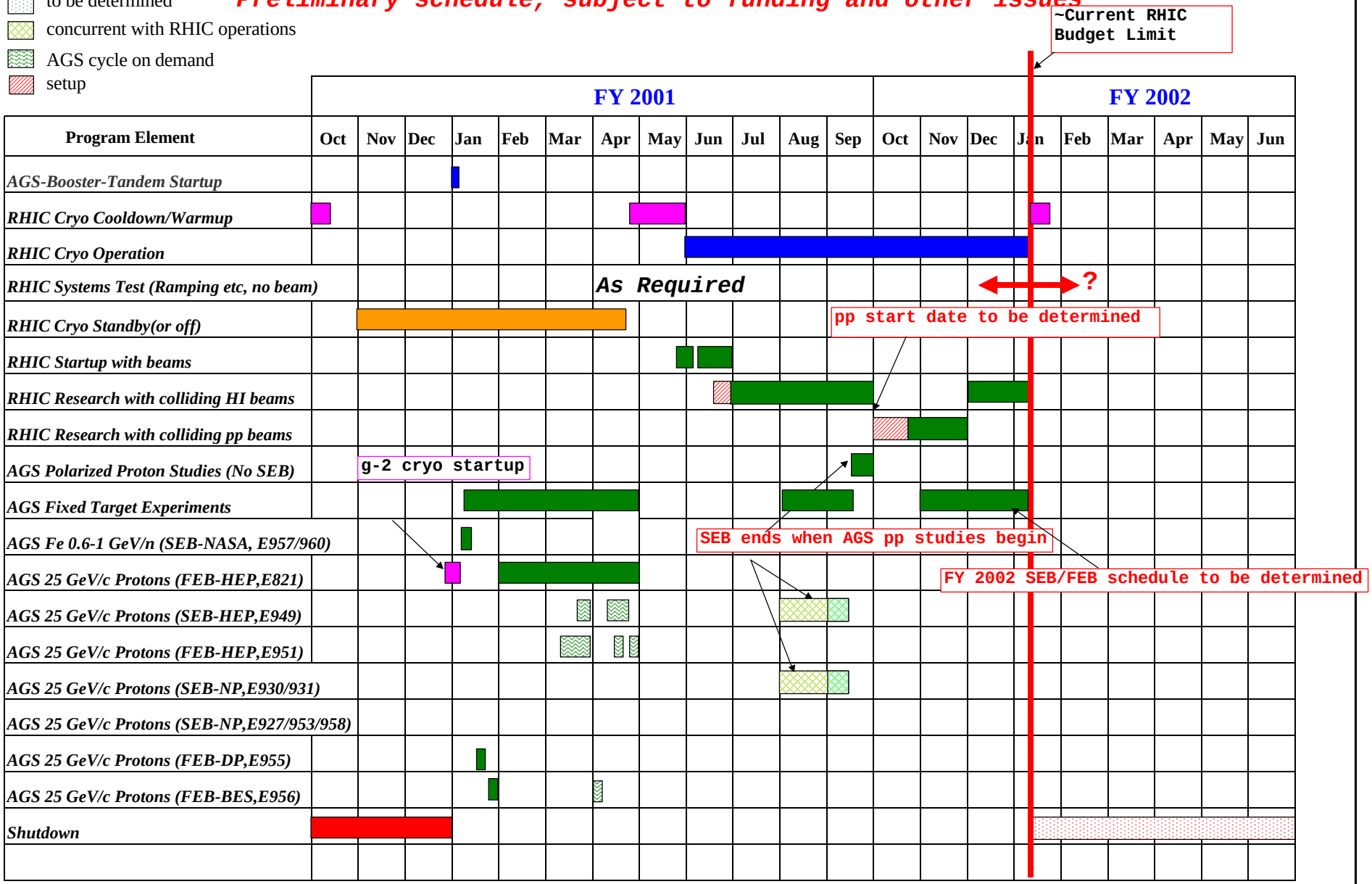
http://server.c-ad.bnl.gov/esfd

C-A Operations-FY01-02

8 June 01

to be determined
concurrent with RHIC operations
AGS cycle on demand
setup

Preliminary schedule, subject to funding and other issues



STAR Goals for FY2001 $\vec{p}\vec{p}$ Run

Goal 1: Obtain reference pp scattering data for heavy-ion program.

Goal 2: Make first measurement of a polarization observable (A) in a $\vec{p}\vec{p}$ collider.

$$P^{n}_{\text{beam}} A_{n} = \frac{Y_{+} - R Y_{-}}{Y_{+} + R Y_{-}} \qquad n = \begin{cases} 1 \rightarrow \text{single spin asym.} \\ 2 \rightarrow \text{two spin asym.} \end{cases}$$

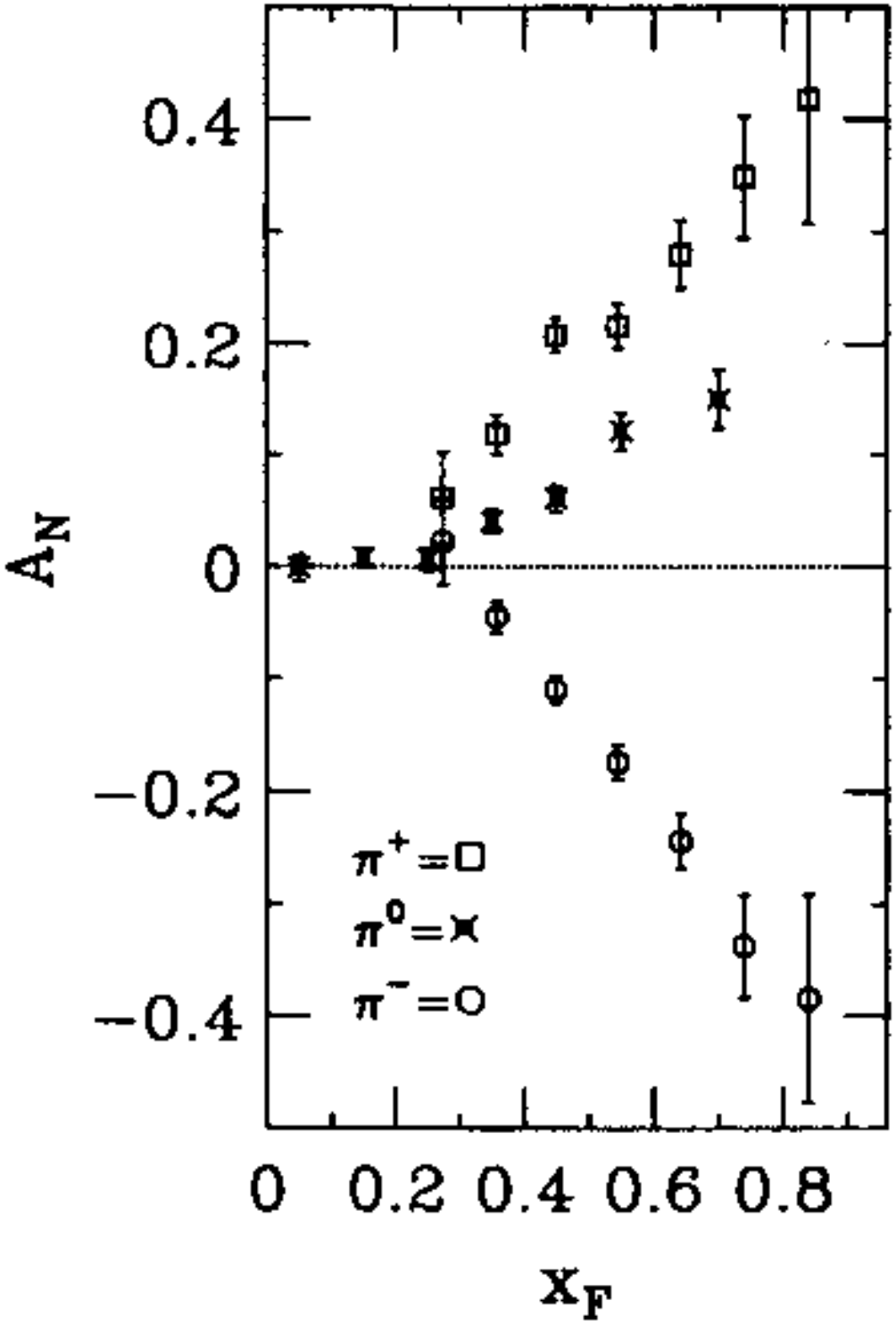
This represents three measurements...

1) Spin dependent yield ($Y_{+/-}$) of some process (process 1)

2) Relative luminosity (R) of '+' and '−' bunch crossings
   → ratio of yields for process 2

3) Magnitude of beam polarization
   → 12 o'clock polarimeter + bootstrap (until calibration exp't with polarized target)

Goal 3: Understand limiting systematic errors for A_{LL} measurements.



What process should be used for first spin asymmetry measurement at RHIC?

Non-zero values of A_N have been observed in FNAL E704...

$$p_{\uparrow} + p \rightarrow \pi + X$$

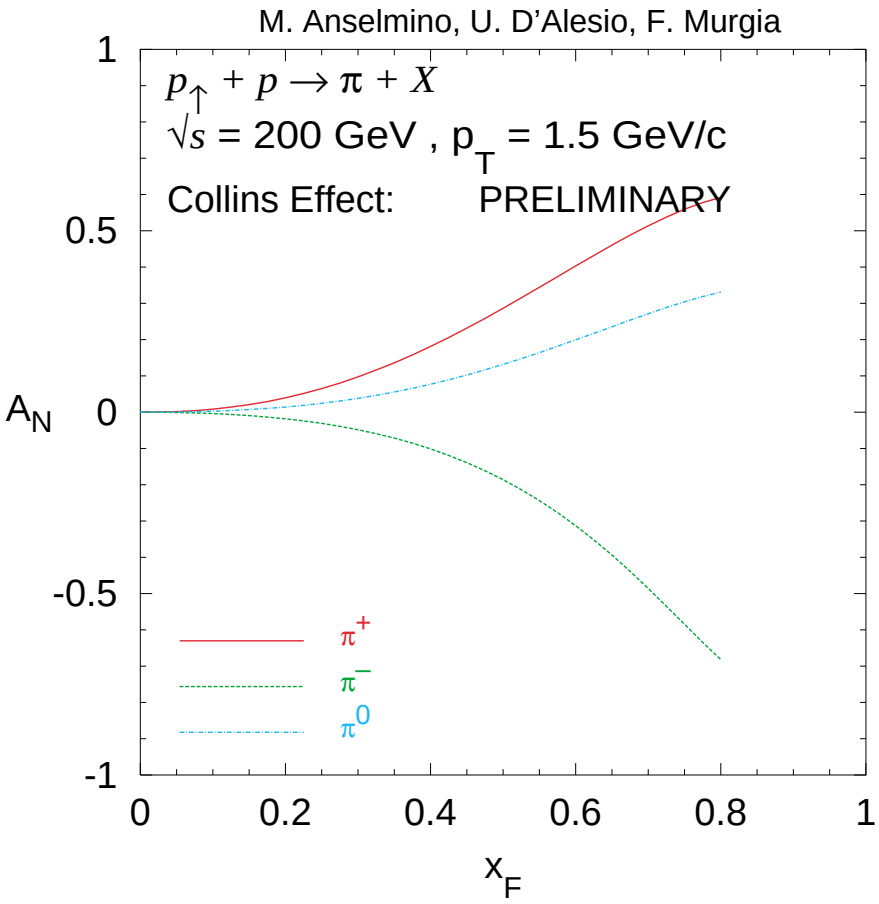
$\sqrt{s}$ = 20 GeV , 0.5 < p_T < 2.0 GeV/c

Theoretical models that explain the E704 data also predict non-zero A_N for pion production at RHIC at $\sqrt{s}$ = 200 GeV.

π^0 - D.L. Adams, et al. Phys. Lett. B261 (1991) 201.

$\pi^{\pm}$ - D.L. Adams, et al. Phys. Lett. B264 (1991) 462.

Expectations for A_N at RHIC



⇒ 'Extrapolations' of E704 experimental results lead to expected non-zero A_N at RHIC.

Considerations for a measurement at RHIC:

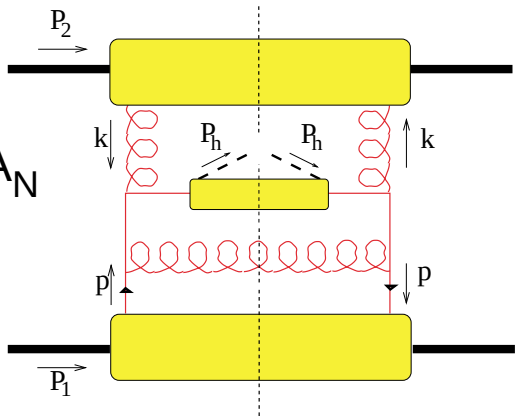
- no momentum analysis in forward direction, $Y(\pi^+) \approx Y(\pi^-)$ and $A_N(\pi^+) \approx -A_N(\pi^-)$

  ⇒ expect zero *net* A_N for forward hadrons (when h^+ is not discriminated from h^-)

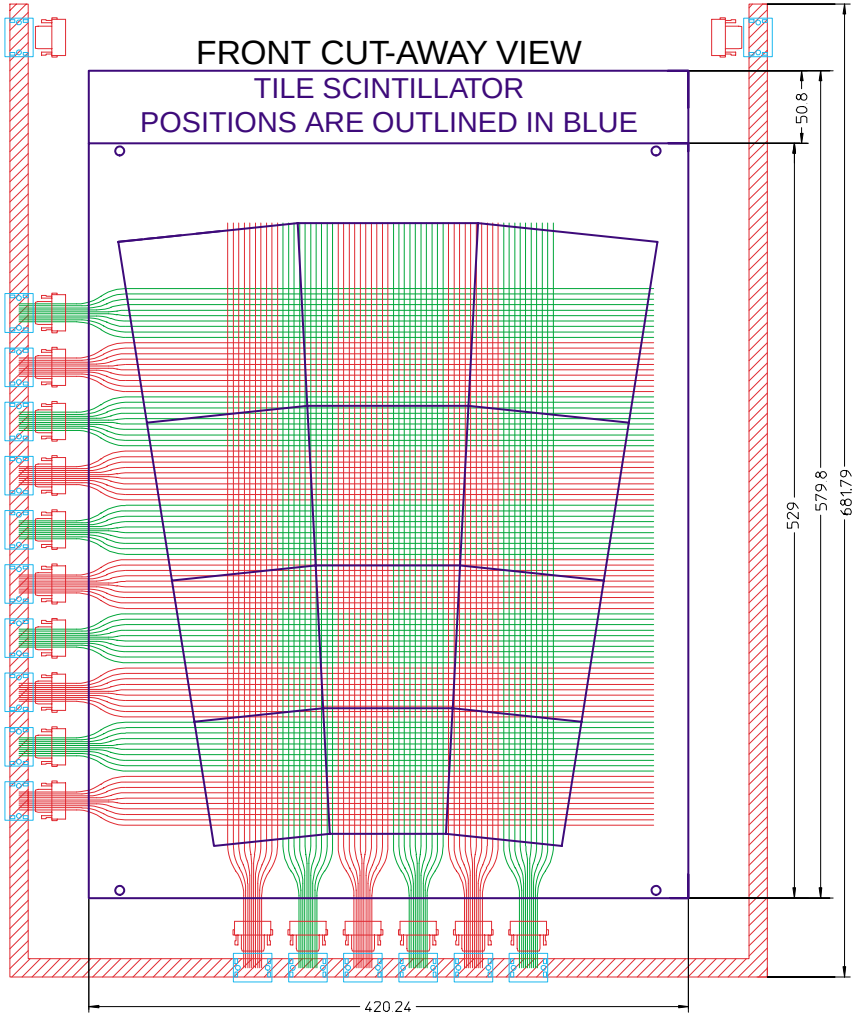
- focus on measuring $A_N(\pi^0)$, but it requires detection of π^0's with E > 20 GeV in the very forward direction (p_T = 1.5 GeV/c ⇒ θ_π ~15 mrad)

Collins Effect as explanation of A_N

$A_N \sim h_1(x_1) \otimes f_1(x_2) \otimes H_1^\perp(z,k_T)$



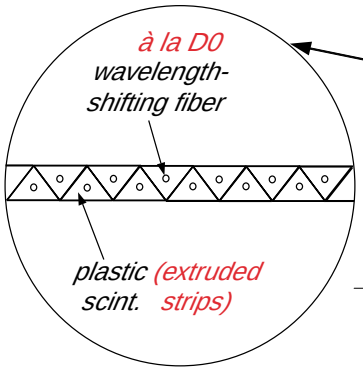
Forward π^0 Detector



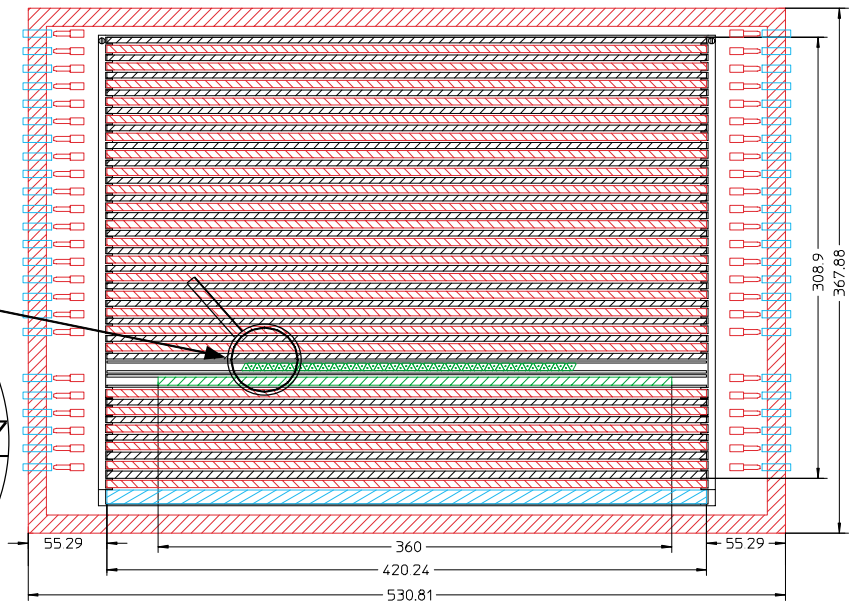
dimensions in mm

- Pb-scintillator sampling electromagnetic calorimeter
- 1/60 prototype of STAR endcap EMC
- Novel shower-maximum detector after 5 radiation lengths ⇒ measure transverse shower profile in two orthogonal directions.

- SMD allows very accurate measurement of $\gamma\gamma$ opening angle and crude determination of individual γ energies.
- π^0 energy measured by EMC to resolution of ~17% / $\sqrt{E}$.

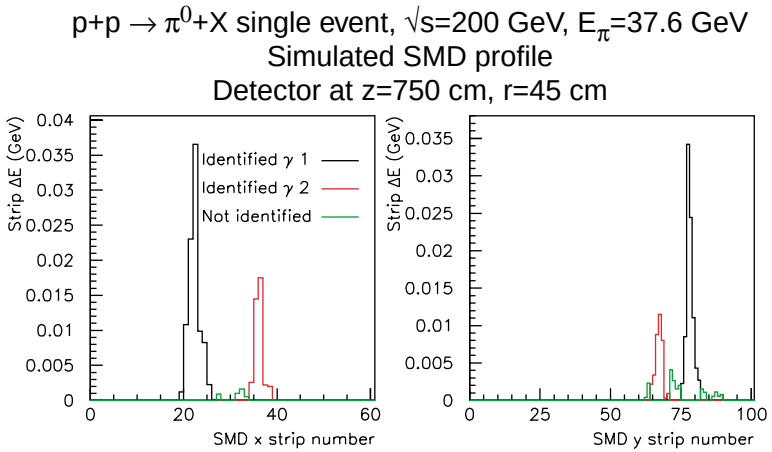


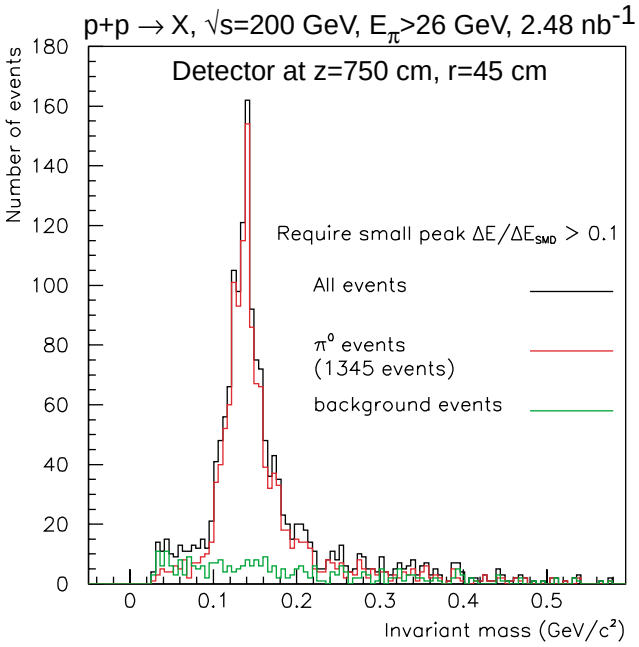
TOP VIEW



Forward π^0 Detector Simulations

Use electromagnetic calorimeter (EMC)
+ *shower maximum detector (SMD)*
to reconstruct $\pi^0 \rightarrow \gamma\gamma$ decays up to E_π~50 GeV.



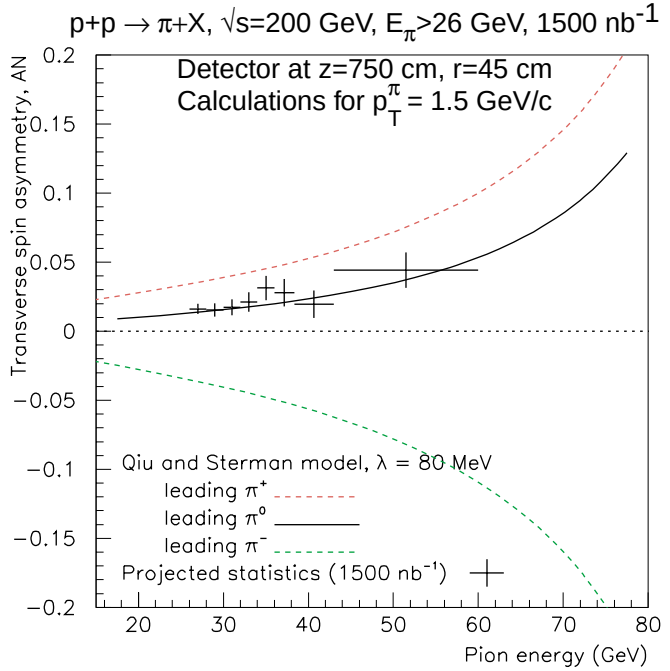


SMD provides good $\gamma\gamma$ opening angle measurement and crude single γ energy measurement $\Rightarrow \pi^0$ reconstruction.

Existing detector (prototype endcap EMC) tested at SLAC with 5,10 and 20 GeV electrons. Good agreement with simulations found.

Use FPD to make *first measurement of polarization observable* at RHIC $\vec{p} + \vec{p}$ collider.

Expect single-spin asymmetry (A_N) to be significant for π^0 with large x_F and moderate p_T from FNAL E704 results.



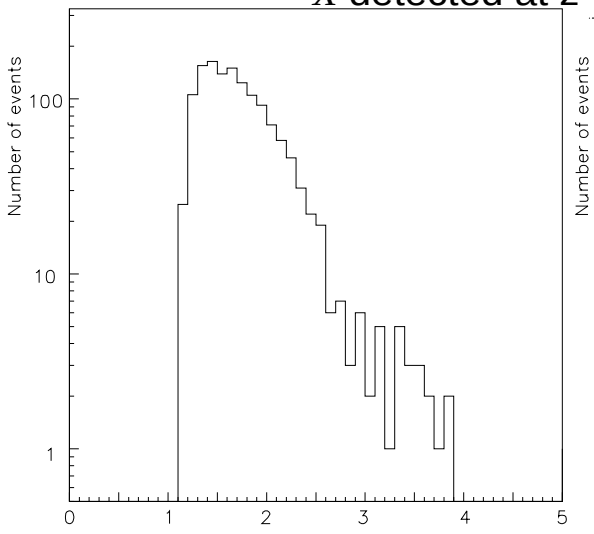
Forward π^0 Detector Installation

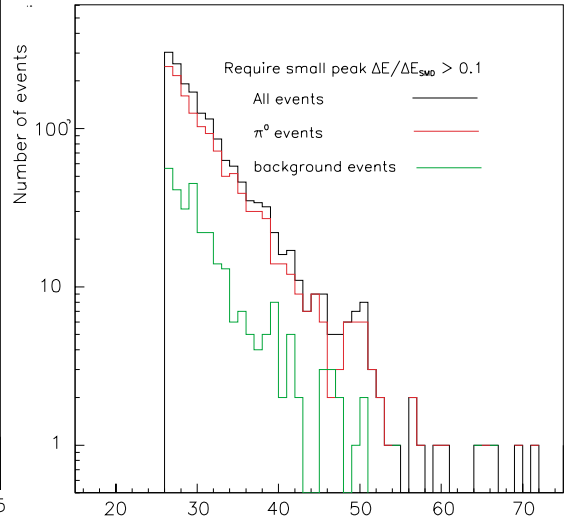
- FPD installation is now complete.
- 'Stand-alone' data acquisition (DAQ) operational.
- Need to complete link to STAR trigger and DAQ systems.

$p_{\uparrow} + p \rightarrow X$, $\sqrt{s}$ = 200 GeV , 2.48 nb^{-1}

X detected at z=750 cm and x=45 cm

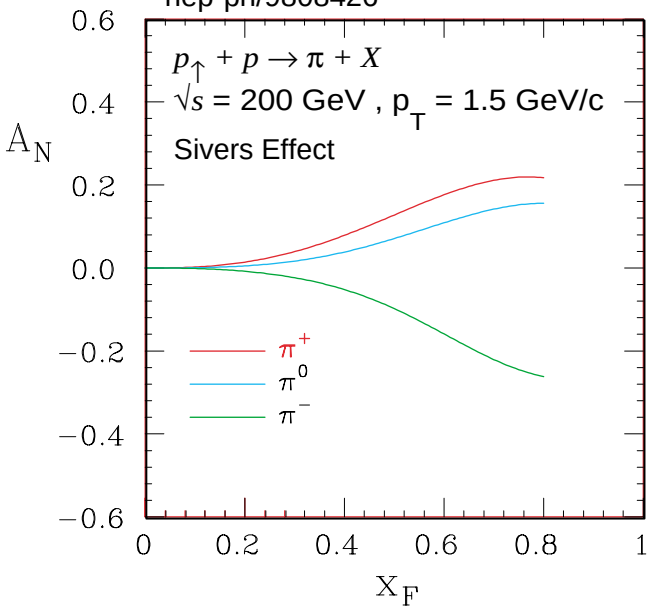
- Simulated p_T and x_F distributions expected for polarized proton collisions.



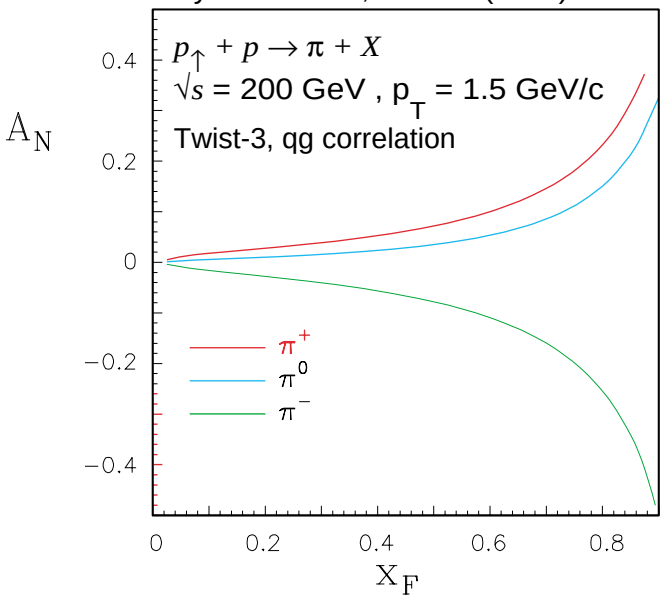


Does A_N for $p_\uparrow + p \rightarrow \pi + X$ probe transversity?

M. Anselmino and F. Murgia,
hep-ph/9808426



J. Qiu and G. Sterman,
Phys. Rev. D59, 014004 (1998)



- There are other explanations for A_N for large x_F pion production...
  - Sivers effect: initial-state interaction
  - twist-3 quark/gluon correlator
- Different models all fit E-704 data and have similar extrapolations to RHIC energies
- Is this a robust way of determining δq?

Concurrent Measurements with Vertical Polarization (FY2001-2002)

- h^+ , h^- and π^0 leading particle asymmetries near x_F ~ 0 (mid-rapidity).
- Λ yield and polarization ($\Rightarrow$ polarization transfer D_{NN}) near x_F ~ 0 (mid-rapidity).

Measurements with Longitudinal Polarization (FY2001-2002)

- If there is measureable A_N for forward π^0 production, then use up/down detectors to check the direction of the proton polarization.
- h^+ , h^- and π^0 leading particle longitudinal spin correlation near x_F ~ 0 (mid-rapidity).

How hard collision can be probed in 2001 ?

Jan Balewski, IUCF
Austin, January , 2001
STAR Collaboration Meeting

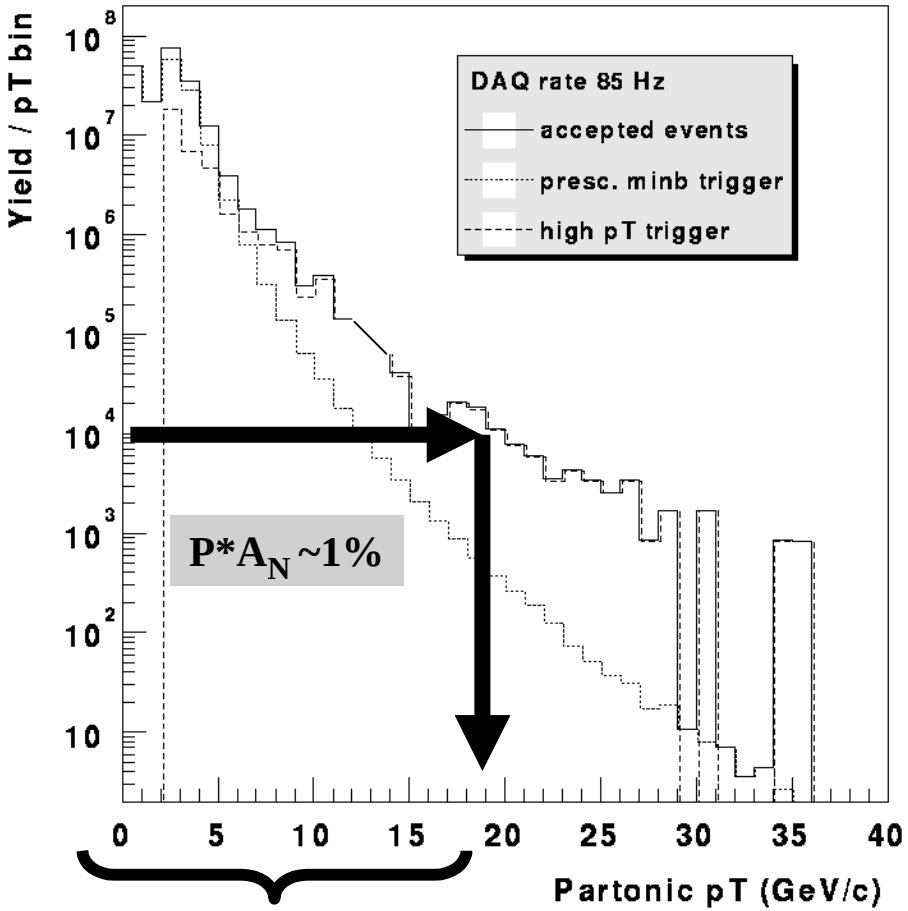
Assuming*)

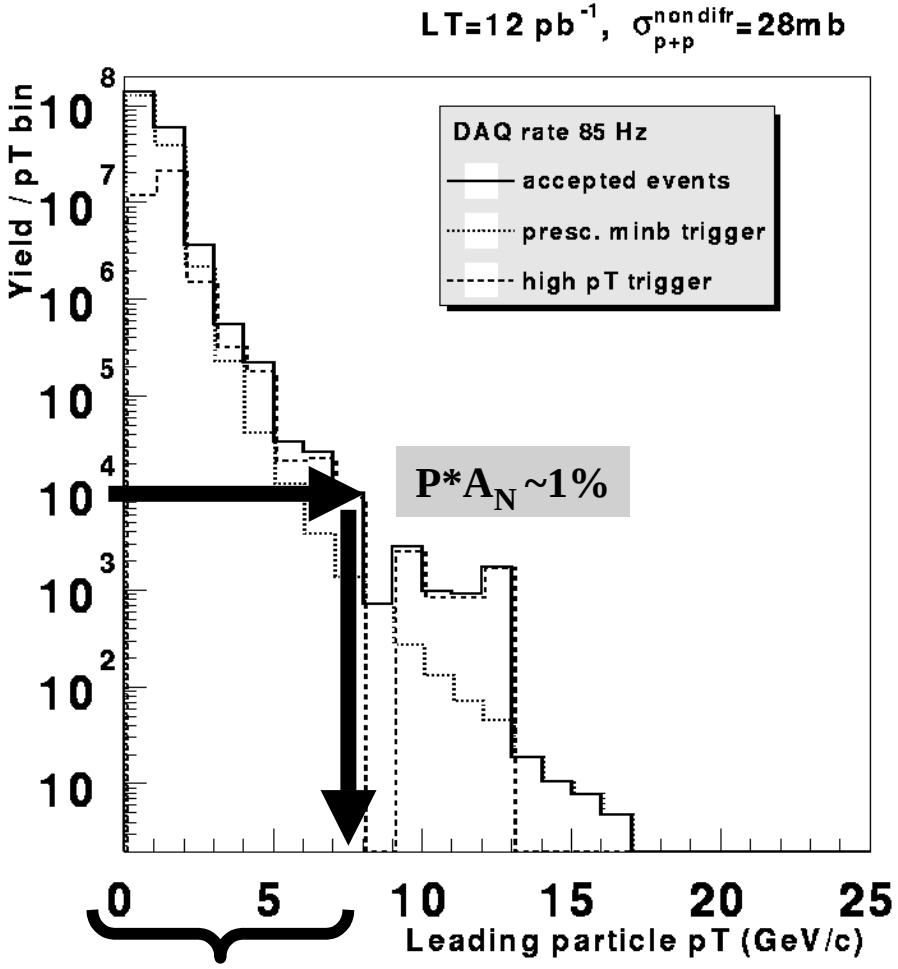
- $L=5 \cdot 10^{30}$ cm^{-2} s^{-1}
- $\sigma_{NON\ DIF}$ =28 mb
- DAQ rate of 85 Hz

Trigger mix:

- 60Hz of MWC minbias trigger
- 15 Hz of CTB high P_T trigger (Σ_{ADC} > thres)

$\rightarrow$ **$2 \cdot 10^8$** events over 4 weeks





*) Reailty: DAQ ~30 Hz, L=~10^{30} , duty cycle 50% $\rightarrow$ ~**10^7** events in total

Longer Term Prospects for Probing δq(x) at RHIC?

- Interference fragmentation functions triggered on away-side jet

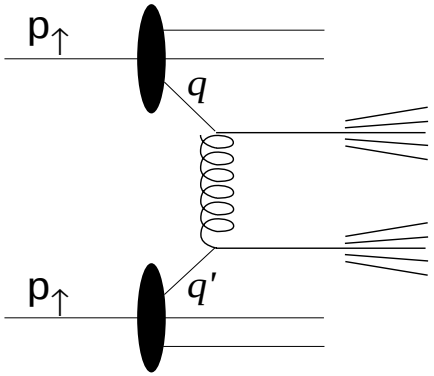
Jet trigger, used to set initial-state partonic x

$p_\uparrow + p \rightarrow \pi^+\pi^- + \pi^0 + X$

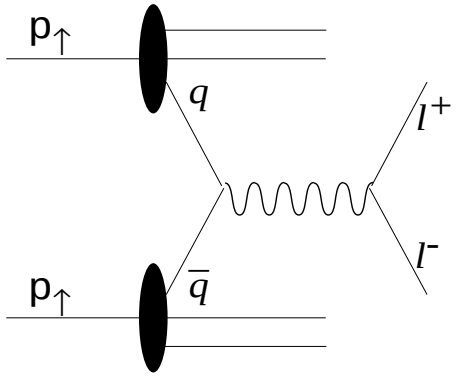
Measure superposition of helicity 0,1 states
$\Rightarrow$ requires good $M_{\pi\pi}$ resolution near M_ρ

Can the interference fragmentation function be measured in e^+e^- collisions?

- Selection of qq' scattering from $p_\uparrow + p \rightarrow$ di-jet events



t-channel QCD analog
of Drell-Yan
$\Rightarrow$ non-zero $A_{TT} \propto \delta q(x_1)\delta q'(x_2)$



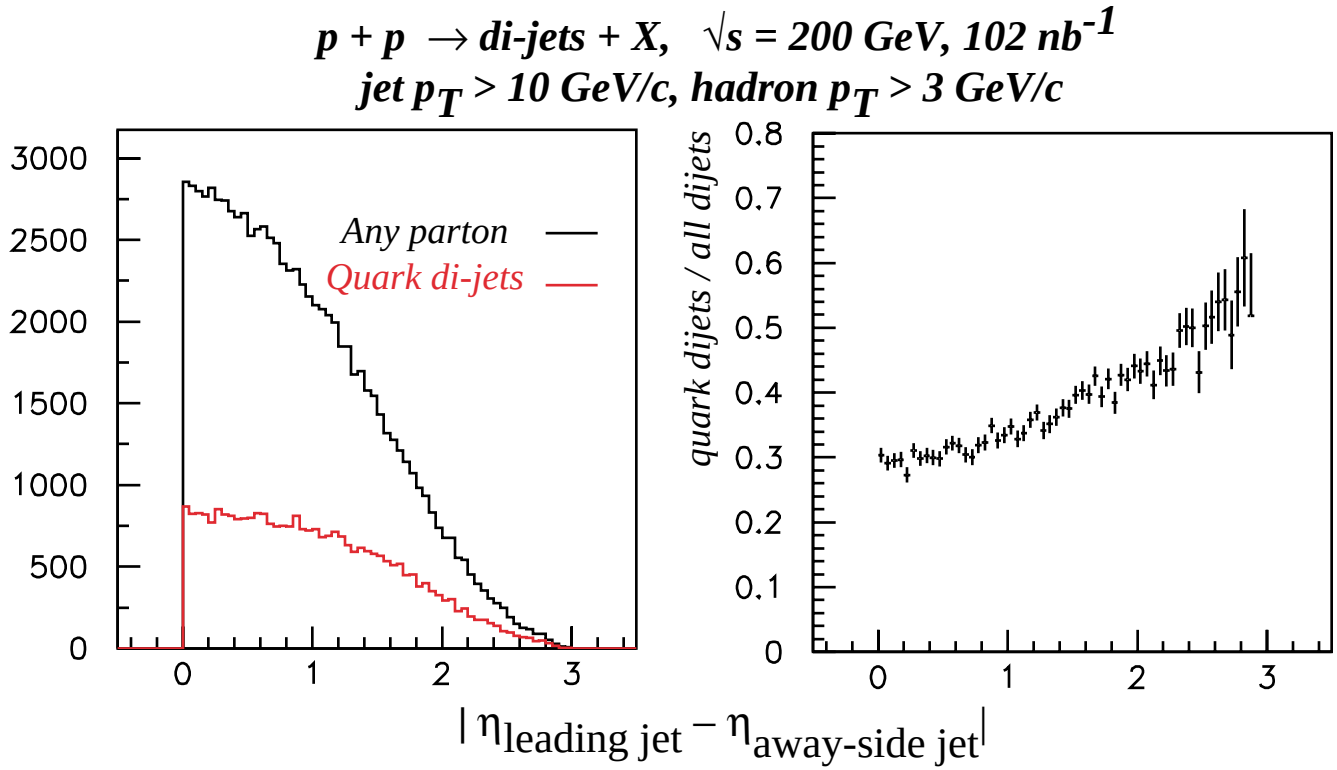
Can qq' scattering be isolated from dominant qg and gg contributions to di-jet yields?

For p + p $\rightarrow$ di-jets + X, get significant dilution of sensitivity to $\delta q(x)$ because of qg and gg scattering contributions $\Rightarrow$

$$A_{TT} = \frac{\delta\sigma_{qq'}}{\sigma_{qq'} + \sigma_{qg} + \sigma_{gg}} \ll A_{TT}^{qq'}$$

Suppress qg and gg scattering conributions by phase space cuts $\Rightarrow$

- selecting large invariant mass di-jets (large rapidity gap)
- exploiting fragmentation differences (demand high p_T fragments)



$\Rightarrow$ gain sensitivity to qq' scattering $\Rightarrow$ probe $\delta q(x)$?

Outlook for RHIC spin

- The present RHIC run (FY2001-2002) will produce the first polarized proton collisions at $\sqrt{s}$ = 200 GeV.

- The first polarized proton collisions at RHIC will be with vertical polarization for experimental reason ($\int L\,dt$ ~1.5 pb^{-1}).

- The first measurement of a polarization observable in a polarized proton collider will be for π^0 production at large x_F and small p_T, in similar kinematics for which anomalously large A_N was first observed in E704 at $\sqrt{s}$ = 200 GeV. Is there a relation to $\delta q(x)$?

- Subsequent years will see the completion of the STAR and PHENIX detectors, and the installation of spin rotators $\Rightarrow$ focus on longitudinal polarization measurements:

  $\Rightarrow$ measure ΔG via $\vec{p} + \vec{p} \rightarrow \gamma$ + jet + X.

  $\Rightarrow$ measure Δq_{val} and $\Delta \bar{q}_{sea}$ via $\vec{p} + p \rightarrow W^{\pm}$ + X.

- Vertical polarization runs in subsequent years may provide definitive measurements of $\delta q(x)$ via $\pi^+\pi^-$ correlations (interference fragmentation function).

PHENIX detector at RHIC