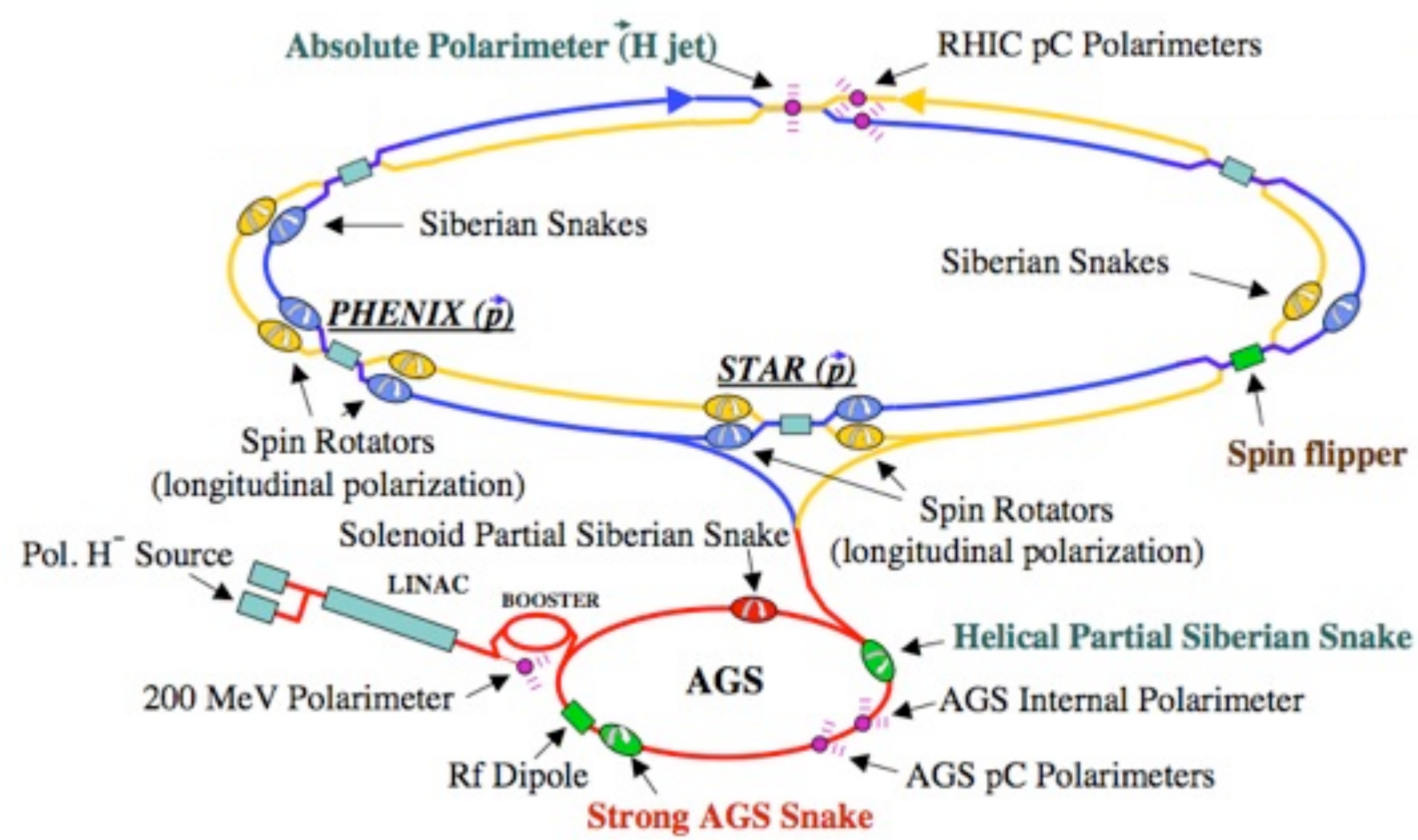
STAR upgrades and Drell-Yan

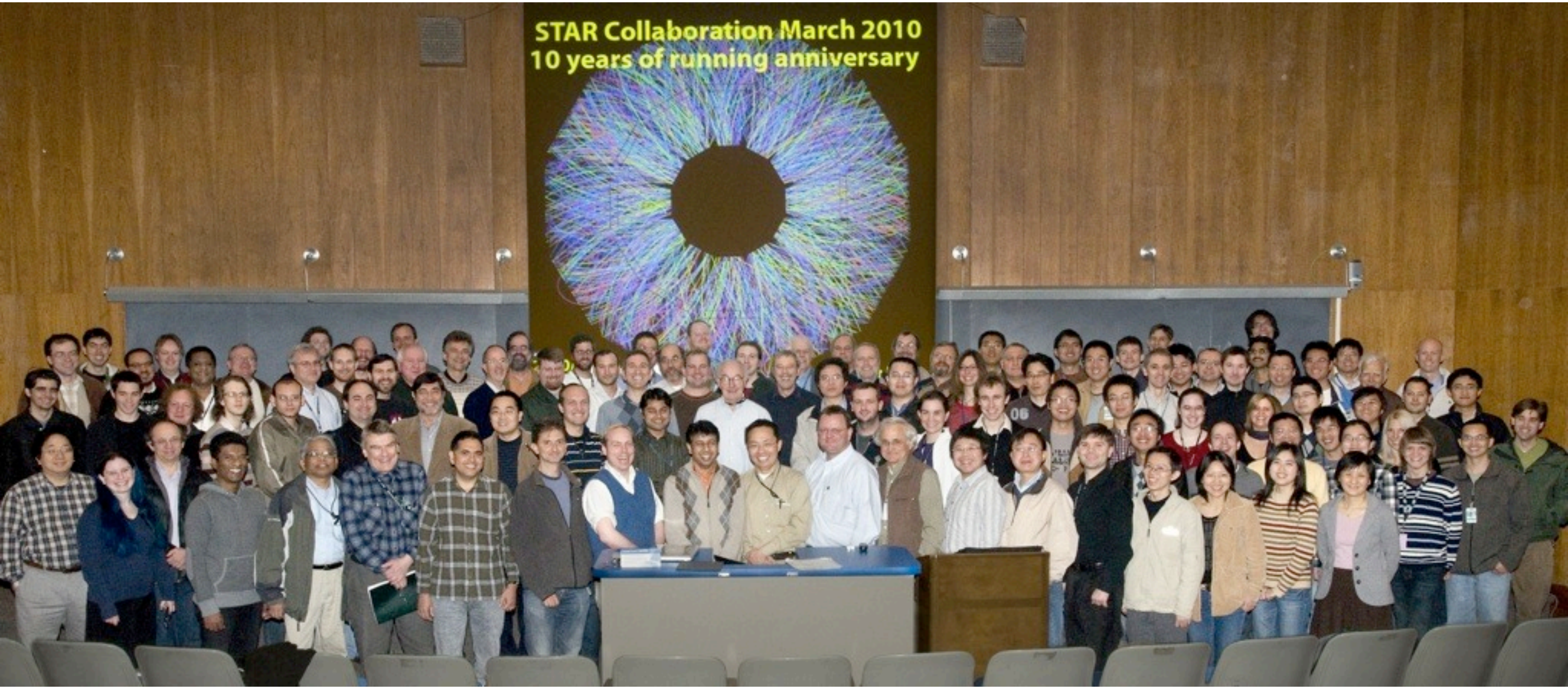
Ernst Sichtermann (LBNL)
for the STAR Collaboration

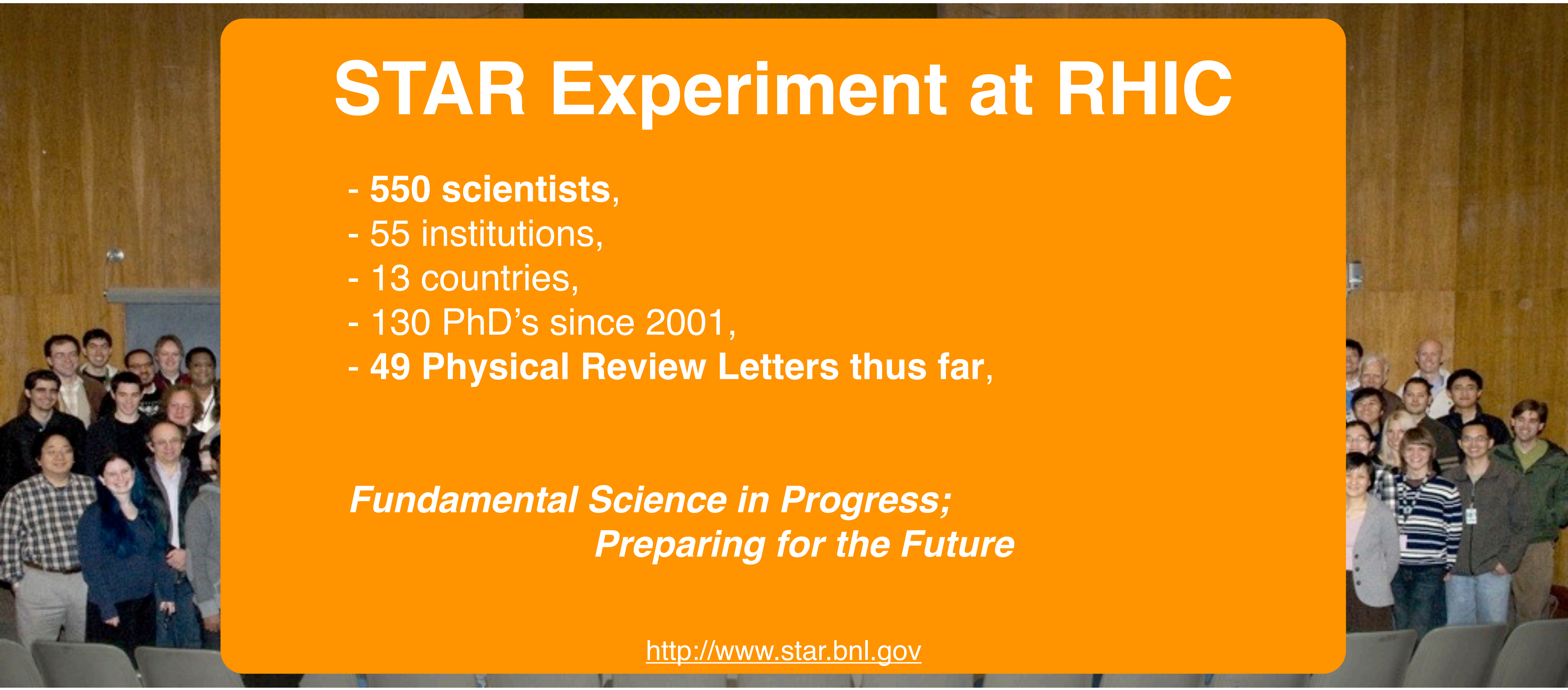


Santa Fe Polarized Drell-Yan Physics Workshop
October 31 and November 1, 2010 - Santa Fe, NM

Many thanks to Ming and his team,
for organizing this timely and topical workshop!

And, also, to colleagues and friends
in STAR and elsewhere.


STAR Collaboration March 2010
10 years of running anniversary



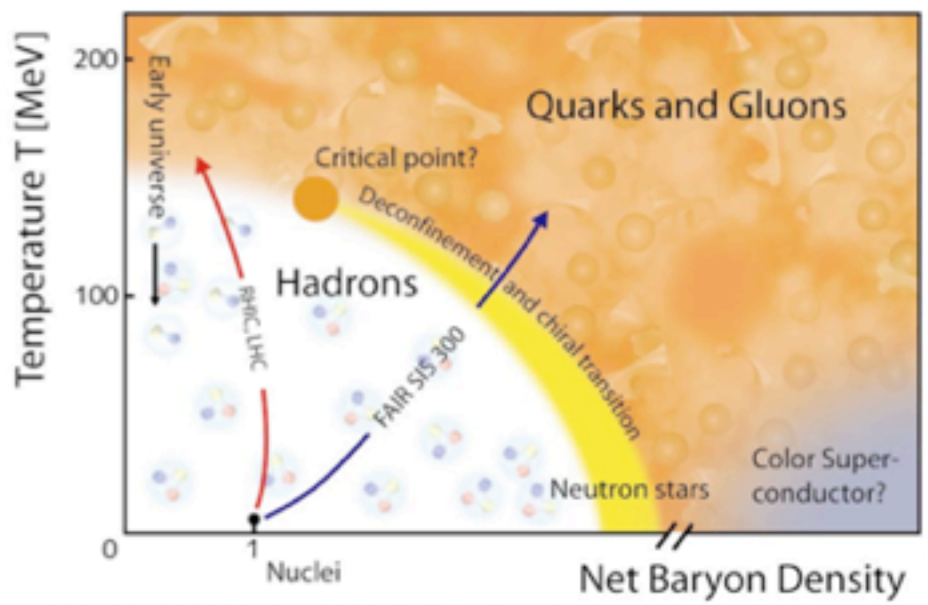
STAR Experiment at RHIC

- **550 scientists**,
- 55 institutions,
- 13 countries,
- 130 PhD’s since 2001,
- **49 Physical Review Letters thus far**,

Fundamental Science in Progress;
Preparing for the Future

http://www.star.bnl.gov

STAR Physics - QCD Matter

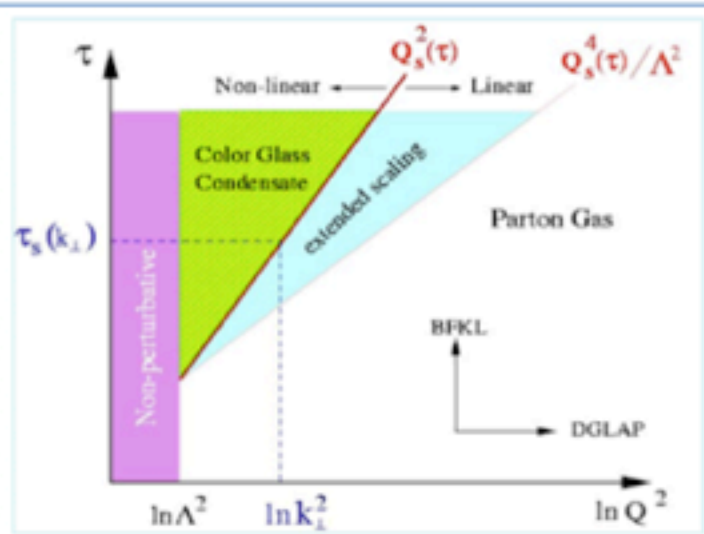


1) At 200 GeV top energy

- Study ***medium properties, EoS***
- pQCD in hot and dense medium

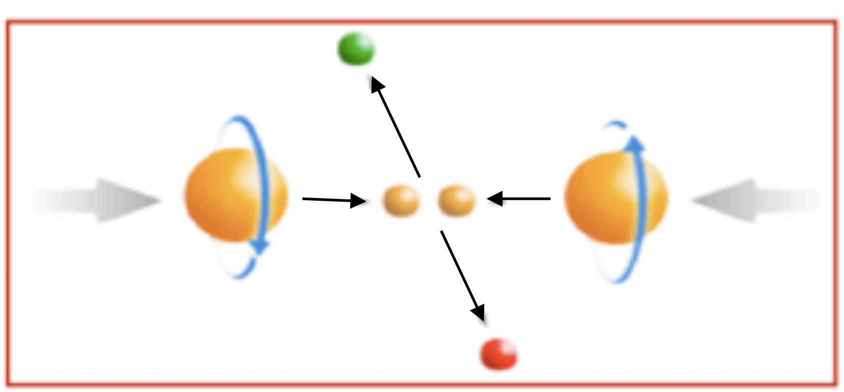
2) RHIC beam energy scan (BES)

- Search for the ***QCD critical point***
- Chiral symmetry restoration



Forward program

- Study low-x properties, initial condition, search for ***CGC***
- Study elastic and inelastic processes in pp2pp

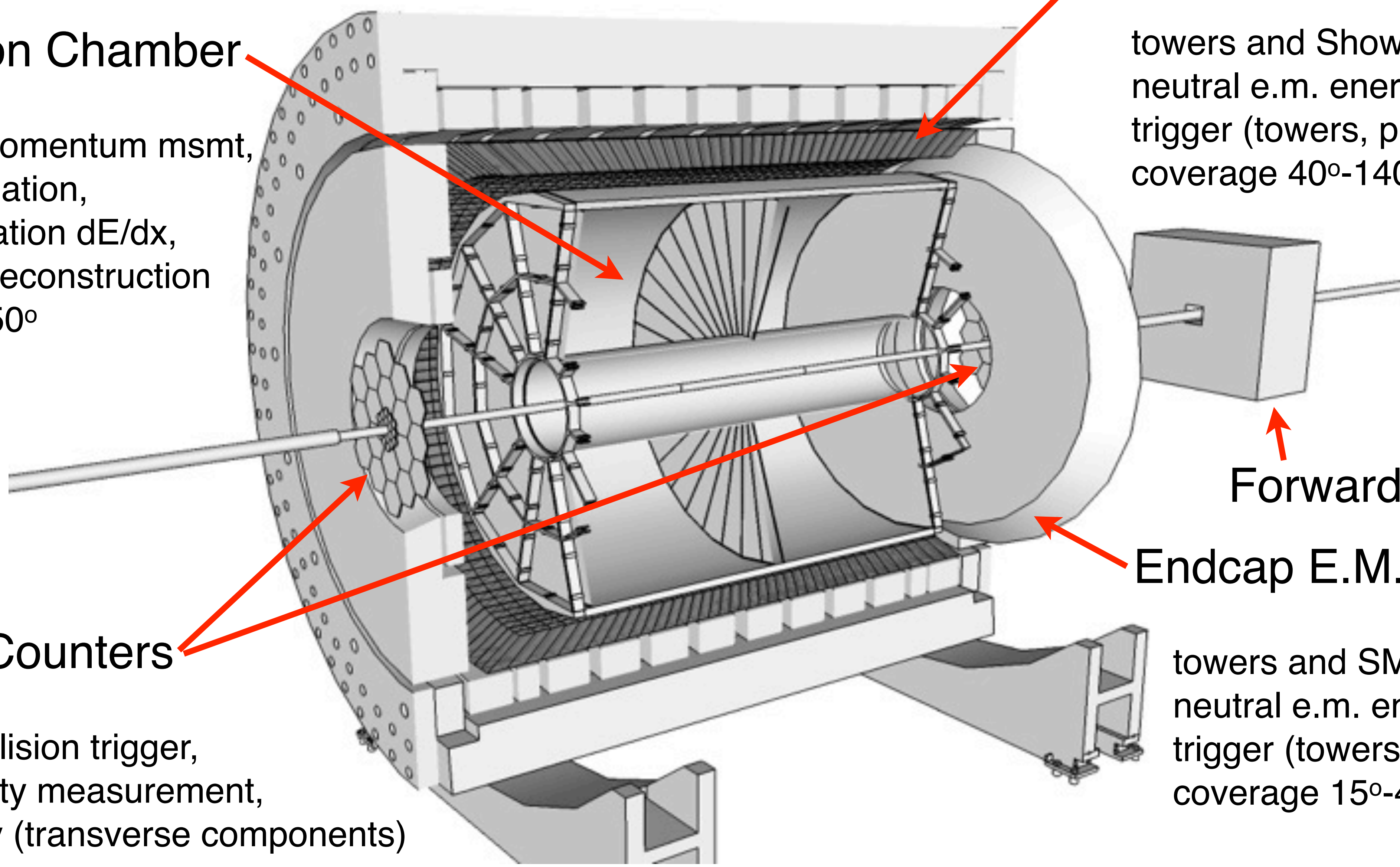


Polarized *p*+*p* program

- Study ***proton intrinsic properties***
  role of spin in QCD

STAR - Solenoid Tracker at RHIC

Nucl. Instrum. Meth. A499, 624, 2003



Time Projection Chamber

charged track momentum msmt,
charge determination,
particle identification dE/dx,
collision vertex reconstruction
coverage 30^o-150^o

Barrel E.M. Calorimeter

towers and Shower Maximum Det.
neutral e.m. energy measurement,
trigger (towers, patches of towers)
coverage 40^o-140^o

Forward Meson Spectr.

Endcap E.M. Calorimeter

towers and SMD.
neutral e.m. energy measurement,
trigger (towers, patches of towers)
coverage 15^o-40^o

Beam-Beam Counters

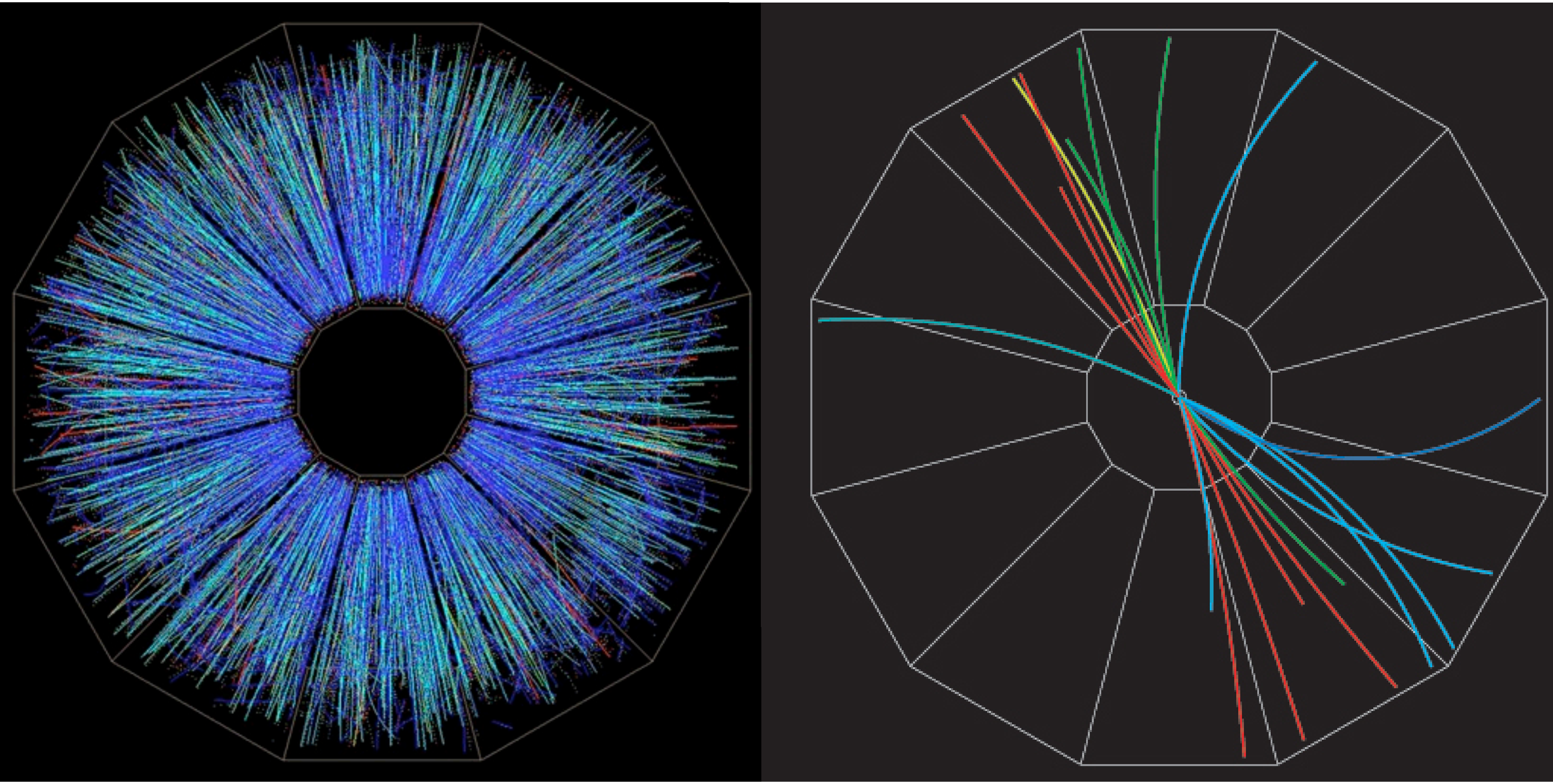
proton beam collision trigger,
relative luminosity measurement,
local polarimetry (transverse components)

0.5 T Solenoidal Magnetic Field

Several detectors not shown, e.g. ZDC, FPD, Time-of-Flight (complete for run-10), RP, ...

A very versatile instrument, with an *evolutionary* and *physics-driven* upgrades.

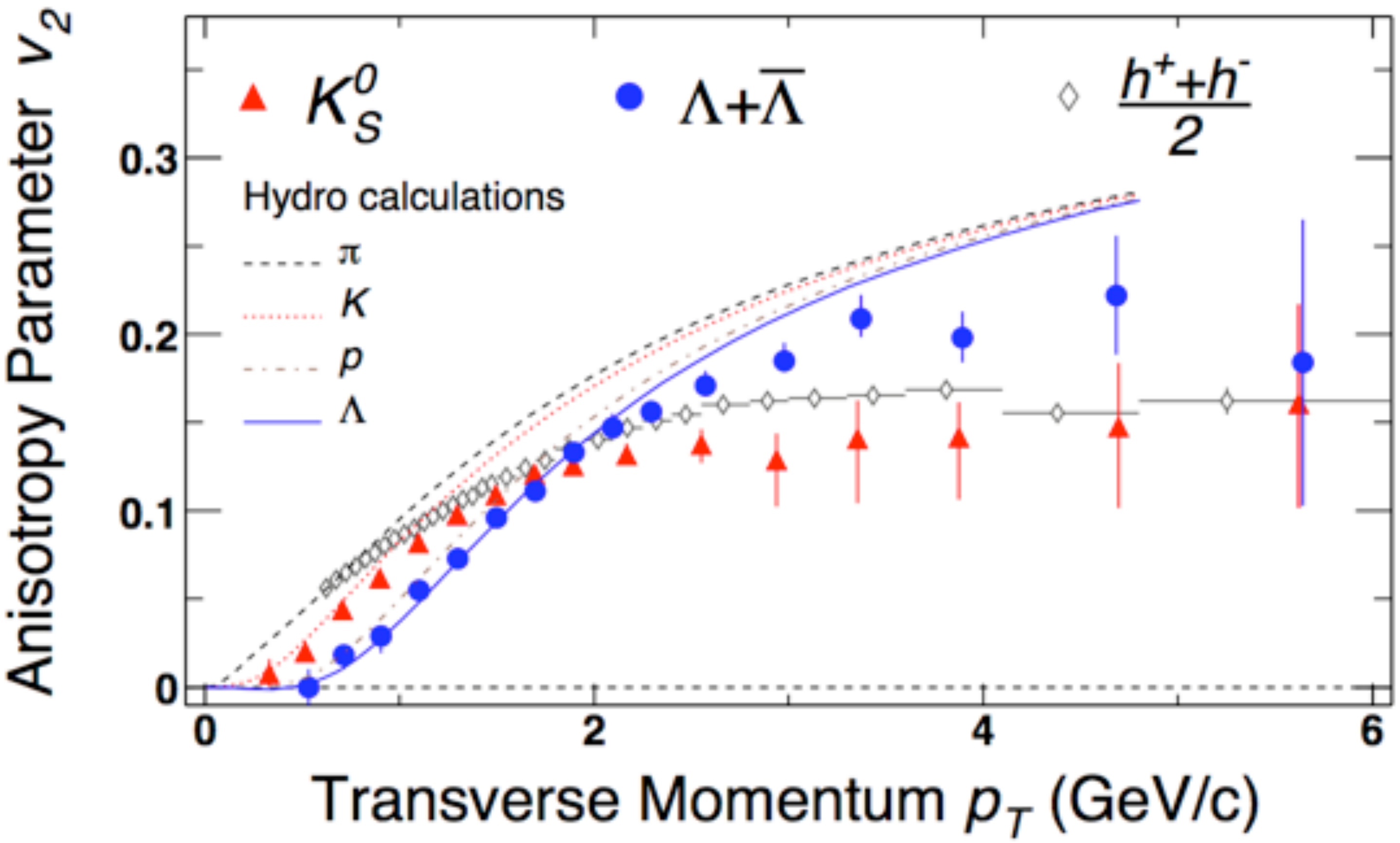
STAR - Solenoid Tracker at RHIC

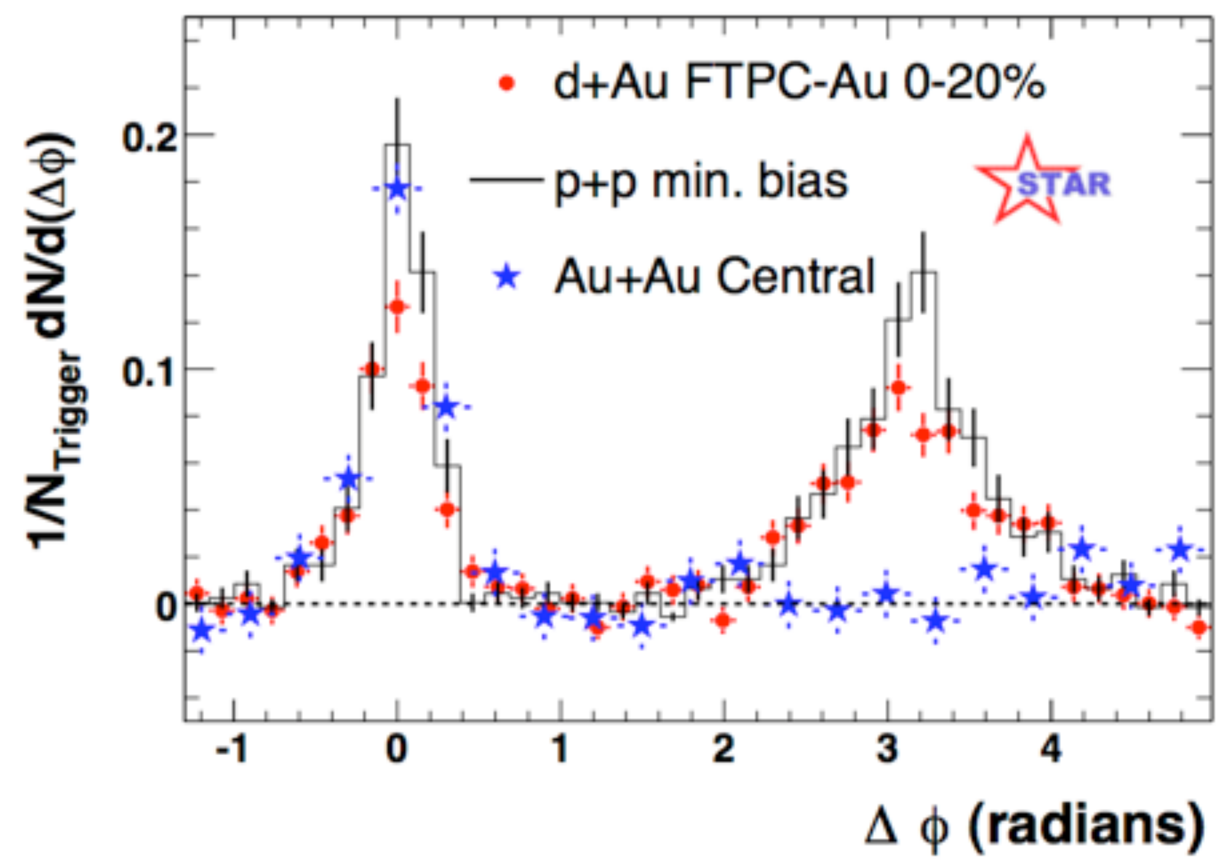


A versatile instrument to study QCD: Au+Au, d+Au, p+p, $\sqrt{s}$ = 7.7 - 500 GeV, polarization.

Strengths: Large acceptance at mid-central rapidities, particle identification,
Collective motion, jets, and correlations.

STAR - Selected Mid-rapidity Results

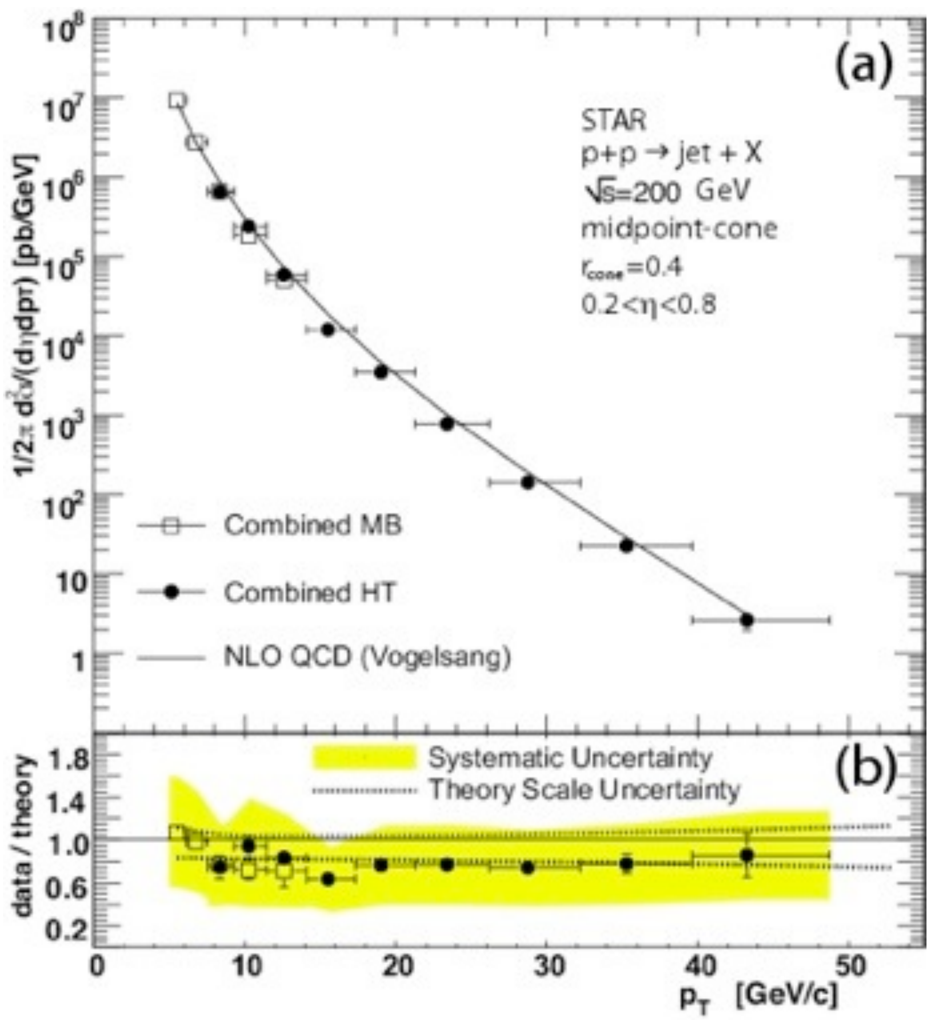


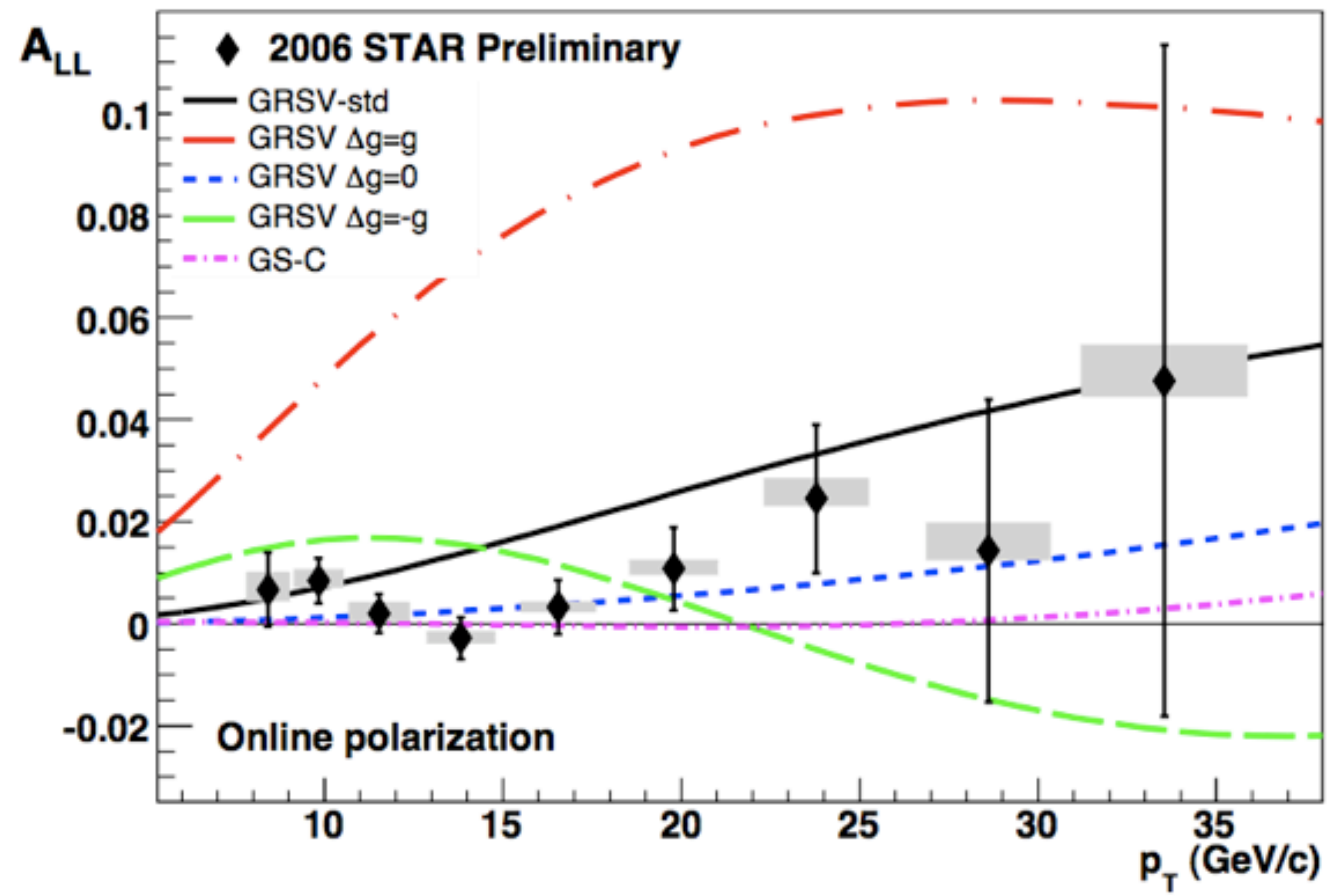


A key future step: heavy flavor (HFT, MTD upgrades)

J. Adams et al., Phys.Rev.Lett.92:052302,2004,
J. Adams et al., Nucl.Phys.A757:102,2005.

STAR - Selected Mid-rapidity Results



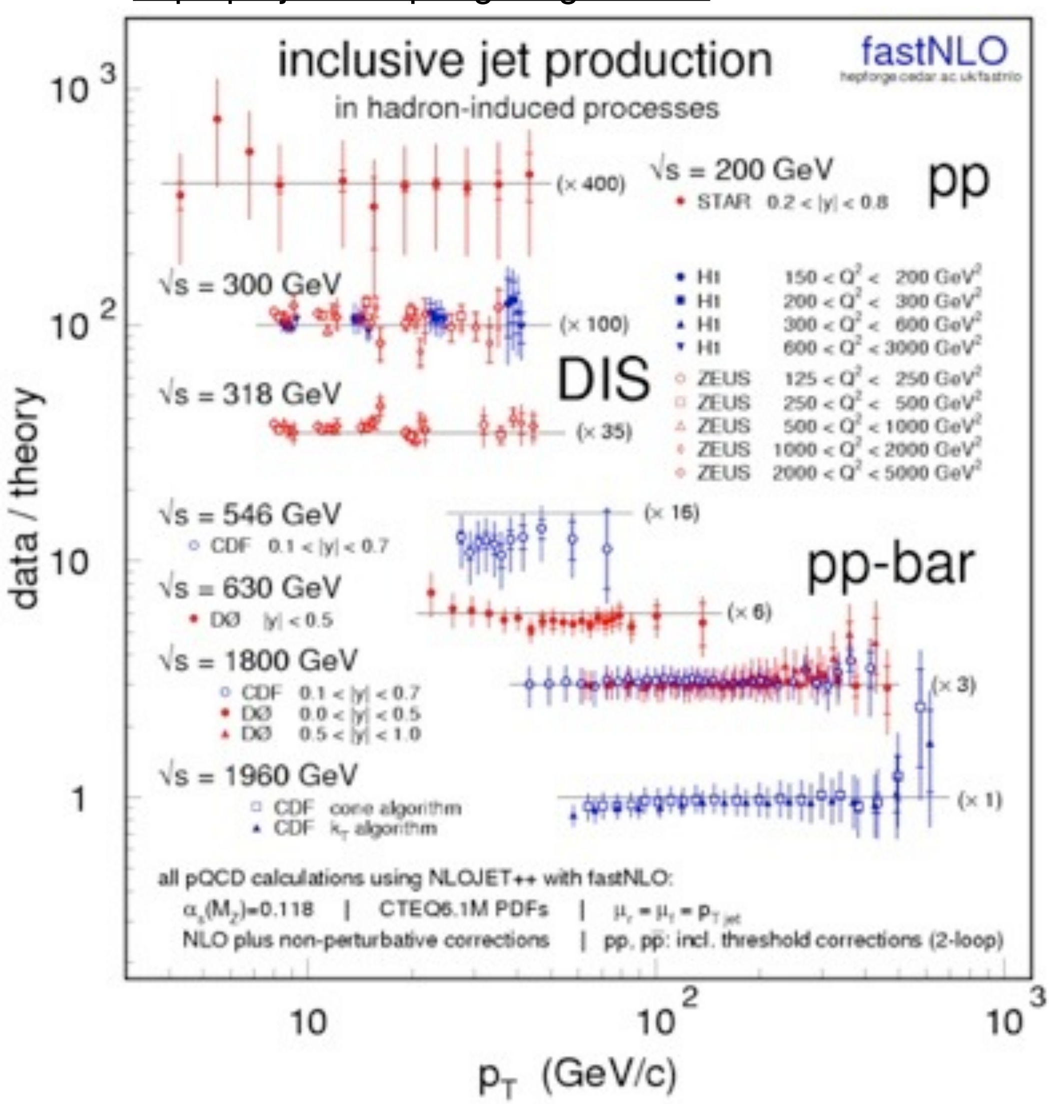


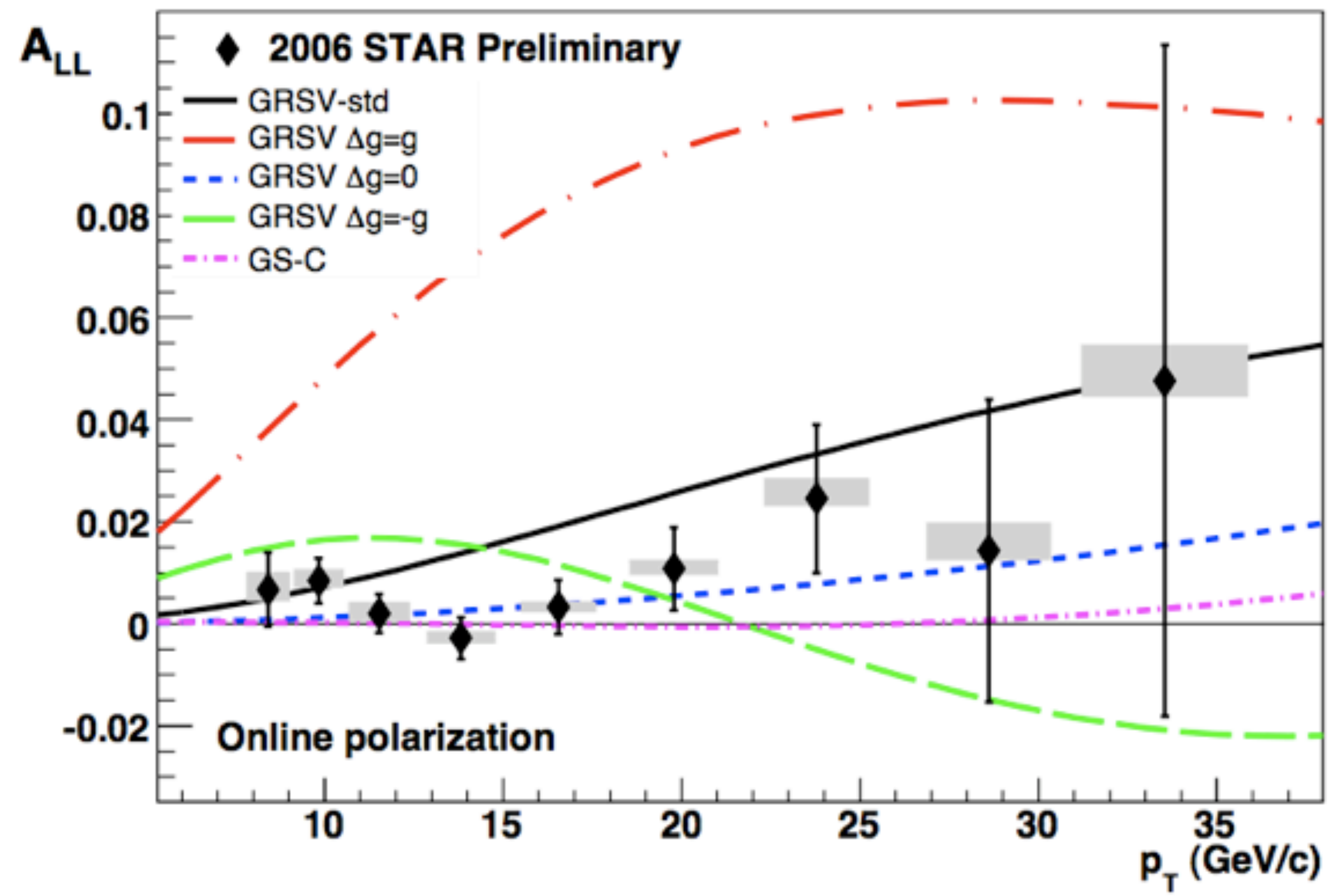
Collinear factorization forms a good description of the spin-averaged cross-section(s),

B. Abelev et al., Phys.Rev.Lett.97:252001,2006
B. Abelev et al., Phys.Rev.Lett.100:232002,2008

STAR - Selected Mid-rapidity Results

T. Kluge, K. Rabbertz, M. Wobisch,
http://projects.hepforge.org/fastnlo/

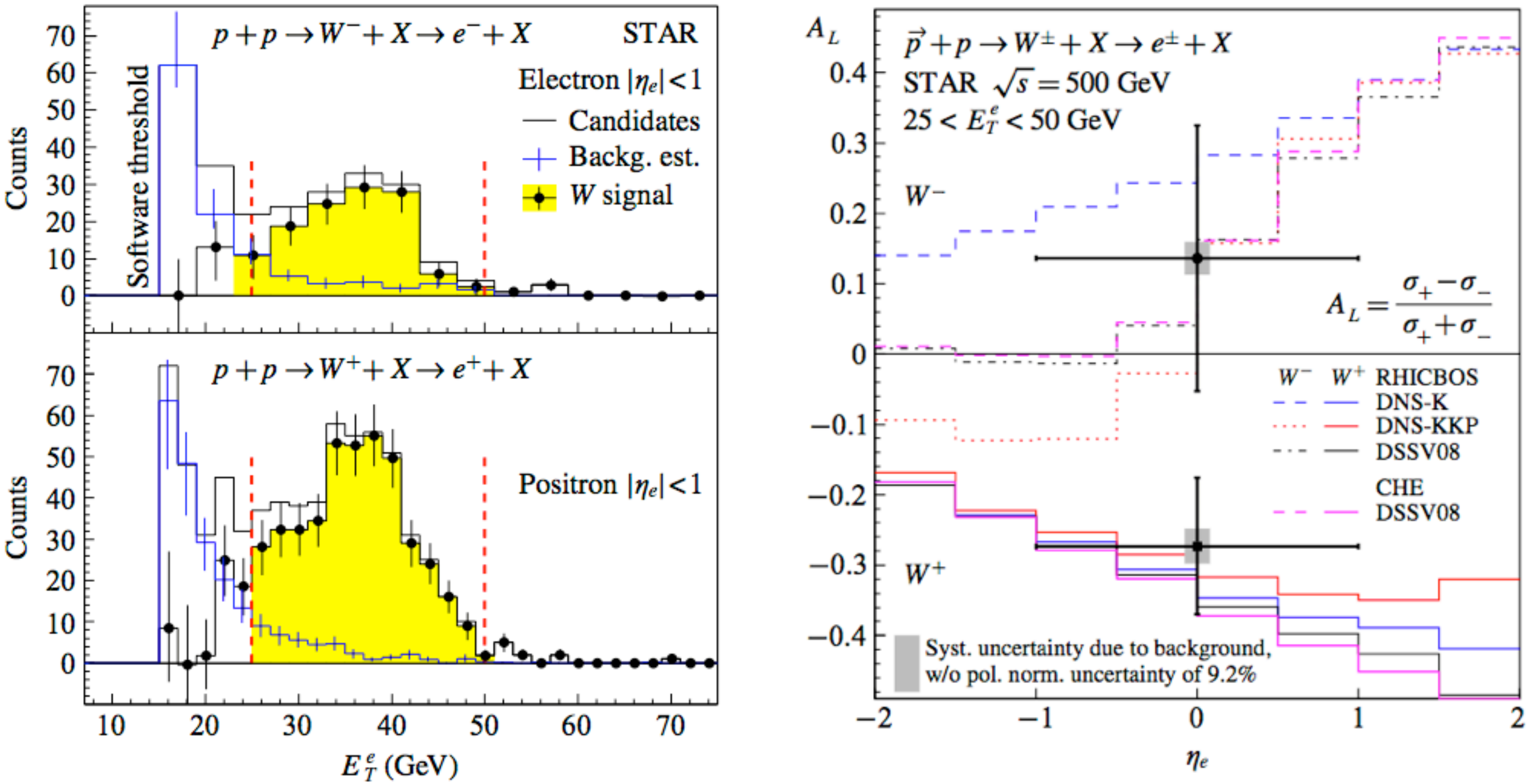




Collinear factorization forms a good description of the spin-averaged cross-section(s),
Precision insight in gluon polarization for ~0.03 < *x* < 0.3,
Key future steps resolve x (correlations) and extend its range (√s, pseudorapidity).

B. Abelev et al., Phys.Rev.Lett.97:252001,2006
B. Abelev et al., Phys.Rev.Lett.100:232002,2008

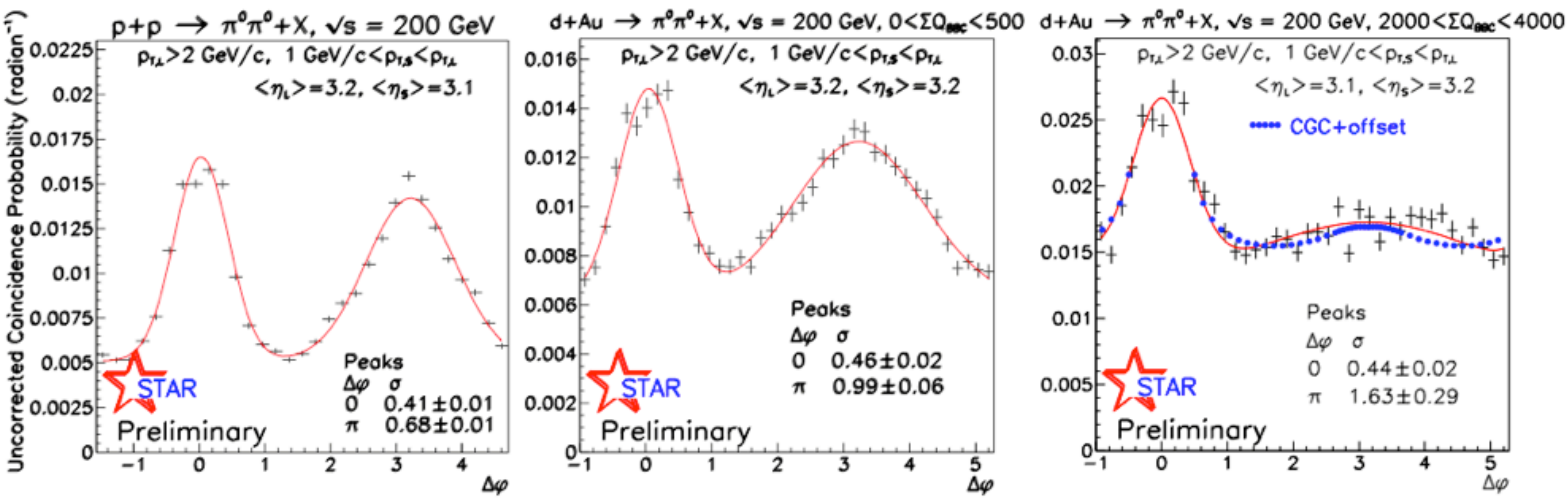
STAR - Selected Mid-rapidity Results



Experimental tour-de-force; RHIC √s = 500 GeV, STAR e/h discrimination, STAR e^+, e^-
Yields agree with expectations,
Next: precision, extend to forward region (FGT tracking upgrade).

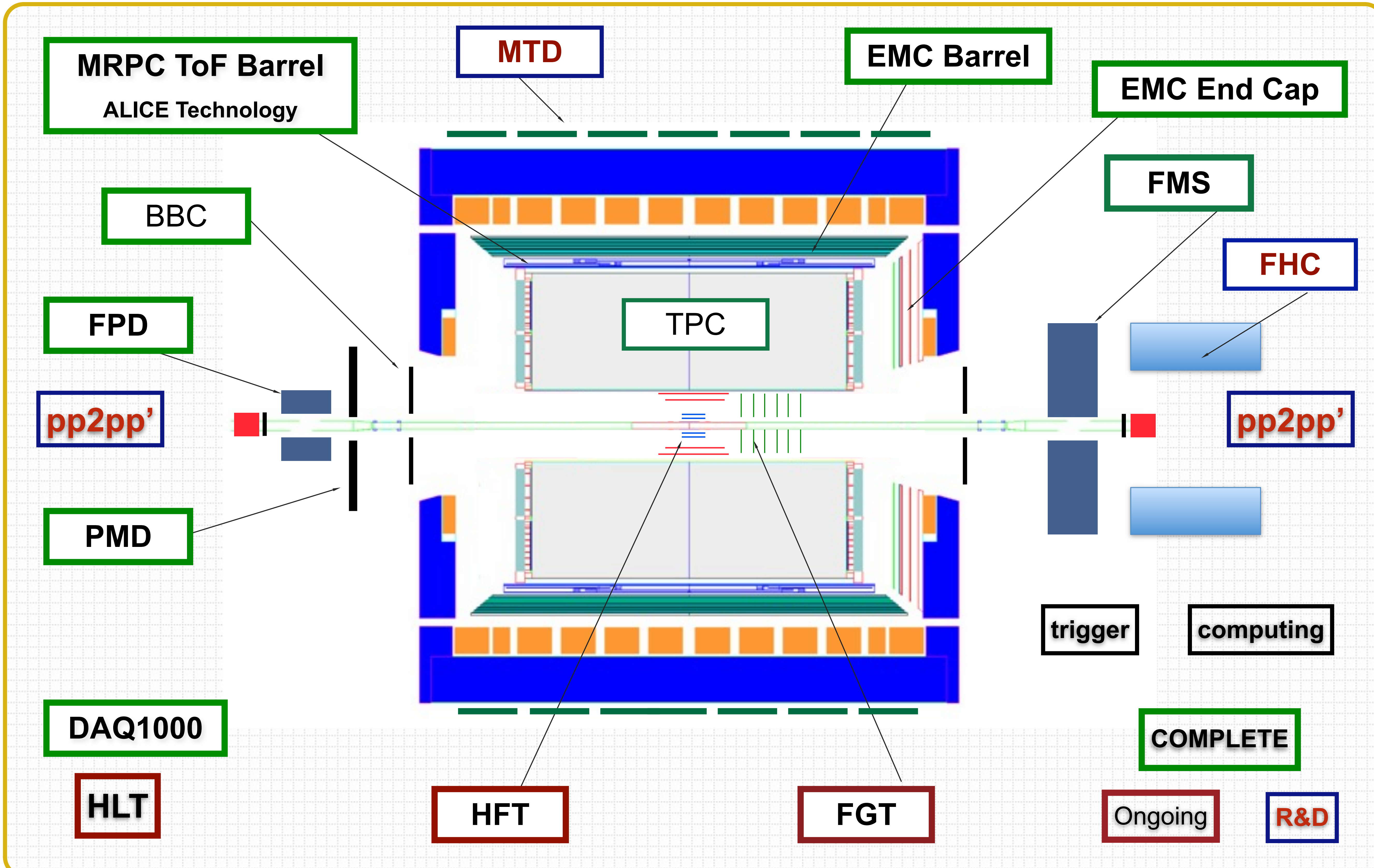
arXiv 1009.0362, submitted to Phys.Rev.Lett.

STAR - Selected Forward Results

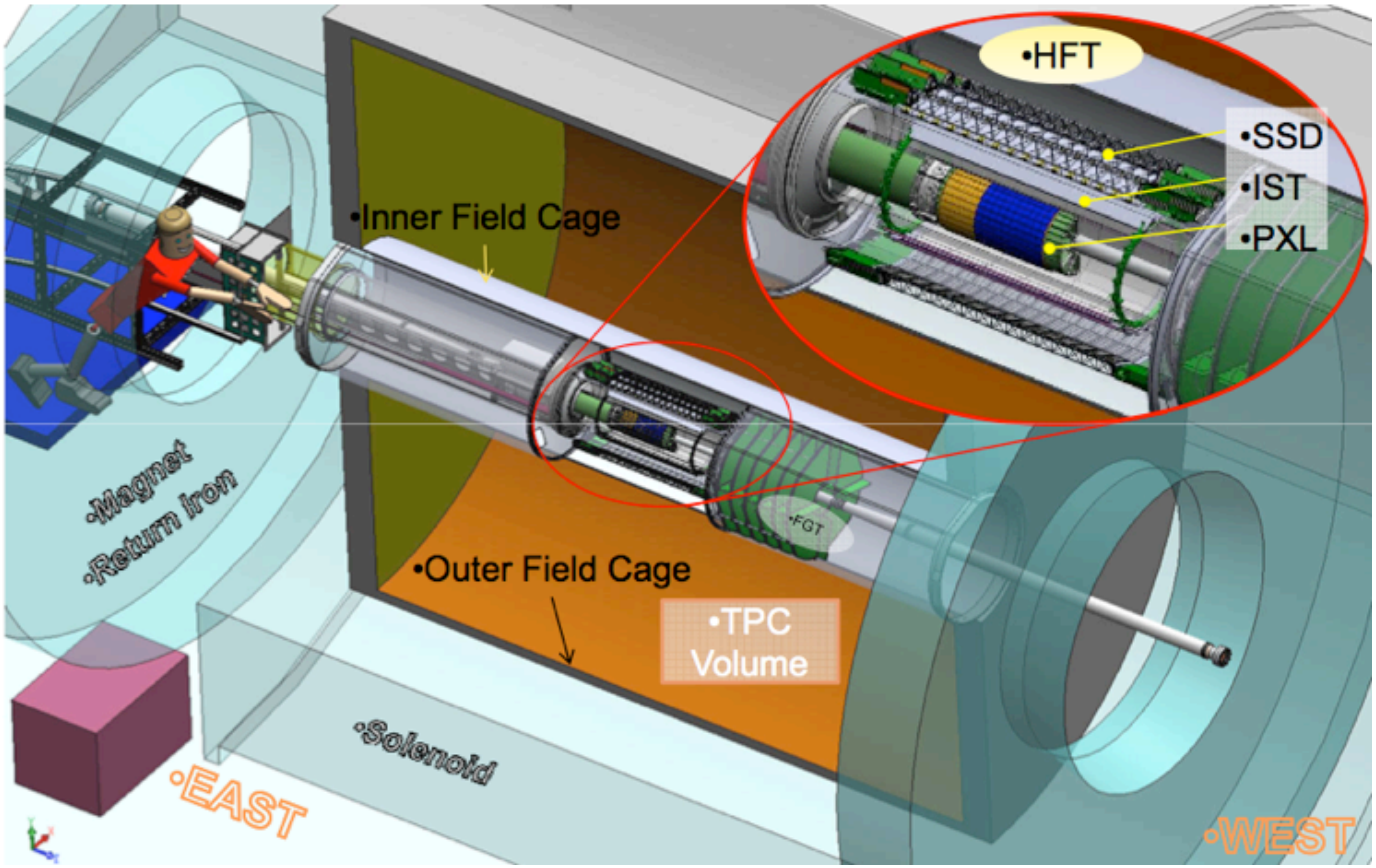


Ermes Braidot, *for the collaboration*, QM 2009

STAR Experiment - Upgrades



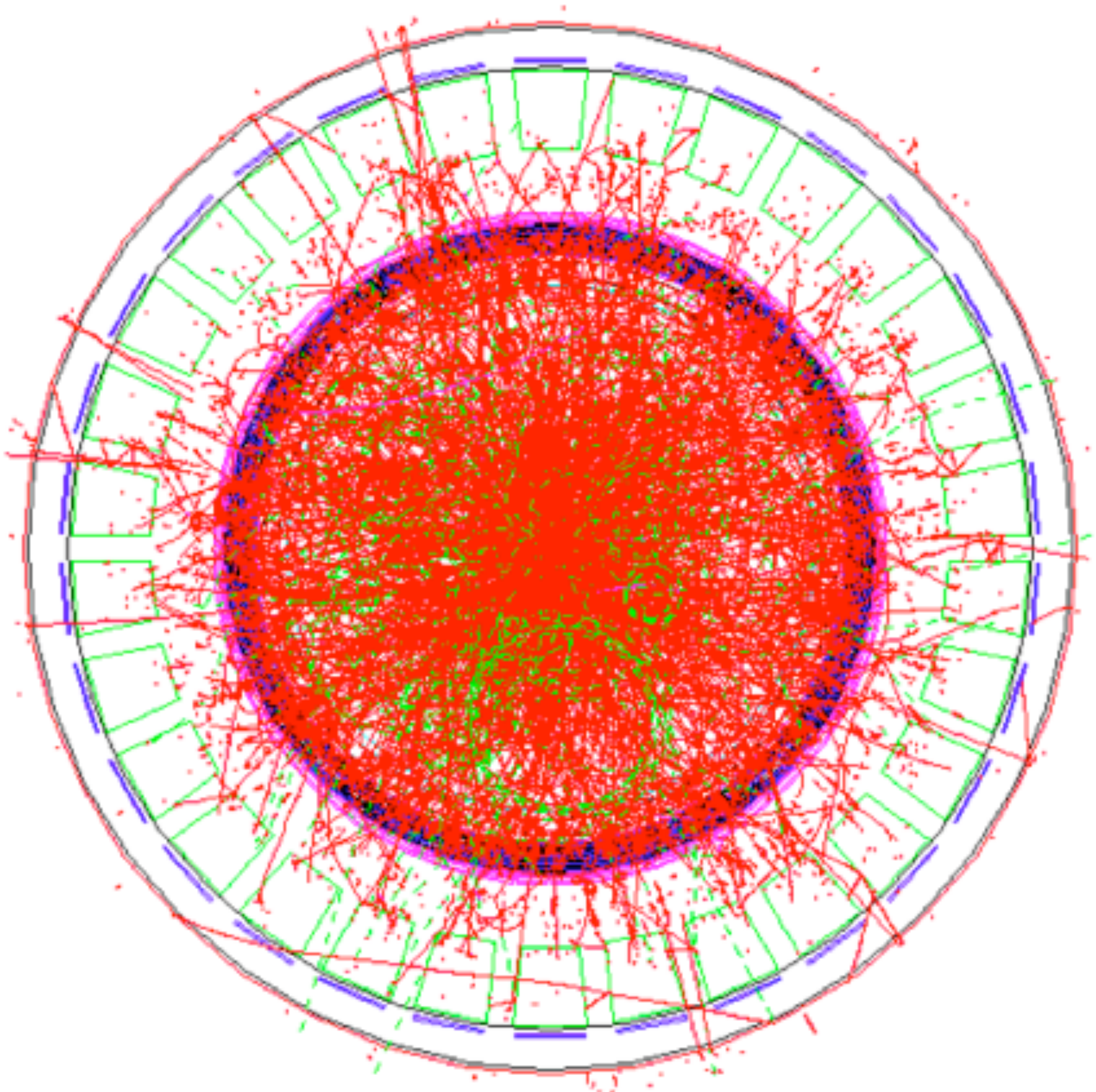
STAR Experiment - Tracking Upgrades

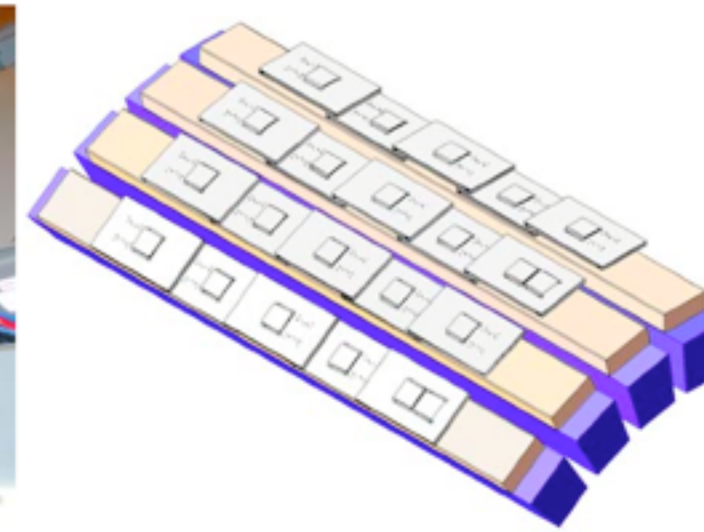


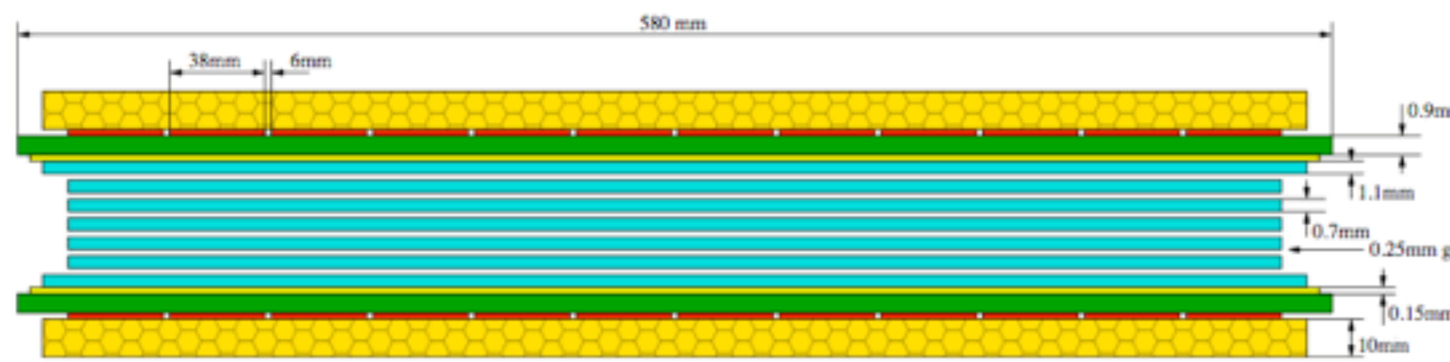
FGT: charge discrimination for forward electrons/positrons from W decay,
installation planned before run-12, ~3 year physics operation.

HFT: heavy quark measurements via precision topological identification of decays,
CD-1 approval as of August 31, 2010,
completion aimed for run-14, multi-year physics operation in Au+Au, p+p.

STAR Experiment - Muon Telescope Upgrade







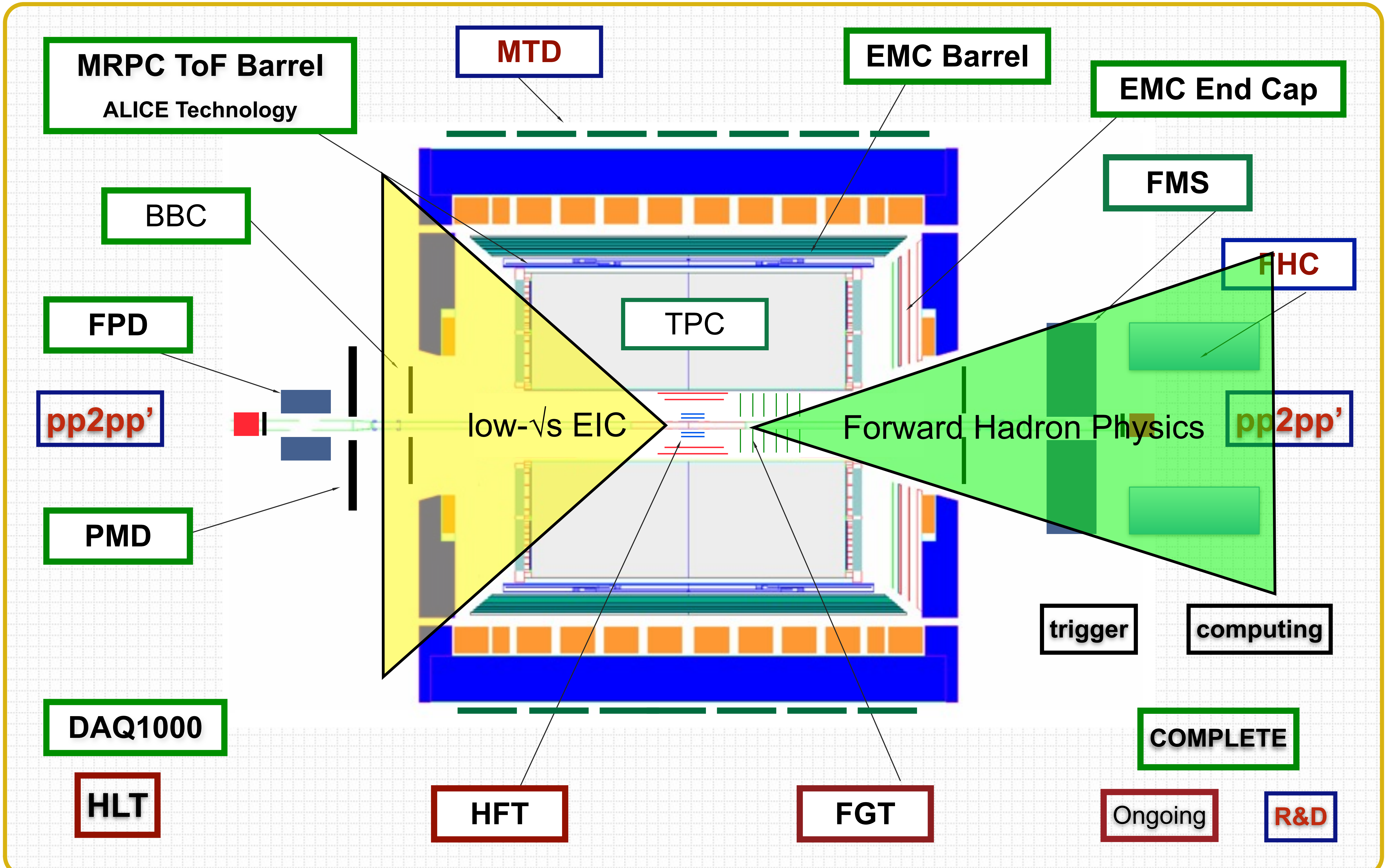
MTD: di-muon physics, Upsilon measurements with separation to 3 S-states, low p_T J/psi, electron-muon correlations.

long MRPCs covering the magnet iron bars while leaving the gaps in between uncovered;

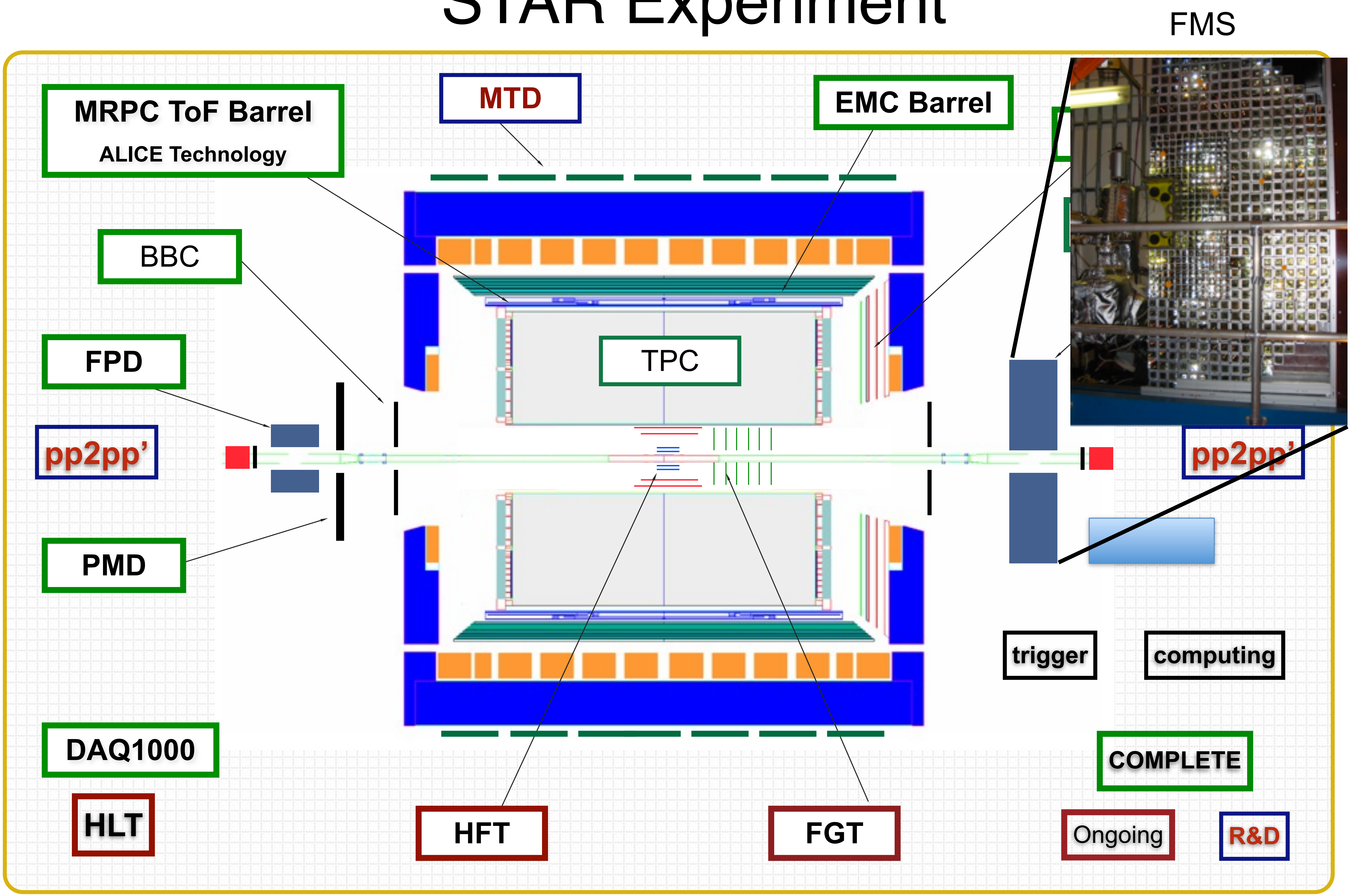
- ~45% acceptance for rapidity +/- 0.5,
- 117 modules, 1404 readout strips, 2808 readout channels,
- similar to STAR TOF.

Technically driven schedule: before run-14.

STAR Experiment - Upgrade Concepts



STAR Experiment

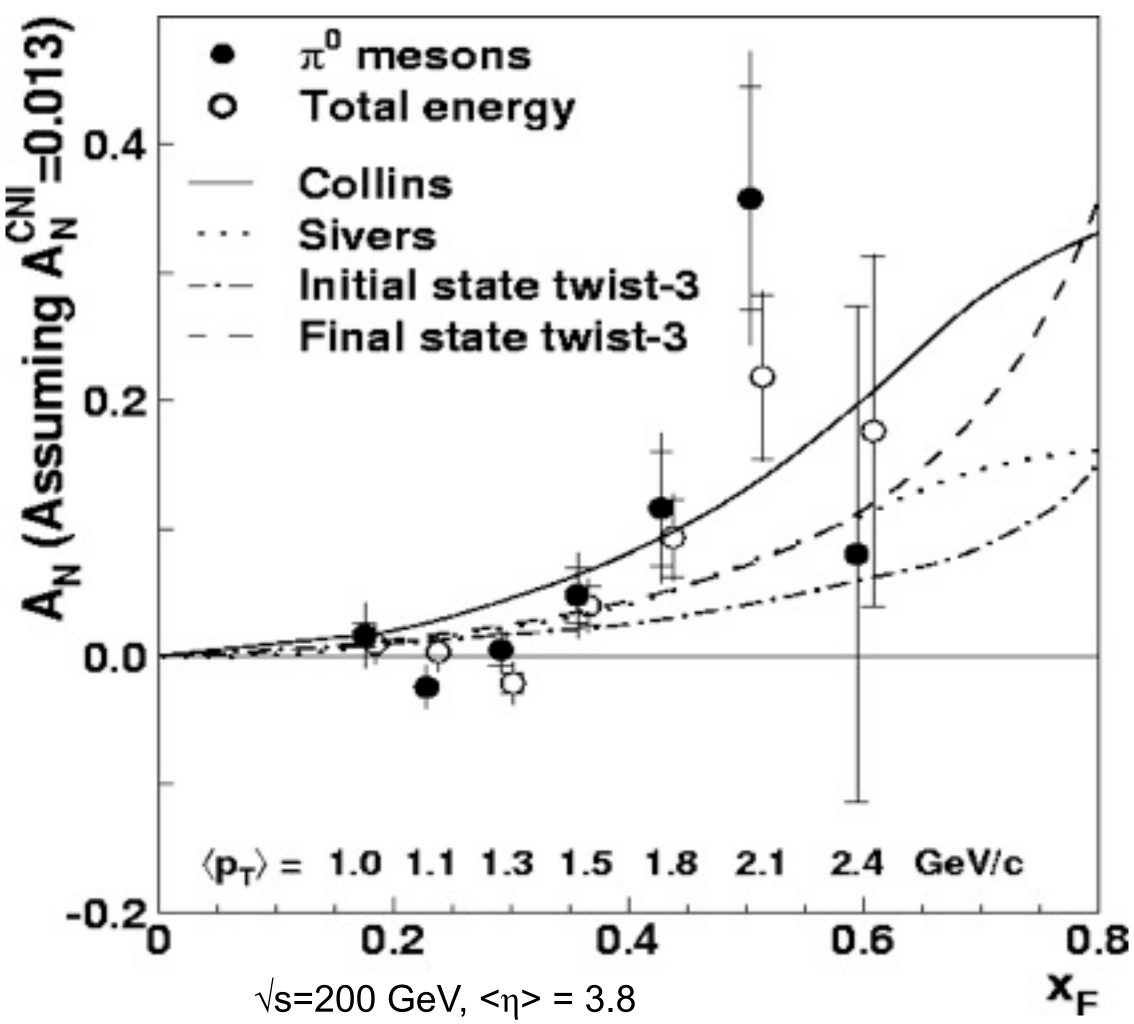


STAR - Transverse Spin Phenomena

Large A_N observed at $\sqrt{s}$ = 200 GeV, in the pQCD regime,

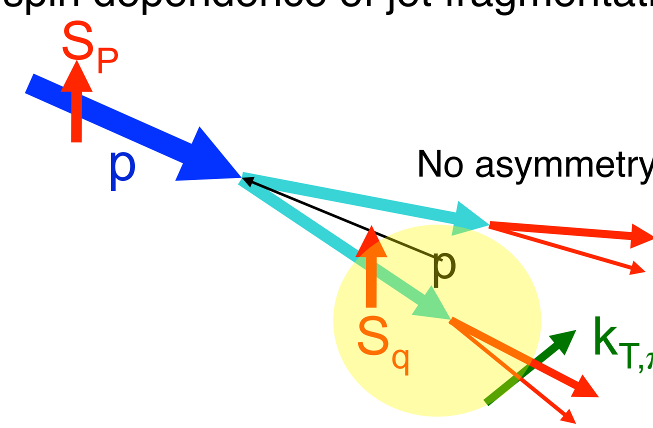
- what causes this?
- a path beyond collinear pQCD?

PRL 92, 171801 (2004)

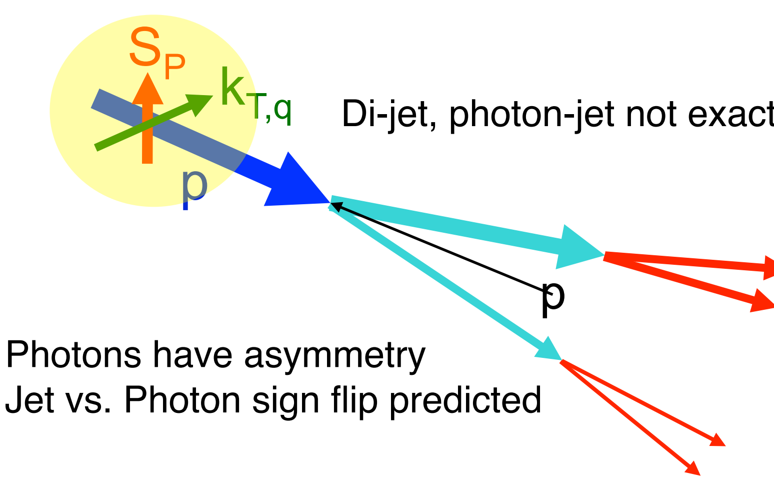


$\sqrt{s}$=200 GeV, <η> = 3.8

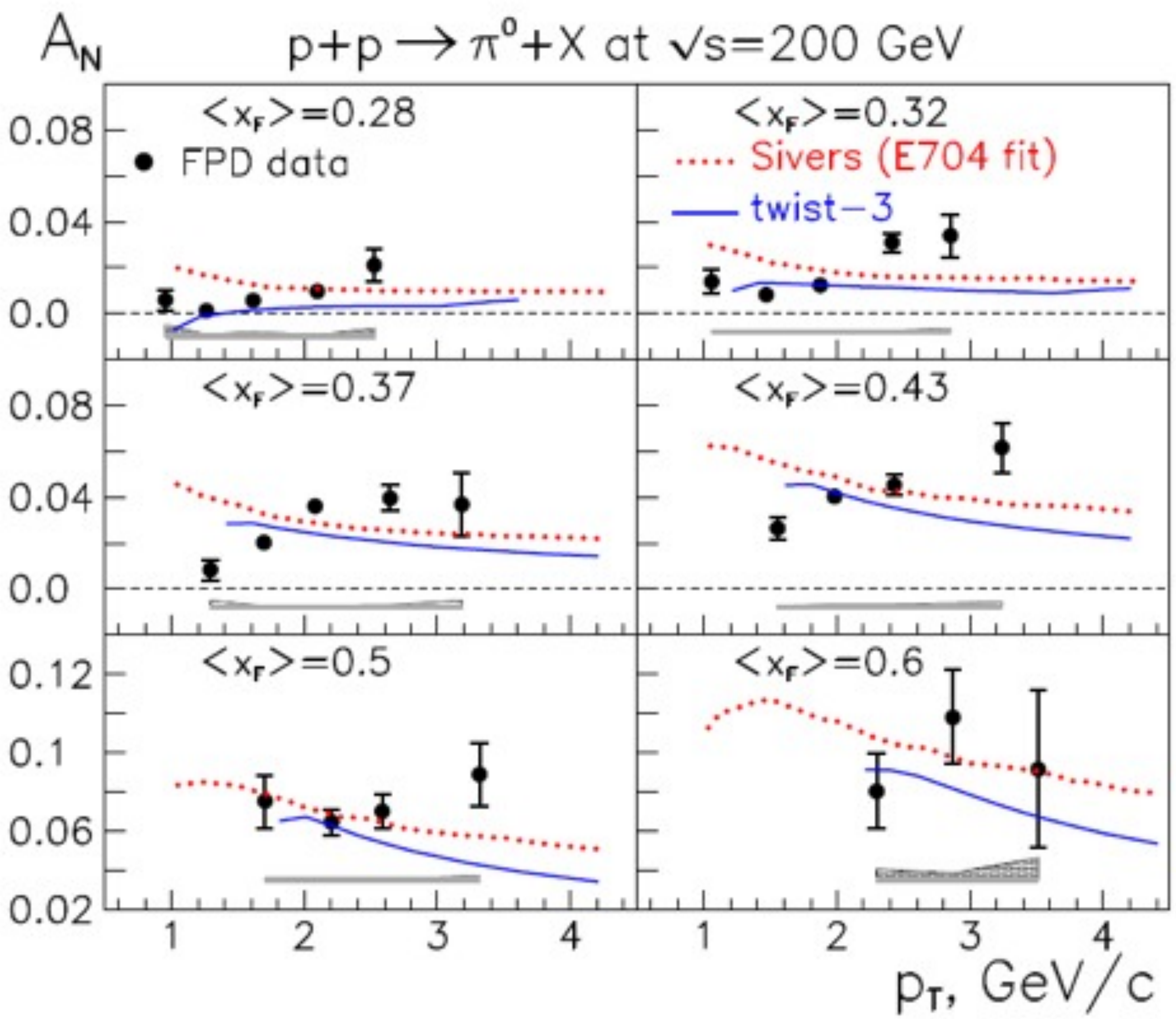
• **Collins effect**: asymmetry comes from the transversity and the spin dependence of jet fragmentation.



• **Sivers effect**: asymmetry comes from spin-correlated k_T in the initial parton distribution



    # STAR - Transverse Spin Phenomena



Phys.Rev.Lett.101:222001,2008

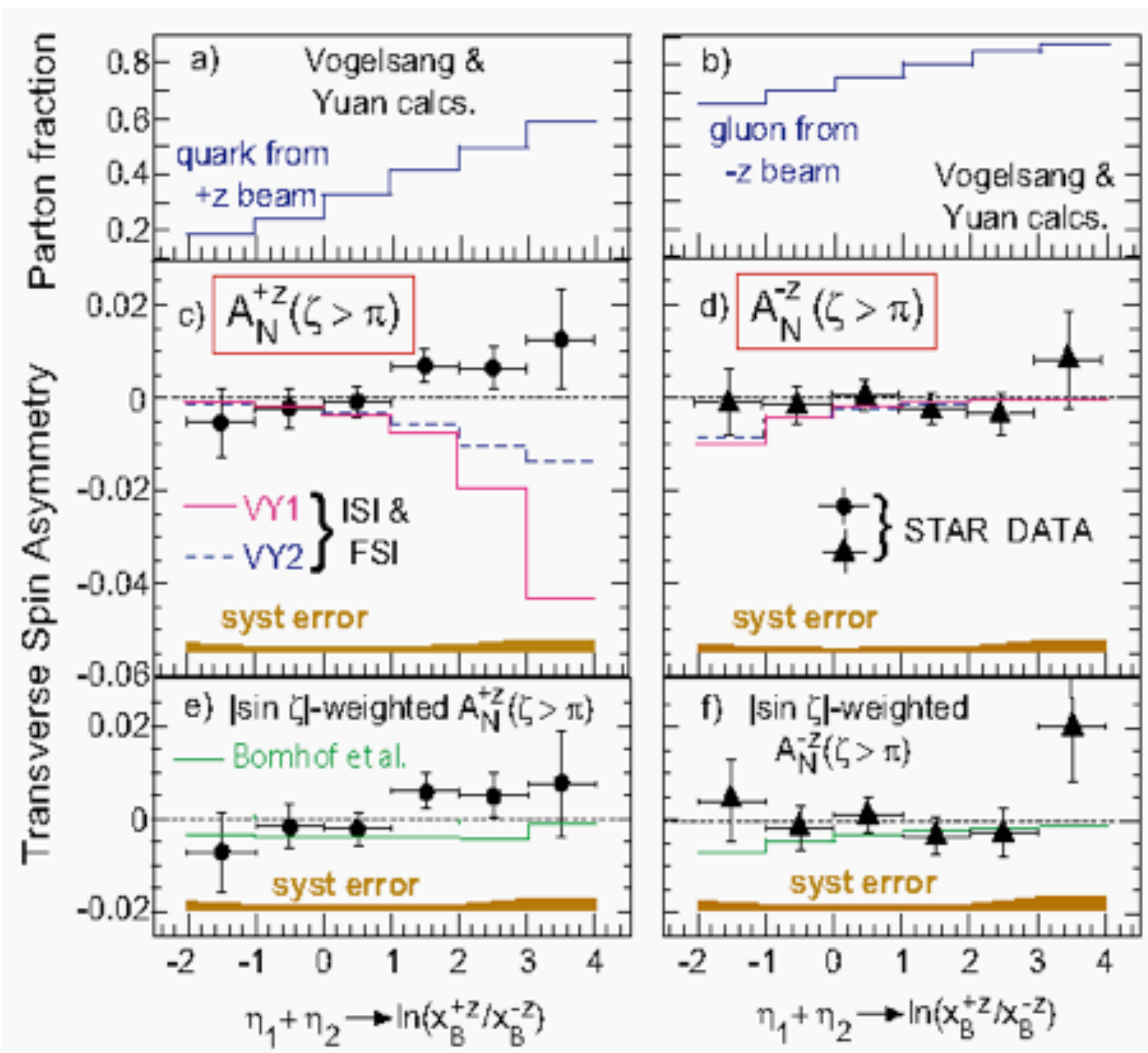
U. D'Alesio, F. Murgia, Phys. Rev. D **70**, 074009 (2004).

J. Qiu, G. Sterman, Phys. Rev. D **59**, 014004 (1998).

Model calculations can qualitatively explain x_F dependence of large A_N,

Models fall short for the p_T dependence,

STAR - Transverse Spin Phenomena



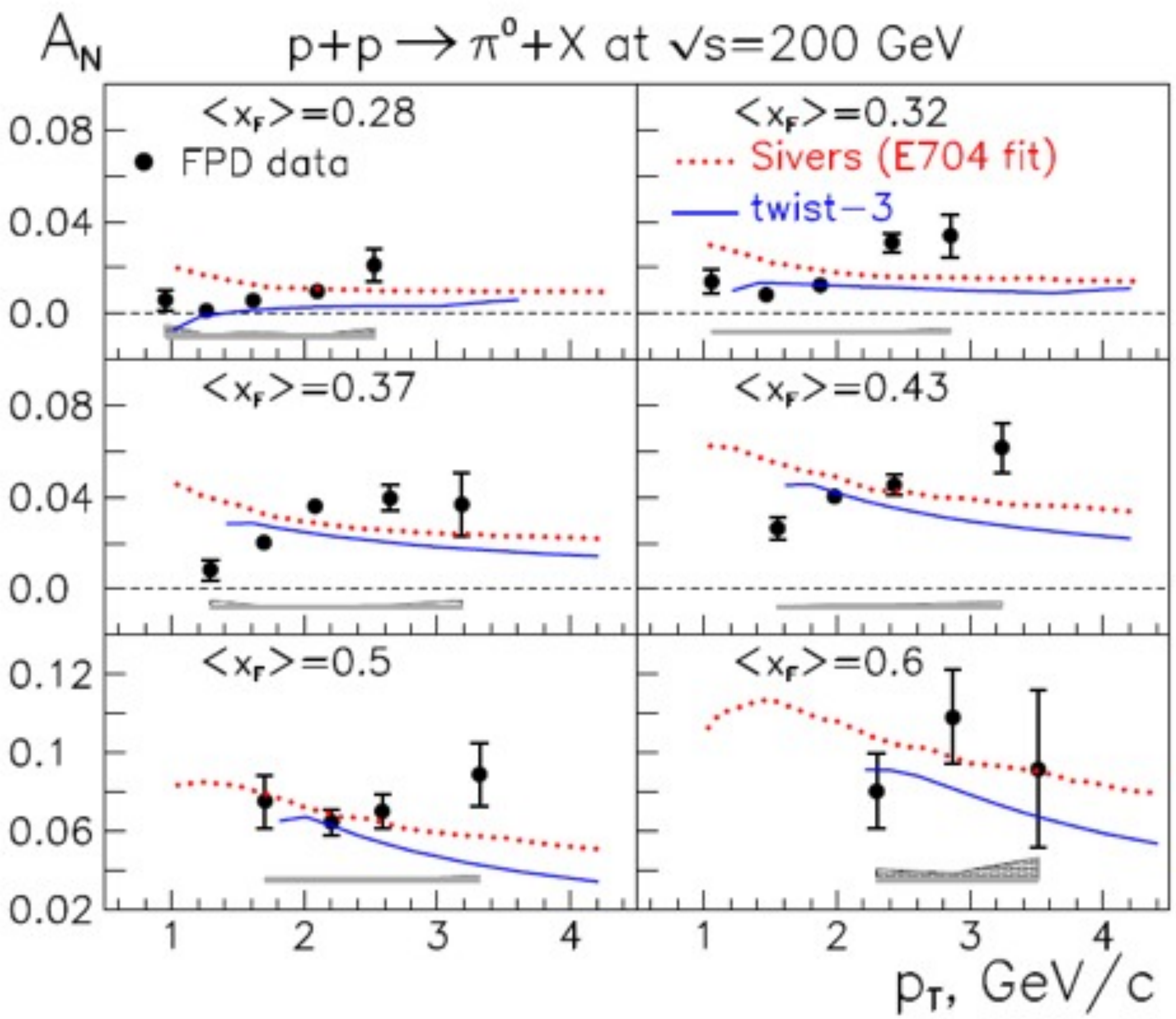
B. Abelev et al, Phys.Rev.Lett.99:142003,2007.

Model calculations can qualitatively explain x_F dependence of large A_N,

Models fall short for the p_T dependence,

We have probably learned what can be learned at mid-rapidity,

STAR - Transverse Spin Phenomena



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Model calculations can qualitatively explain x_F dependence of large A_N,

Models fall short for the p_T dependence,

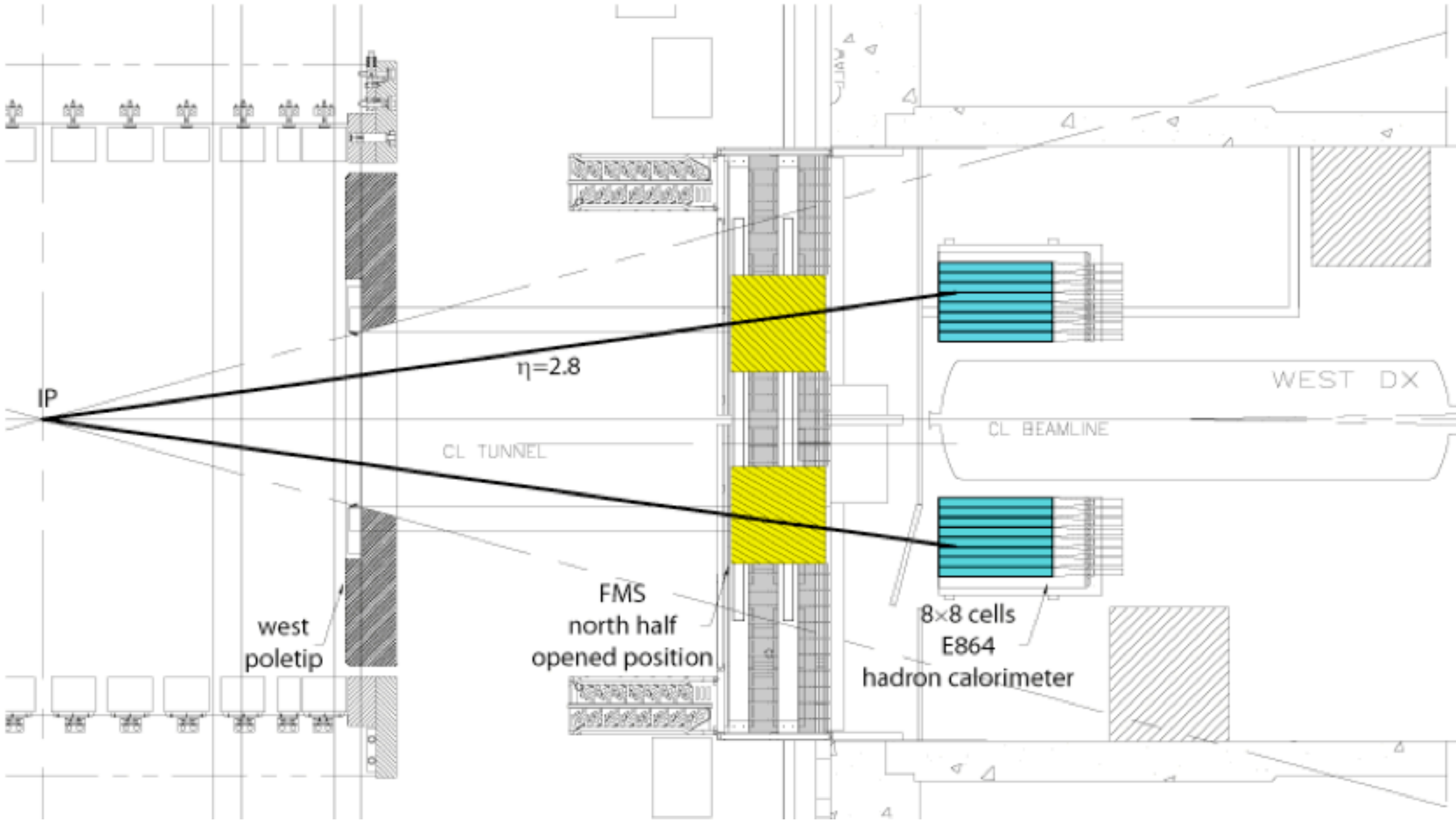
STAR aims to:

- extend the p_T range,
- step beyond inclusive pions to etas, Lambdas, jet(-like) events, photons ($\sqrt{s}$ = 200 GeV), correlations, and ultimately DY

FMS is key to each of these.

Feasibility of A_N for W, Z being studied.

STAR Experiment - Forward Upgrades

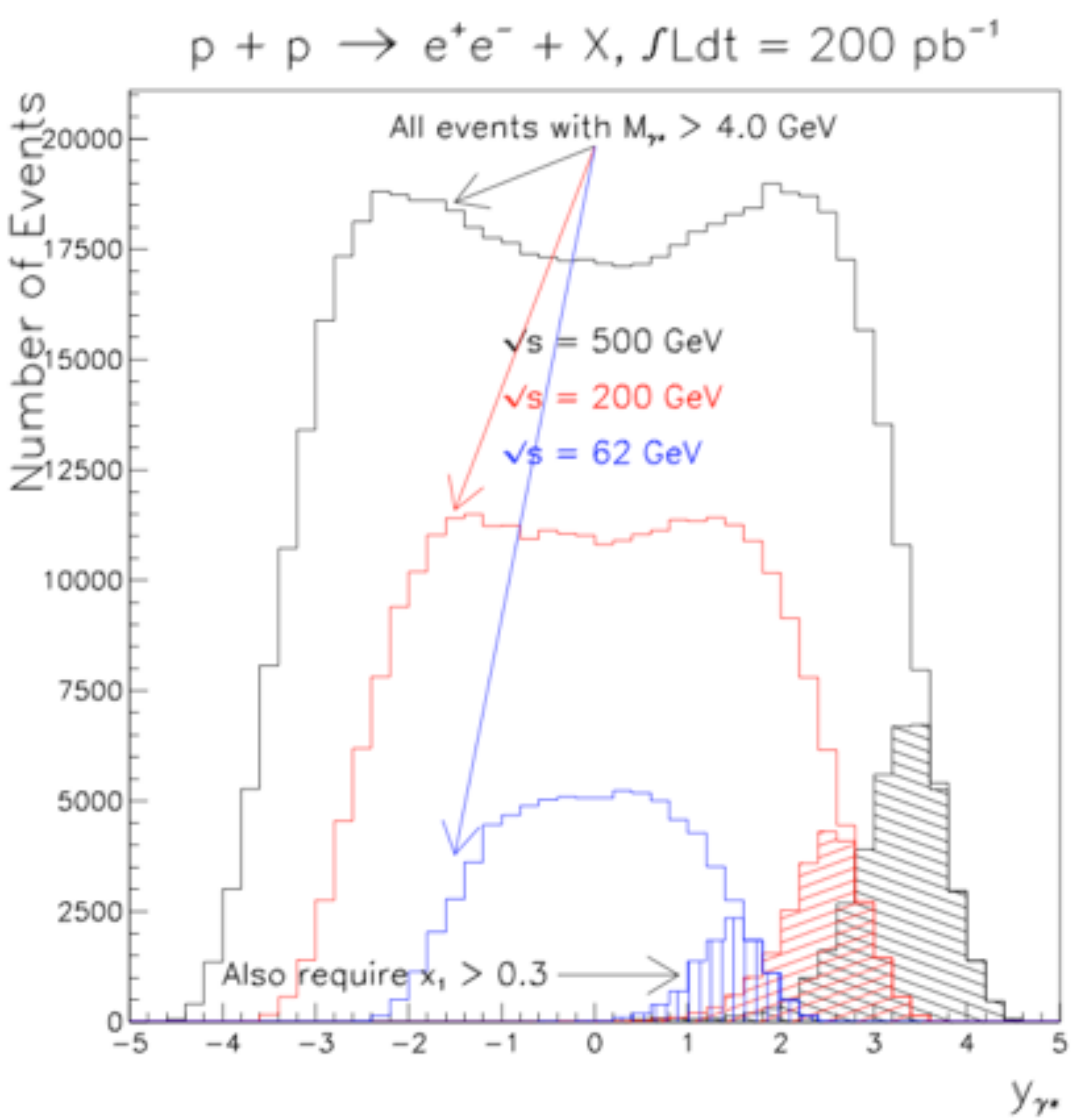


FHC: proposed hadronic calorimetry behind the FMS,
essential towards understanding of forward single-spin asymmetries,
enable forward (anti-)Lambda studies, ...

Would be part of a broader forward upgrade concept that is currently being discussed/studied within STAR,
e.g. extended tracking in the form of additional FGT-like disks,
preshower or TRD, converter, and shower-maximum detector for the FMS,
possibly a RICH to separate protons and advanced trigger.

Drell-Yan

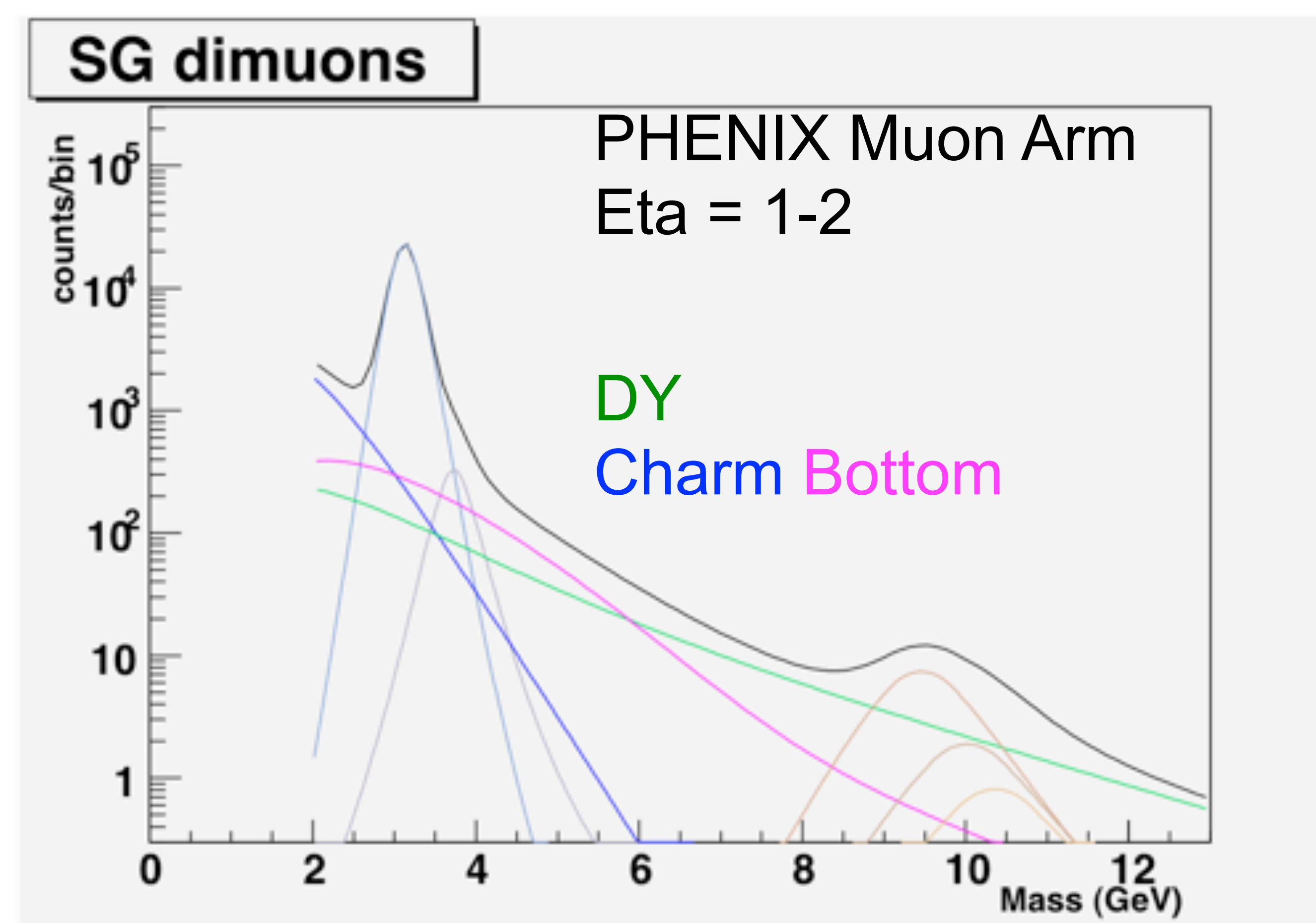
DY : ~7 x 10^{-5} mb at √s = 500GeV → 10^6 → **Hadronic : ~30mb**



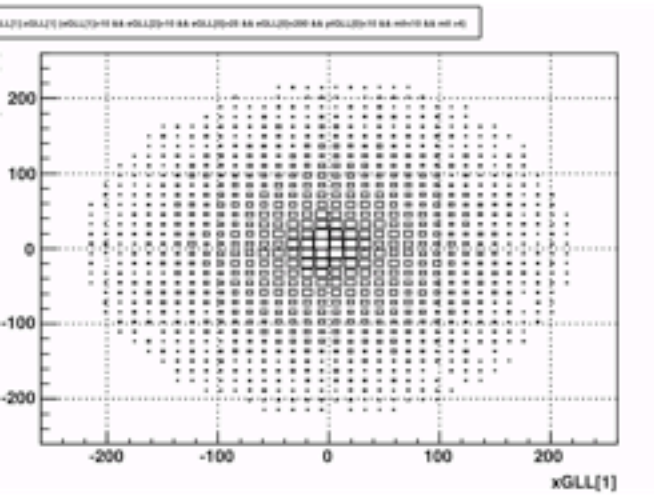
http://spin.riken.bnl.gov/rsc/write-up/dy_final.pdf

Hadron and photon backgrounds
Charm and bottom backgrounds

Background simulations ~10^{11} events.

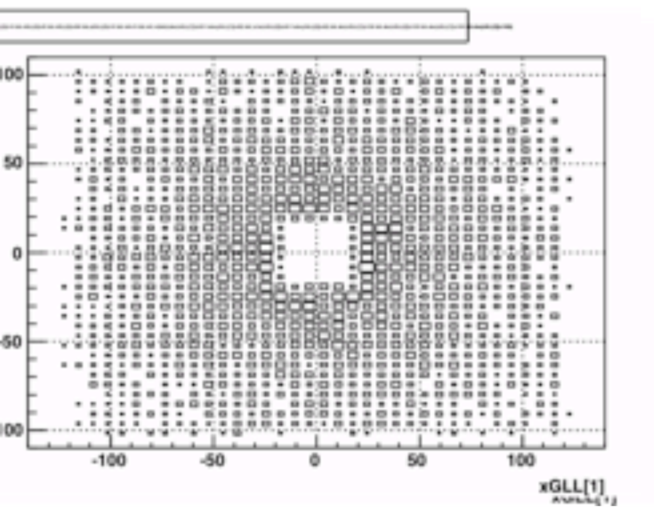


Drell-Yan Signal



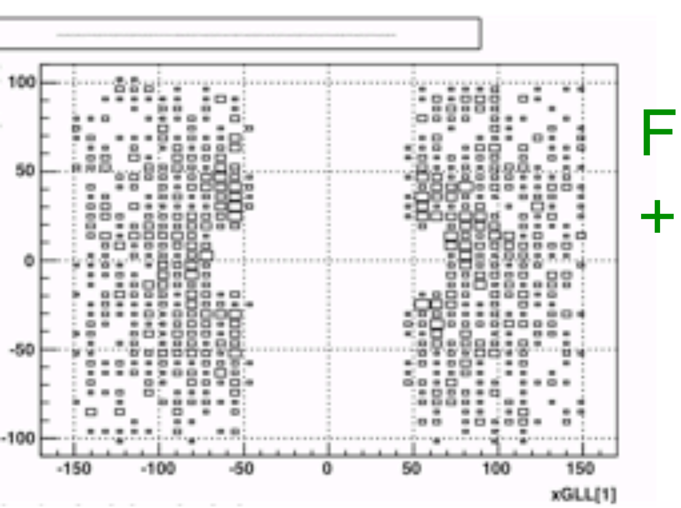
Everything $\eta>2$

14799 events



FMS closed
(FHC cannot
be closed due
to DX magnet)

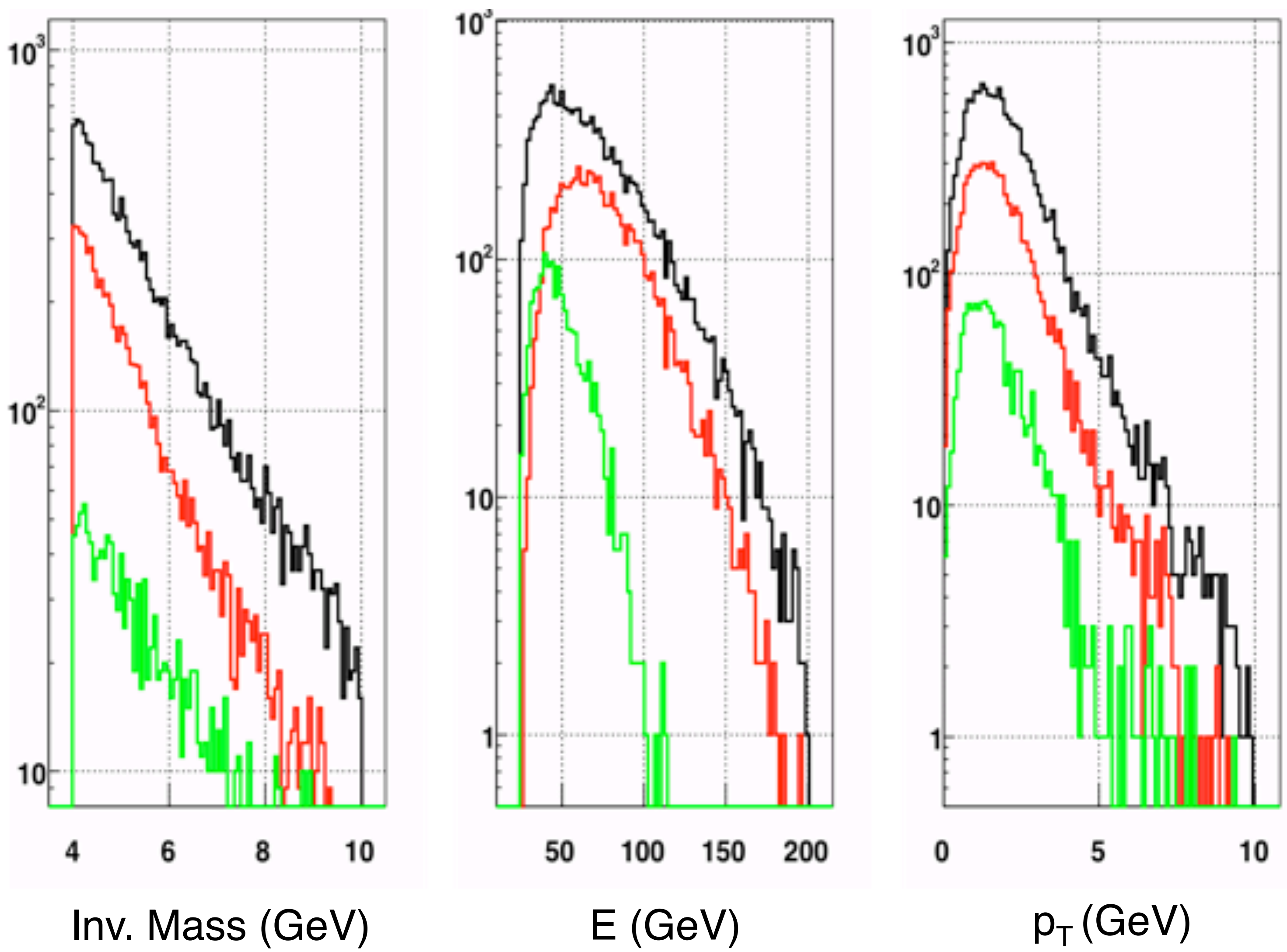
6512 events



FMS open (x=50cm)
+ FHC (x=60cm)

1436 events
(1/5 from closed)

pythia 6.222, p+p @ $\sqrt{s}$ = 500 GeV
4M DY events/7.10^{-5}mb ~ 60/pb
e^{+-} energy > 10GeV, and $\eta>2$
$x_F>0.1$ (25GeV)
4 GeV < invariant mass < 10 GeV

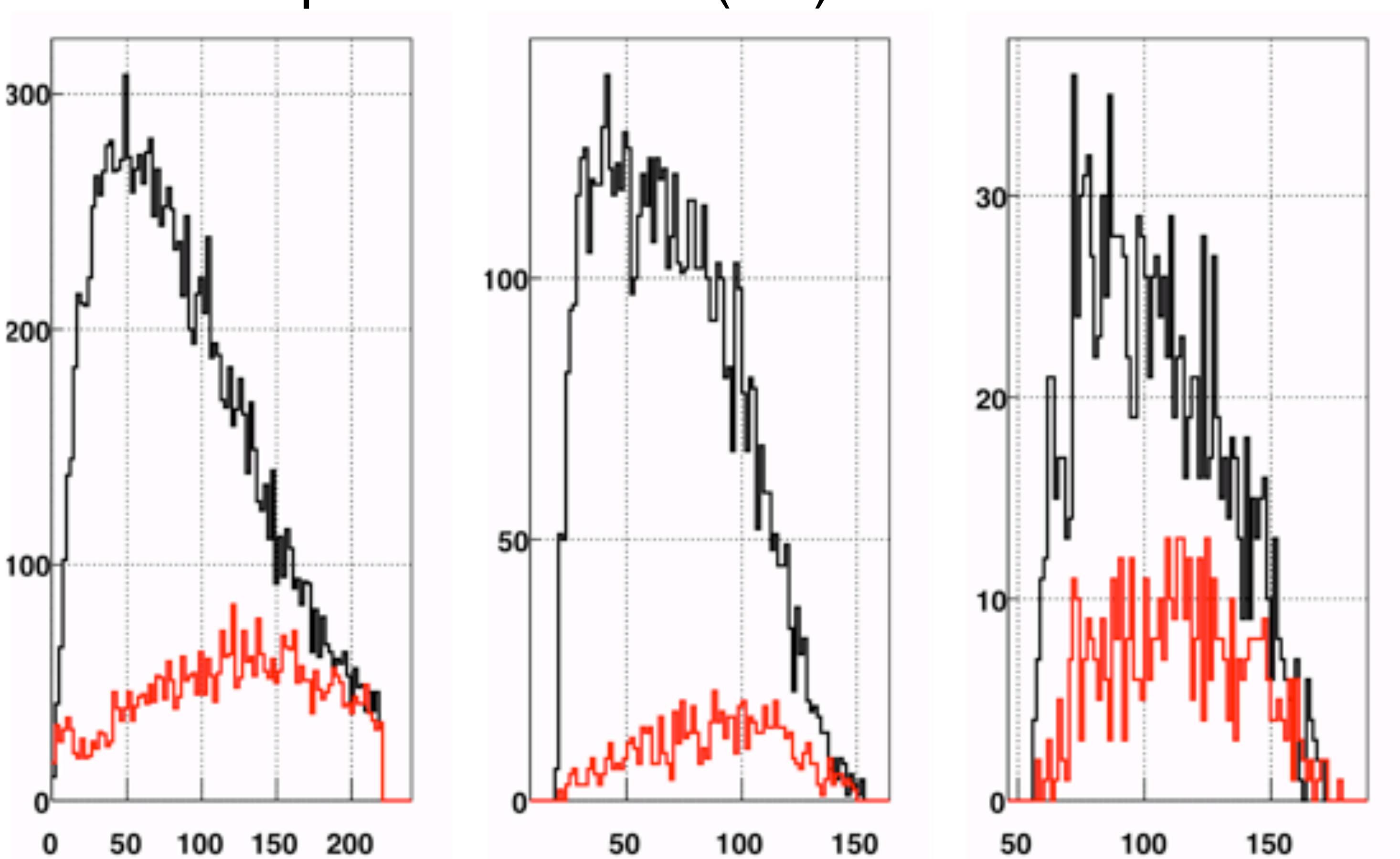


High-x_F Drell-Yan at STAR - Needs

- High $\eta > 4$ coverage,
- Additional *e/h* separation ~ 10^{-3} per hadron
- Additional e/γ separation ~ 10^{-3}, incl. $\gamma \to e^+e^-$
- Trigger upgrades,
- Forward tracking for charge-like and -unlike signs (?)
- Infrastructure
- ...

Direct Bottom Backgrounds - Drell-Yan

Electron/position radius (cm) from beam at FMS



Everything η>2 | FMS closed | FMS open (x=50cm) + FHC (x=60cm)

pythia 6.222, p+p @ $\sqrt{s}$ = 500 GeV
4M DY events/7.10^{-5}mb ~ 60/pb
e^{+-} energy > 10GeV, and η>2
x_F>0.1 (25GeV)
4 GeV < invariant mass < 10 GeV
300M B events/5.10^{-3}mb ~ 60/pb

DY
Direct B

FMS closed : small at high x_F and high eta; mostly unlike sign
FMS opened + FHC : significant at low x_F and small eta

Hadron, Photon Backgrounds - Drell-Yan

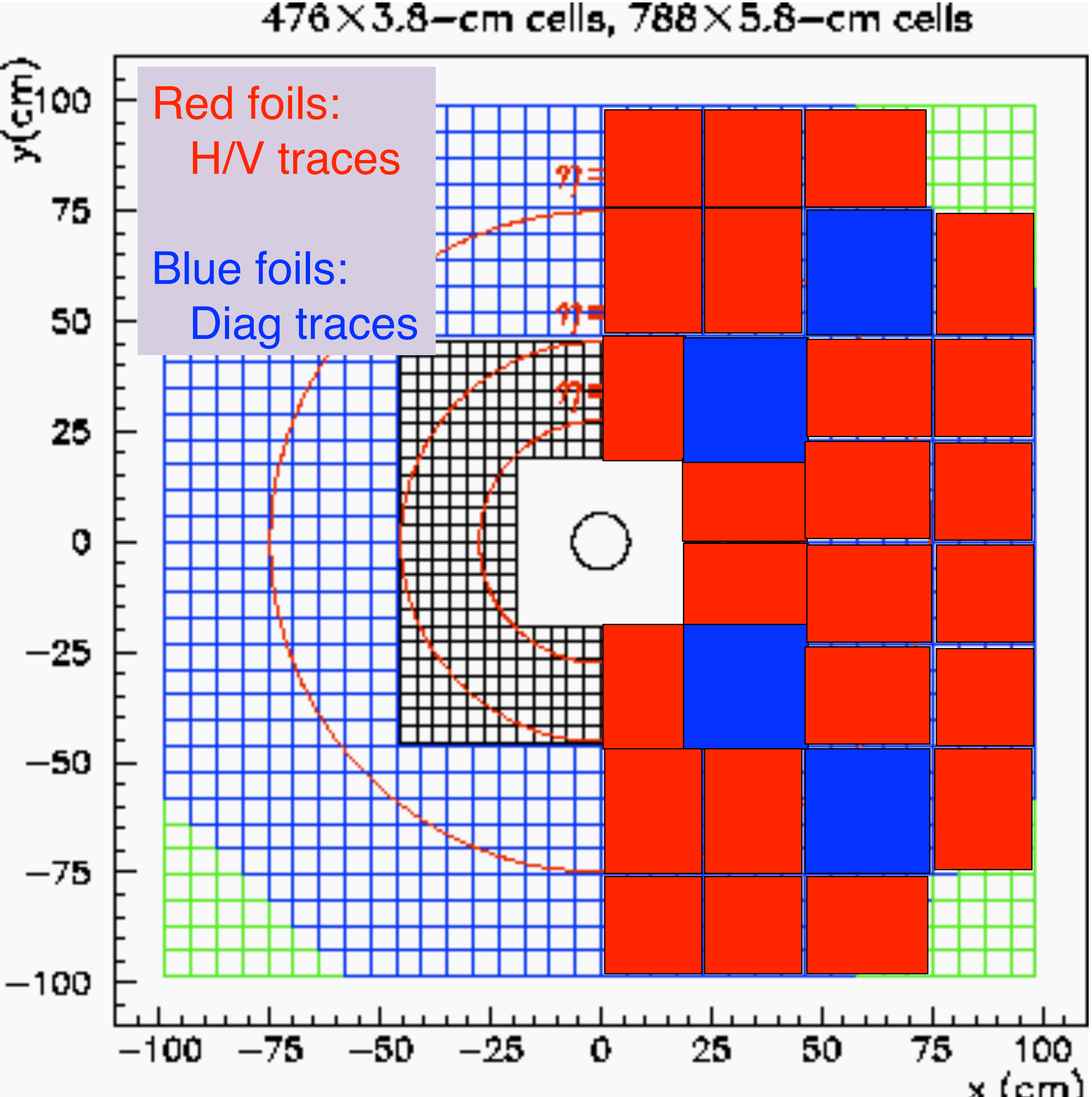
Hadron rejection:

FMS (EM-cal, rarely measures full hadronic energy),
FMS + FHC veto $\sim$ 10^{-1} - 10^{-3}, depending on energy
but note the space constraints!
Converter and early shower detector $\sim$ 10^{-1}
Electron-ID, in the form of a TRD or TR-Tracker $\sim$ 10^{-1} - 10^{-2}
Off-line *E*-over-*p*; hard, initial insights from 200 GeV analysis,
will require detailed tracking simulation,
Off-line shower-shape analysis; needs study.

Photon rejection:

Neutral veto in pre-shower detector $\sim$ 10^{-2}
Conversions in beam-pipe - thin pre-shower with good resolution
Off-line π^0 etc. reconstruction, tracking $\sim 10^{-1}$

Pre-shower and Early-shower concept



GEM based

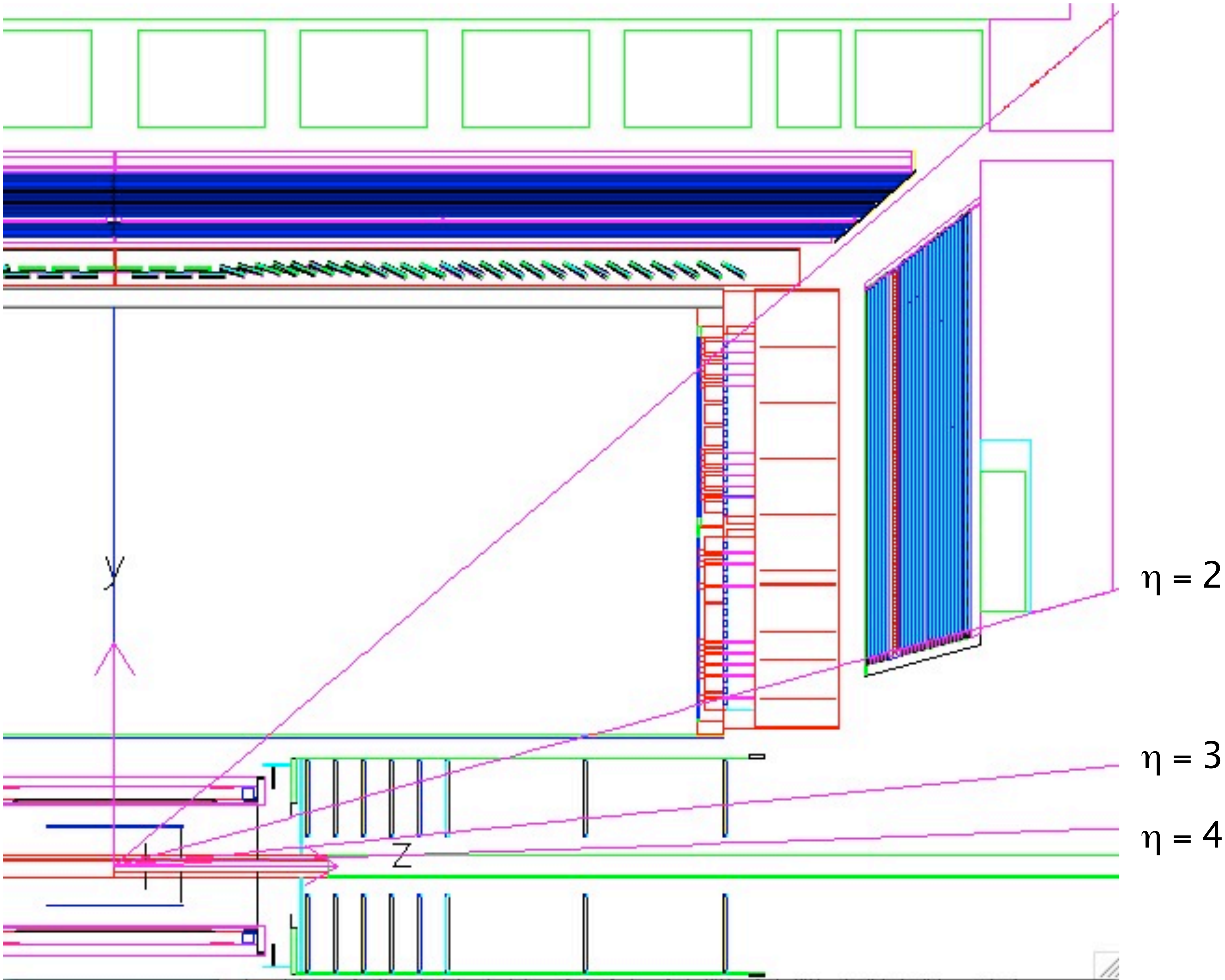
Pre-shower
0.3mm – 0.9mm pitch
55k channels

~2 X_0 Pb Converter

Early-shower
2mm -3mm pitch
11k channel

Total 66k channels

Tracking concept - Far Foward GEM Tracker



(My) Concluding Remarks

Opportunity to study Drell-Yan with STAR at RHIC in the 2nd half of the decade,

Precision at % level would seem feasible with $O(10^2)$ pb^{-1},

High $\sqrt{s}$ = 200-500 GeV appears attractive; spin (p+p) and low-*x* (d+Au)

Evolutionary Detector Upgrades Required; shower detectors, electron ID

Very clear need for R&D; $\sqrt{s}$ = 500 GeV environment, (lack of) need for tracking, ...