STAR and meRHIC

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STAR: A Correlation Machine

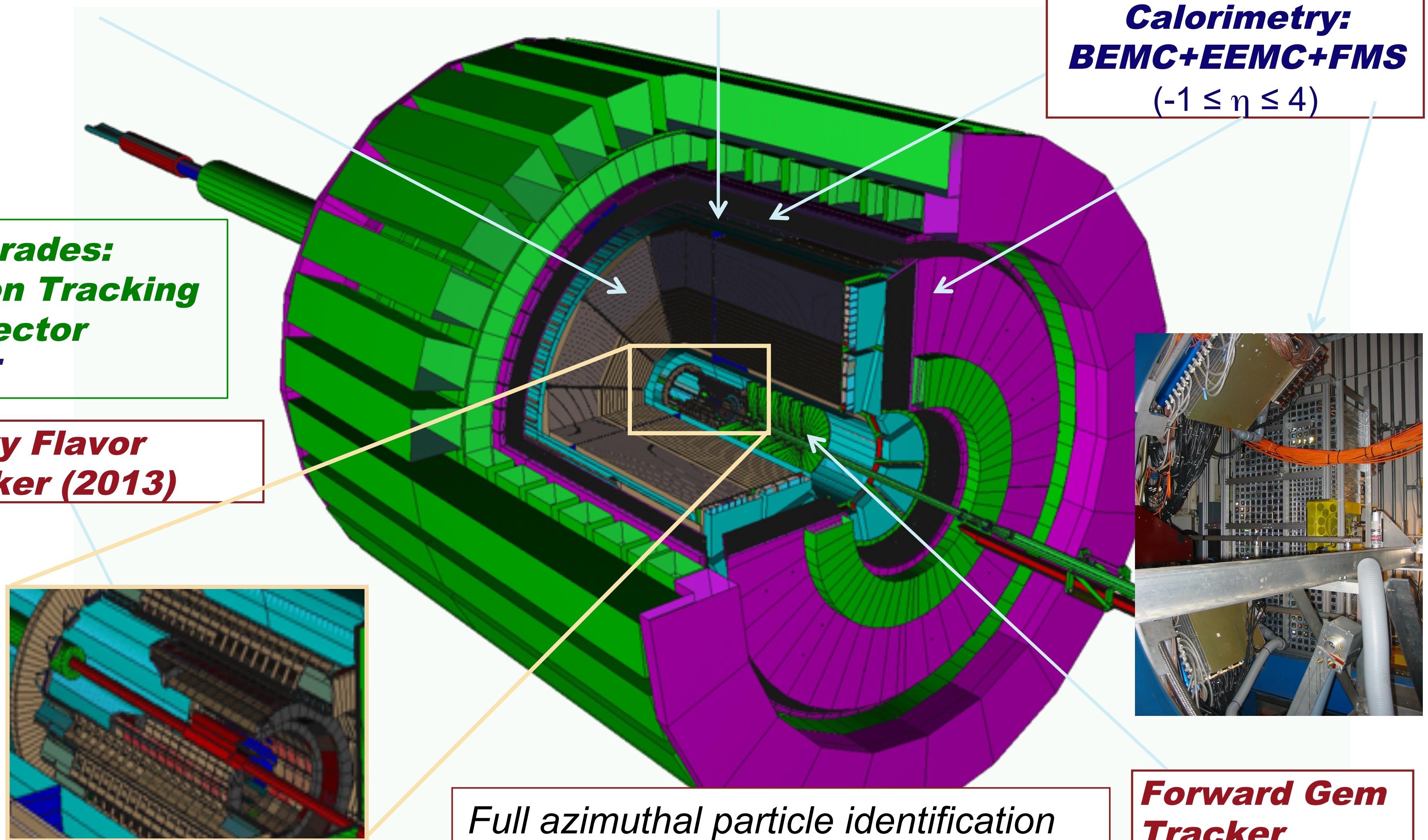
Tracking: TPC

Particle ID: TOF

Electromagnetic Calorimetry: BEMC+EEMC+FMS
($-1 \leq \eta \leq 4$)

Upgrades:
Muon Tracking Detector
HLT

Heavy Flavor Tracker (2013)



Full azimuthal particle identification over a broad range in pseudorapidity

Forward Gem Tracker (2011)

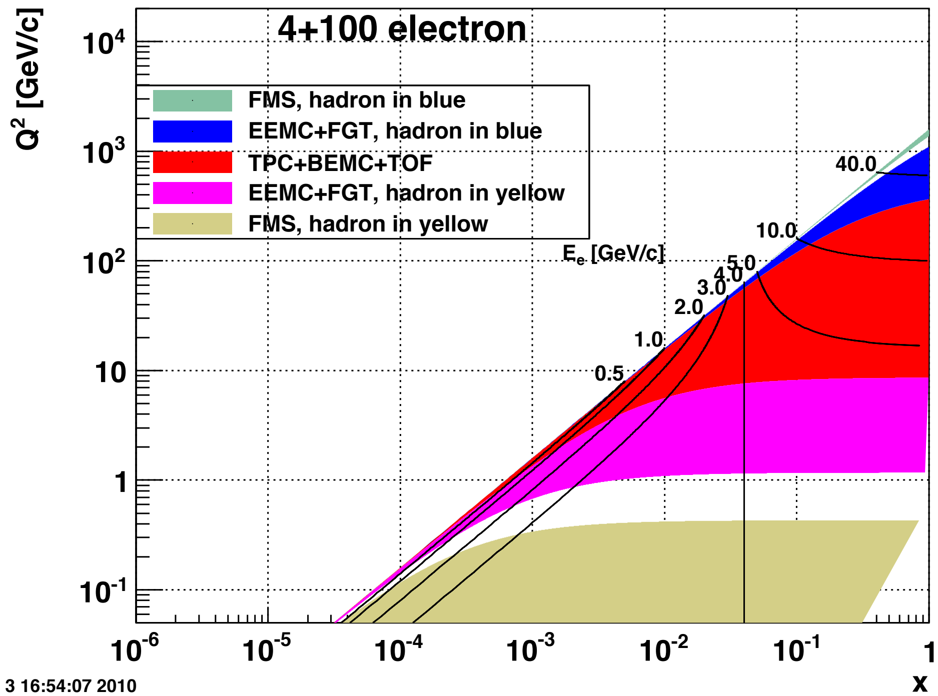
Asymmetric Coverage

- STAR asymmetric: forward detectors face the Blue Beam
  - $\eta < -1$ (facing the Yellow Beam): Empty of detectors
    - Services for the HFT (2014) with lots of material

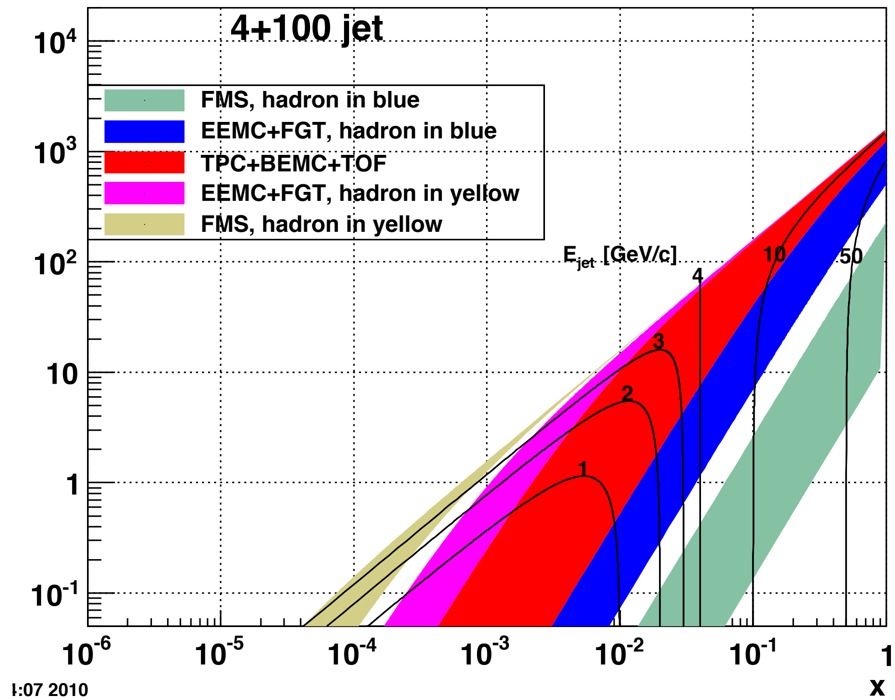
      OR
    - New instrumentation with a major rework of the HFT (or no HFT)
  - TOF+BEMC+TPC: $-1 < \eta < 1$
    - Excellent PID, electron id, proven jet finding to 50 GeV
  - EEMC + FGT: $1 < \eta < 2$ (facing the Blue Beam)
    - Proven EM Calorimetry, new tracking (FGT) optimized for high-E electrons
    - Capabilities for electrons of ~few GeV and hadronic portion of jets need investigation and likely upgrades
  - FMS: $2.5 < \eta < 4$ (facing the Blue Beam)
    - Proven EM calorimetry
    - No tracking at all. Upgrade needed, may need new magnet
  - Upstream (symmetric) Roman pots: upgrade ready by ~mid-decade
  - ZDC's existing and proven on both sides

Kinematics at 4+100

Scattered electron



Scattered jet



4+100 open kinematics: scatters the electron and jet to mid-rapidity

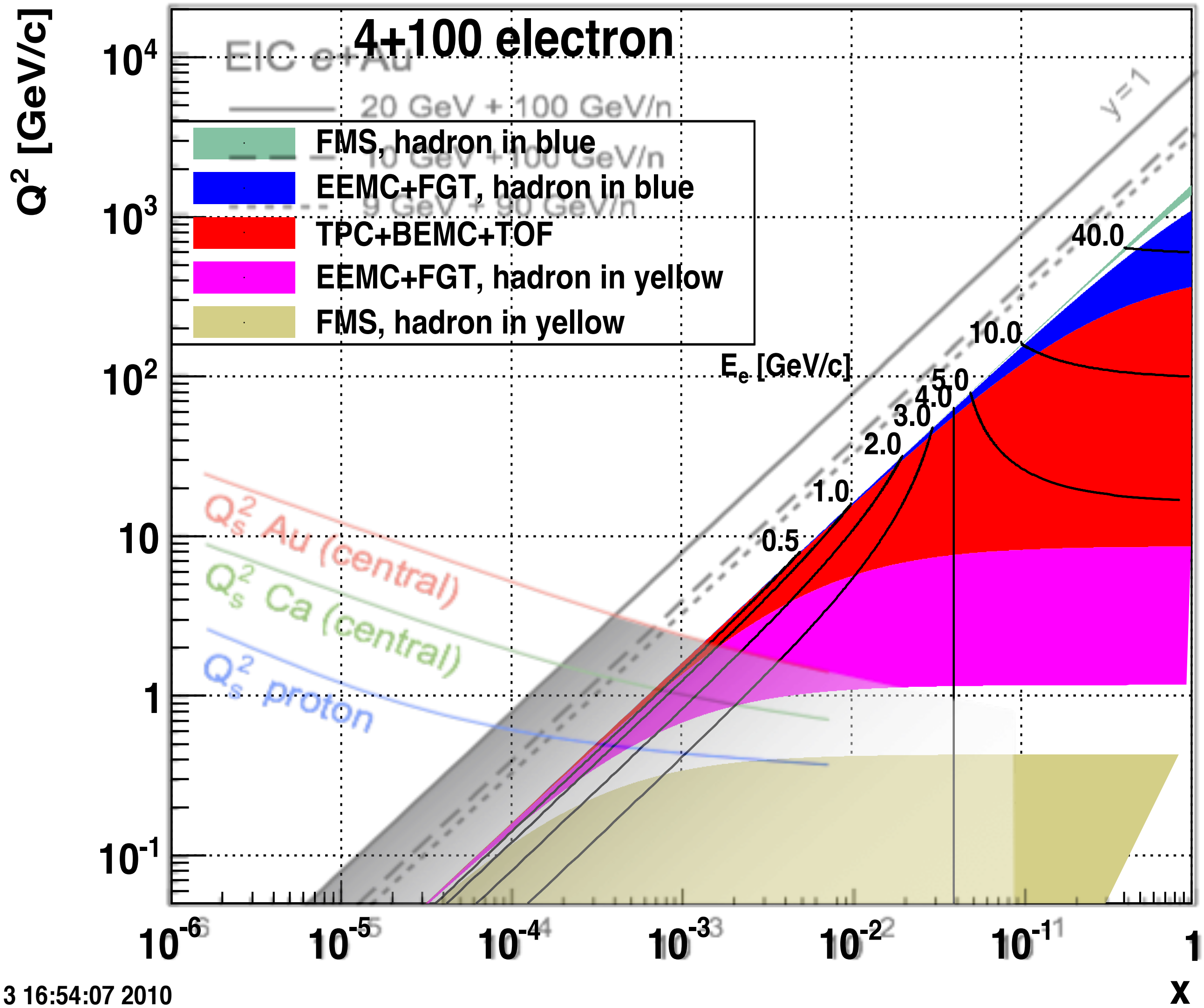
Forward region (FMS): Electron either $Q^2 < 1$ GeV, or very high x and Q^2

Jet either very soft or very hard

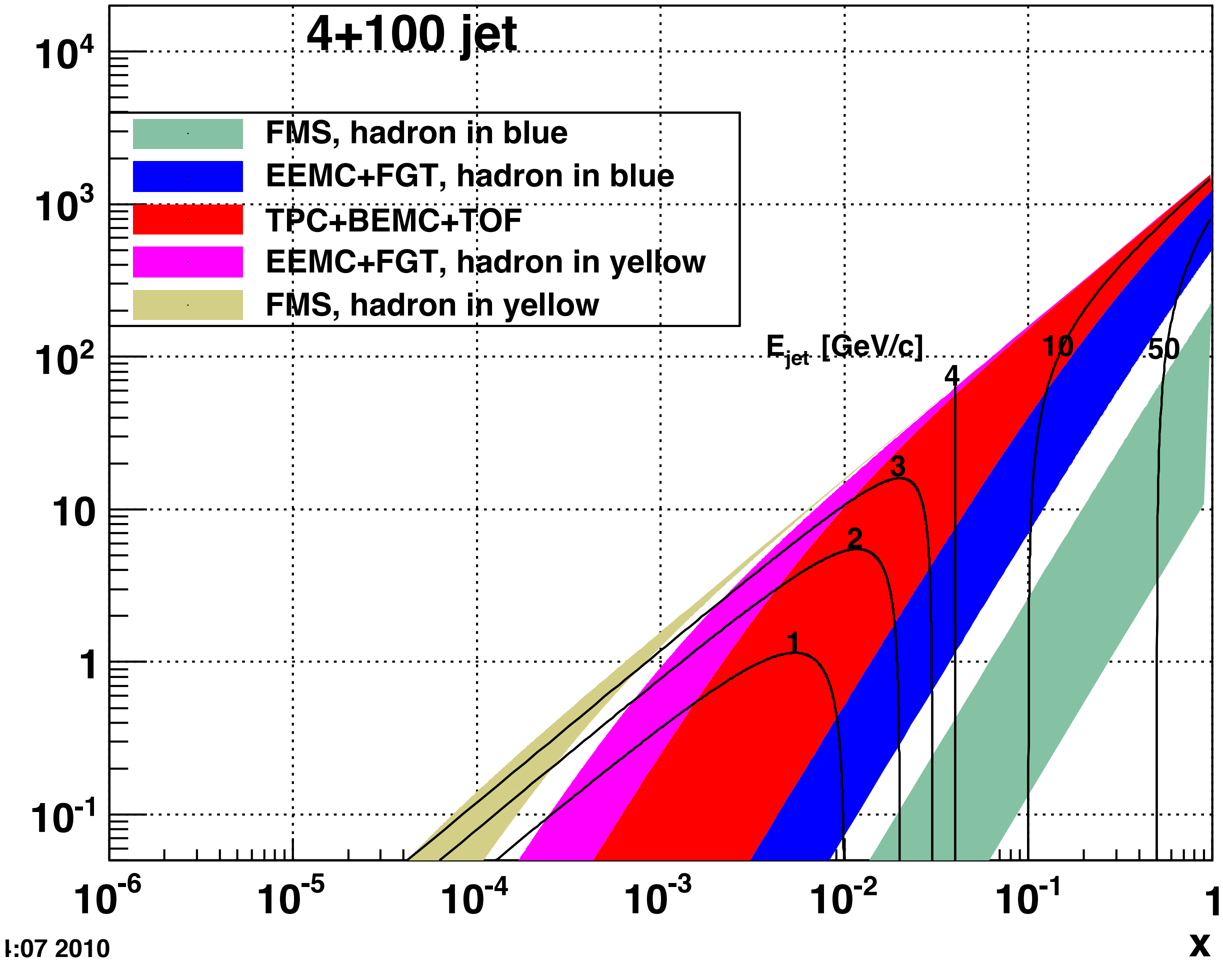
Note: current thinking has hadron in the blue beam: optimized for high x and Q^2

meRHIC and saturation

Only can begin saturation search in Endcap, if hadrons in the yellow beam

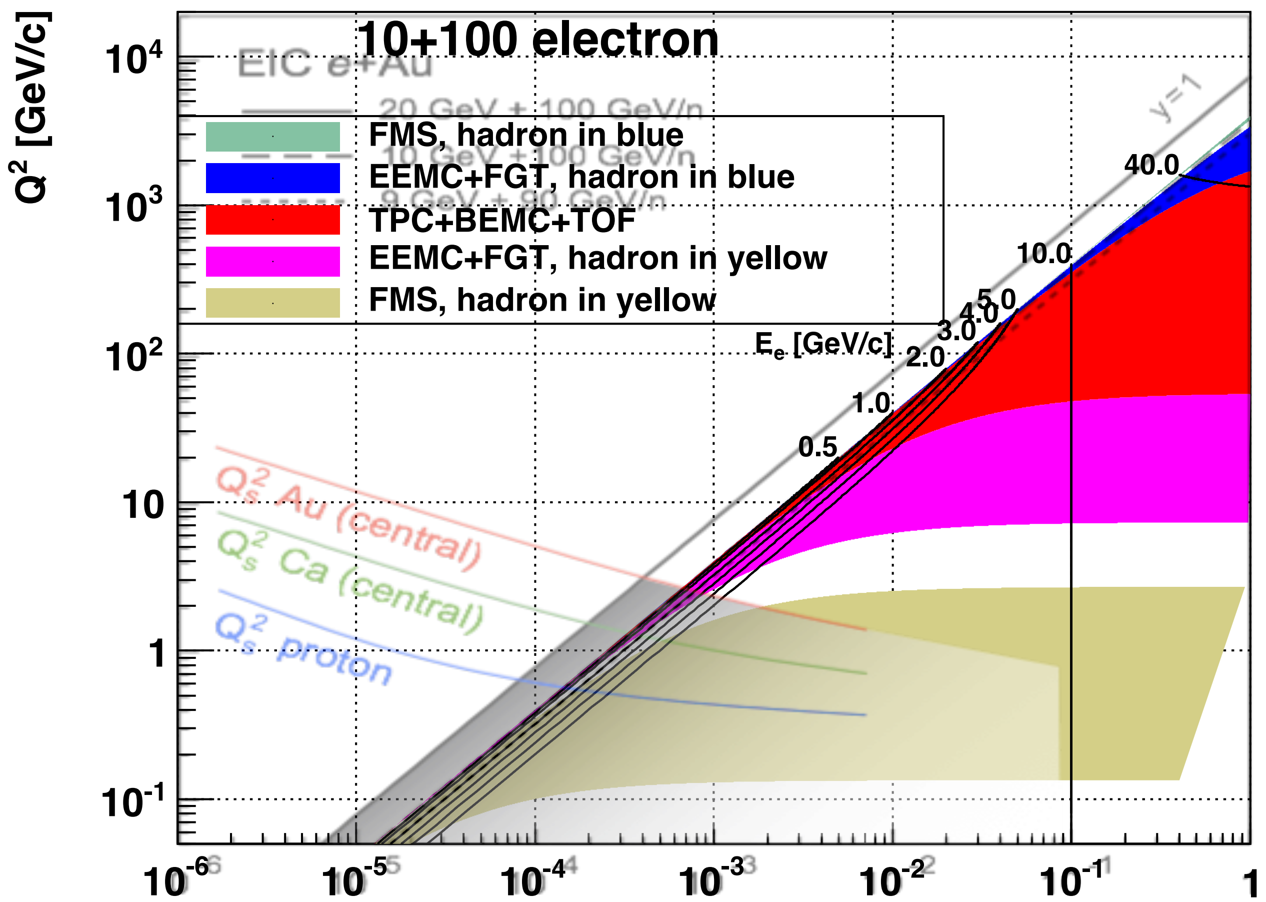


Energy loss in Cold Nuclear Matter



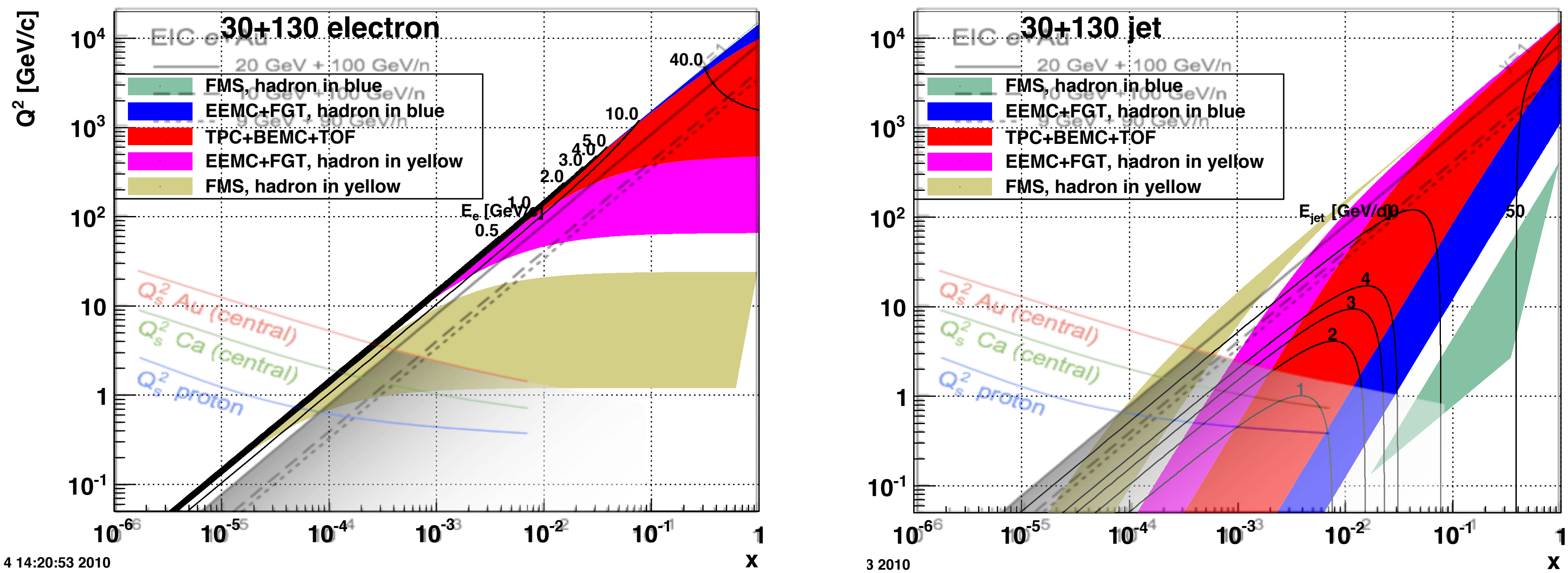
- Reasonable reach in jet energy (20-50 GeV), especially in the choice where the hadron is in the blue beam
- Cross-section ~1/(x Q^4); rate should be Ok

10+100, Saturation reach



- At higher EIC energies, electron should go towards the forward detector to enable reach into saturation region: FMS region

Speculative: 30+130



- Forward region very important for higher energy options

Spin: History and (some) Open Questions

1989 - European Muon Collaboration measured $g_1(x,Q^2)$ down to $x \sim 10^{-2}$, and concluded:

> "*Quark spins contribute only about 20-30% of the proton spin*, and
> *strange quarks are negatively polarized,*"

The former relies on extrapolation to $x \sim 0$, *- How?*

The latter has _*not*_ been confirmed in semi-inclusive DIS (with Kaons), *- Why?*

What is the role of gluon spins? - RHIC has started to answer this, *for* $\sim 0.03 < x < \sim 0.3$, thus leaving *huge* voids to be addressed in second-generation observations (including those at RHIC),

What is the role of Orbital Momenta? - Lattice calculations *suggest* that quark orbital momenta largely cancel; gluon Sivers function measurements at RHIC *might* tell us about gluon orbital momenta,

Future measurements should answer these *- What could stage-I of a polarized EIC do?*

MeRHIC and STAR

Note:

TPC+BEMC is used simply to indicate an existing acceptance region;
actual instrumentation may of course change,

No full simulations have been performed at this time,

Nevertheless,

+ TPC+BEMC acceptance is actually ~reasonable to measure the scattered electron,

- Scattered electron resolution will become limiting at intermediate to large-x and low Q^2,

- TPC+BEMC(+ToF) PID will restrict the small-x reach of semi-inclusive measurements, roughly to $\sim 0.003 < x < \sim 0.03$,

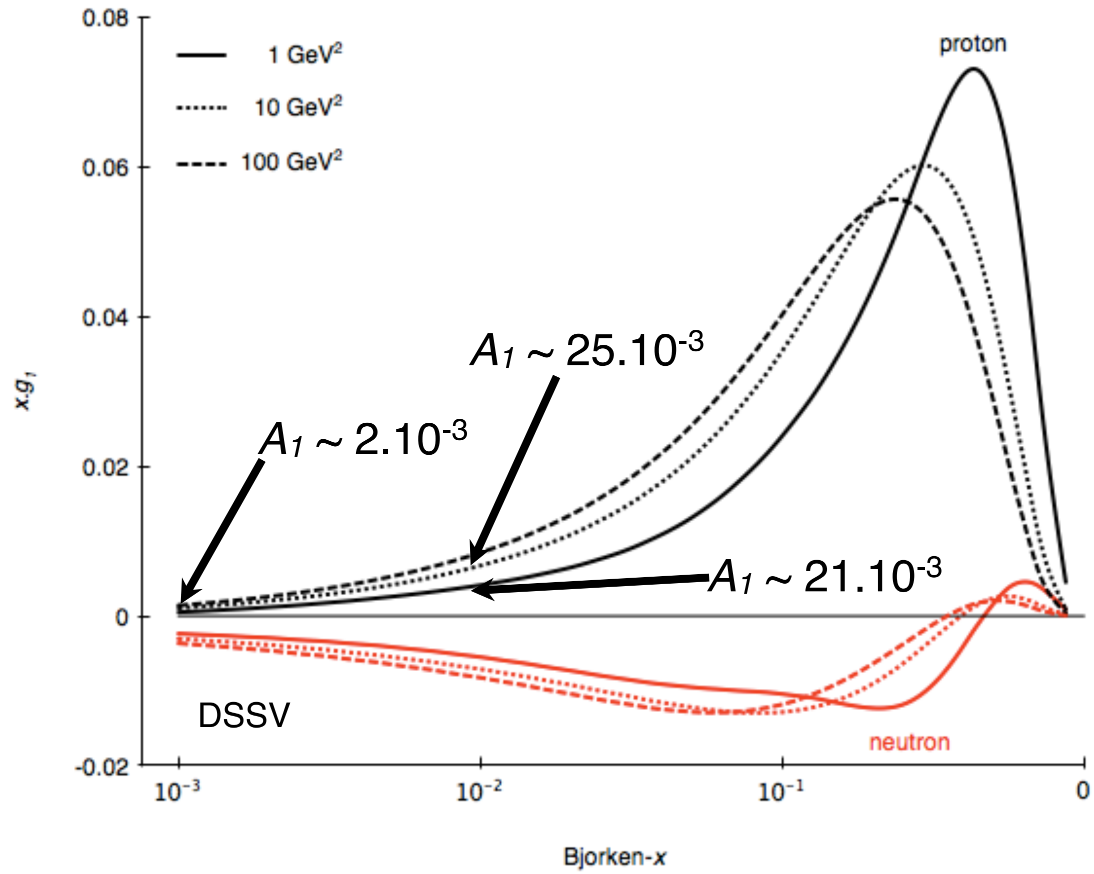
- 1-jet physics, as we currently know it, covers mostly large-x and high Q^2

Tagging of spectator proton(s) with Roman Pots seems feasible (lots to be done, but no show-stoppers found);

nice for ^{3}He; makes on dream of spectator-tagged measurements with polarized D,

essential for any Deeply-Virtual-Compton-Scattering measurements.

MeRHIC and STAR - Baseline Asymmetries



$$A_1 \sim \frac{g_1}{F_1}$$

A_1 should be within reach at smallest Bjorken-*x*,

Running with Q^2 likely observable for $x > \sim 10^{-2}$.

Small(er)-*x*

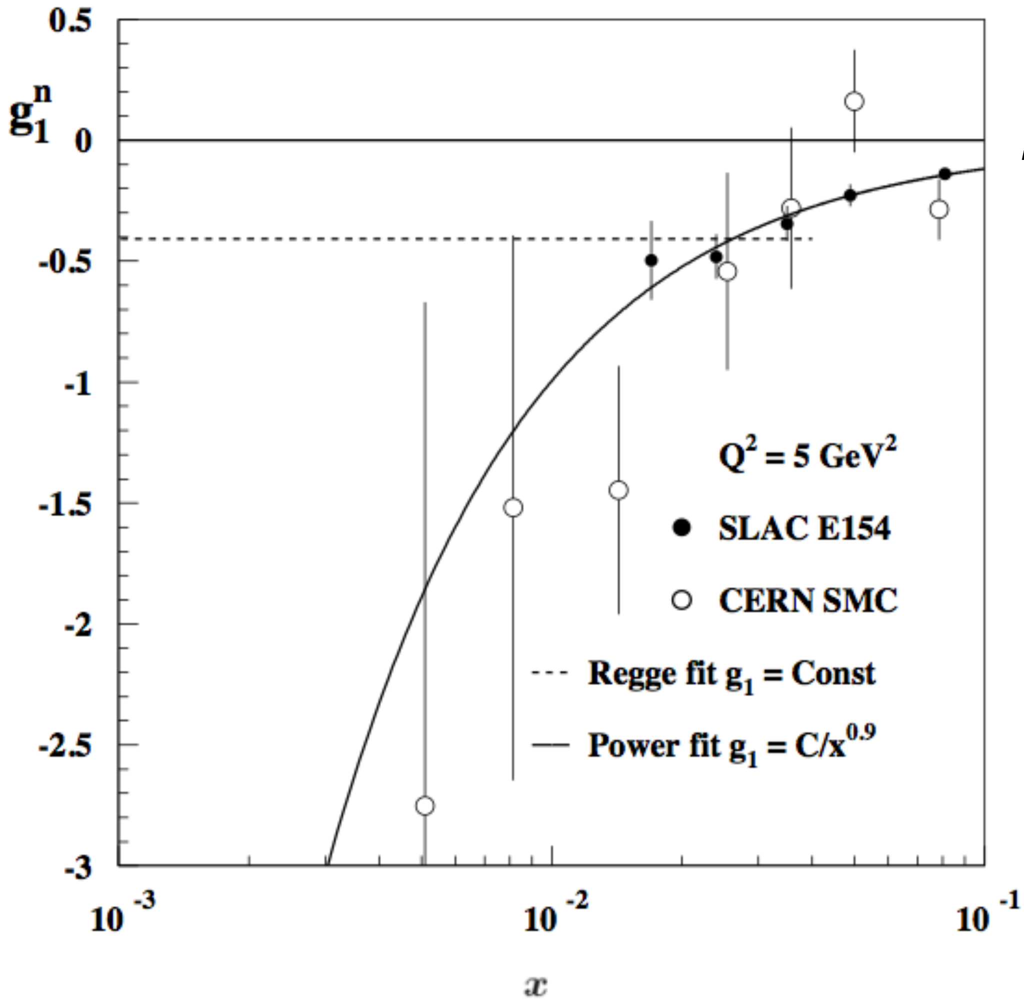


FIG. 3. Results for g_1^n versus x for the low x region from SLAC experiment E154 compared to the CERN SMC experiment. The data is evolved to $Q^2 = 5$ (GeV^2/c^2). Fits that impact the low x extrapolation (discussed in the text) are presented.

Neutron is most striking,

$$g_1^{\rm p}(x) \pm g_1^{\rm n}(x) \;\propto\; x^{-\alpha^{\pm}}, \qquad x \to 0,$$

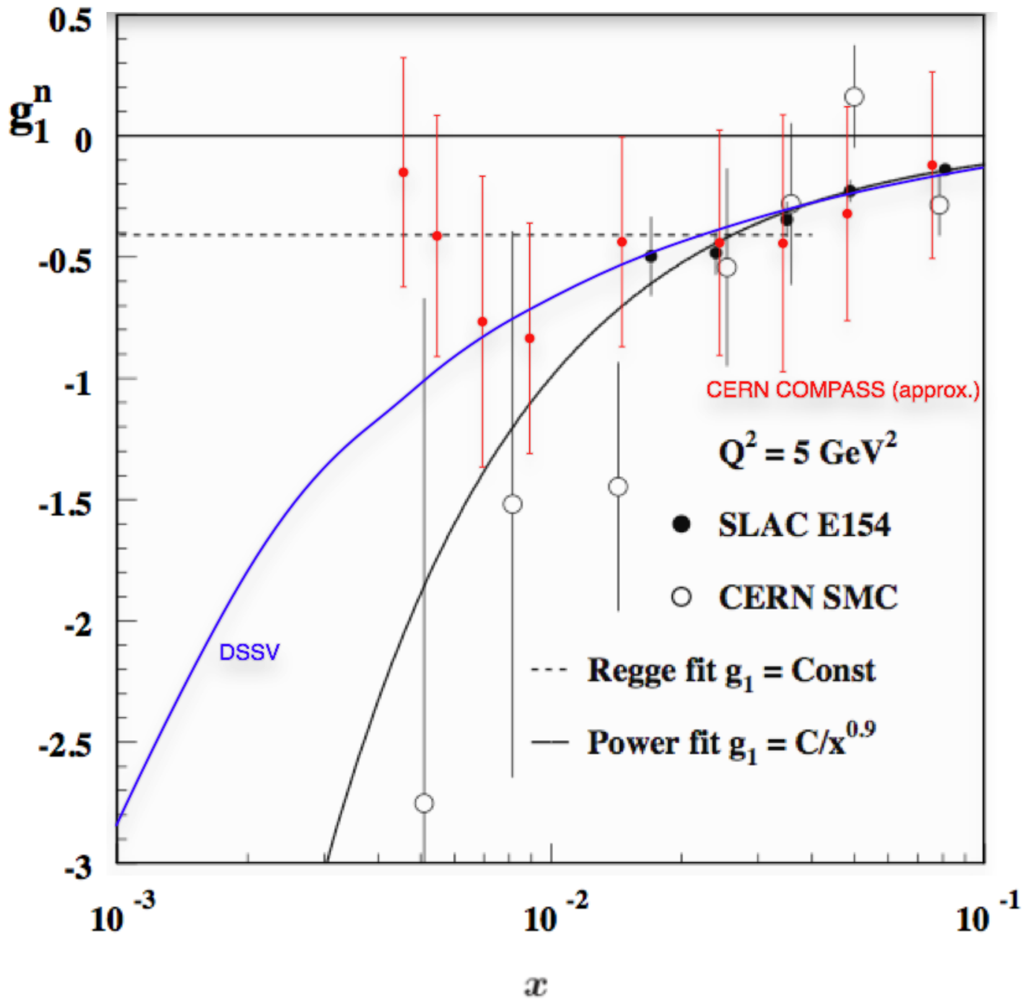
$$g_1(x) \;\simeq\; 0.09\left(2\ln\frac{1}{x} - 1\right), \qquad x \to 0,$$

$$g_1(x, Q^2) \;\propto\; \exp\sqrt{\ln\frac{1}{x}\,\ln\ln\frac{Q^2}{\Lambda^2}}, \qquad x \to 0, \quad Q^2 \to \infty,$$

which, if any?

E154 Collaboration (K. Abe et al.). Phys.Rev.Lett.79:26-30,1997

Small(er)-*x*



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Today's knowledge is better, but remains inconclusive.

E154 used a polarized ^{3}He (neutron) target,

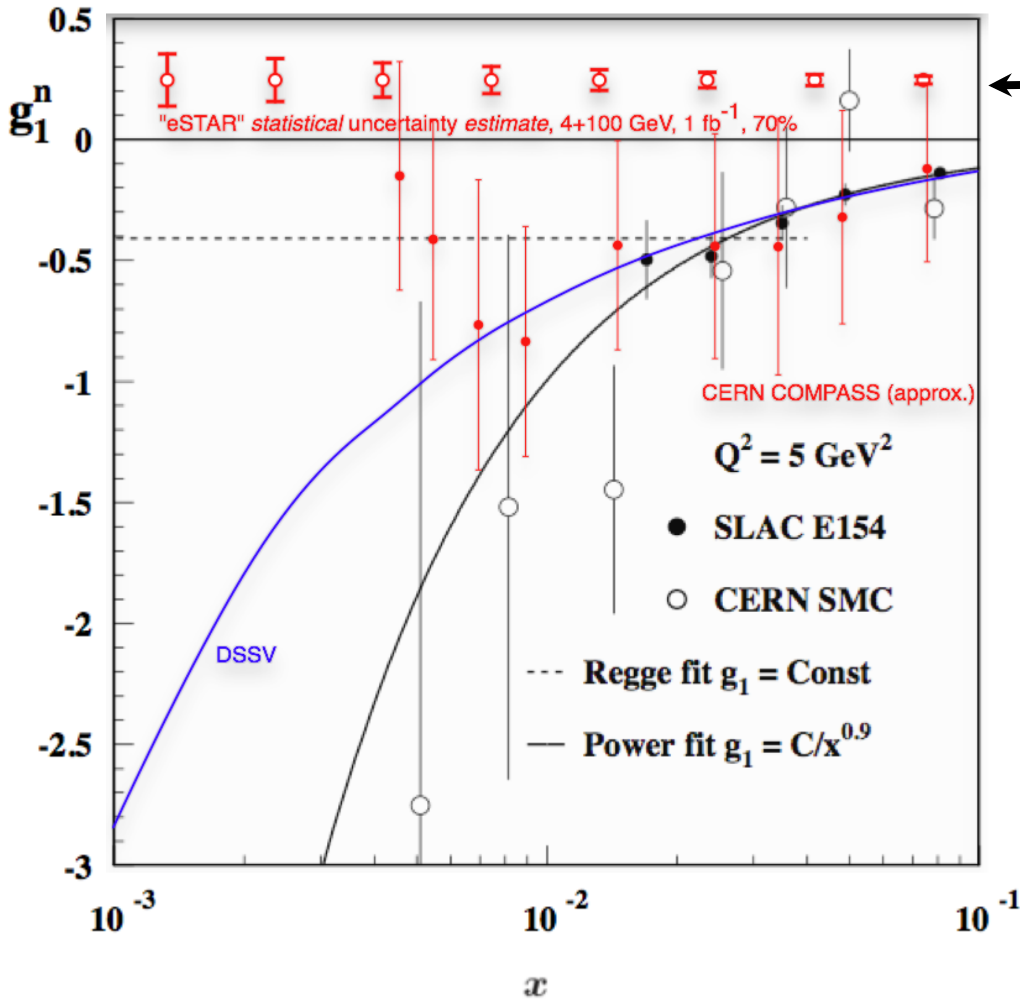
SMC and COMPASS are subtractions of measurements on targets with polarized D and H,

COMPASS aims for an additional H run.

E154 Collaboration (K. Abe et al.). Phys.Rev.Lett.79:26-30,1997

Neutron is most striking,

Small(er)-*x*



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← *Coarse estimate of uncertainty,*

4 + 100 GeV beams at STAR,

1 fb^{-1}, 70% polarizations,

idealized efficiency,

no radiative dilution or corrections,

statistical uncertainty only,

Expect significant impact.

E154 Collaboration (K. Abe et al.). Phys.Rev.Lett.79:26-30,1997

Neutron is most striking,

MeRHIC and STAR - Spin Physics

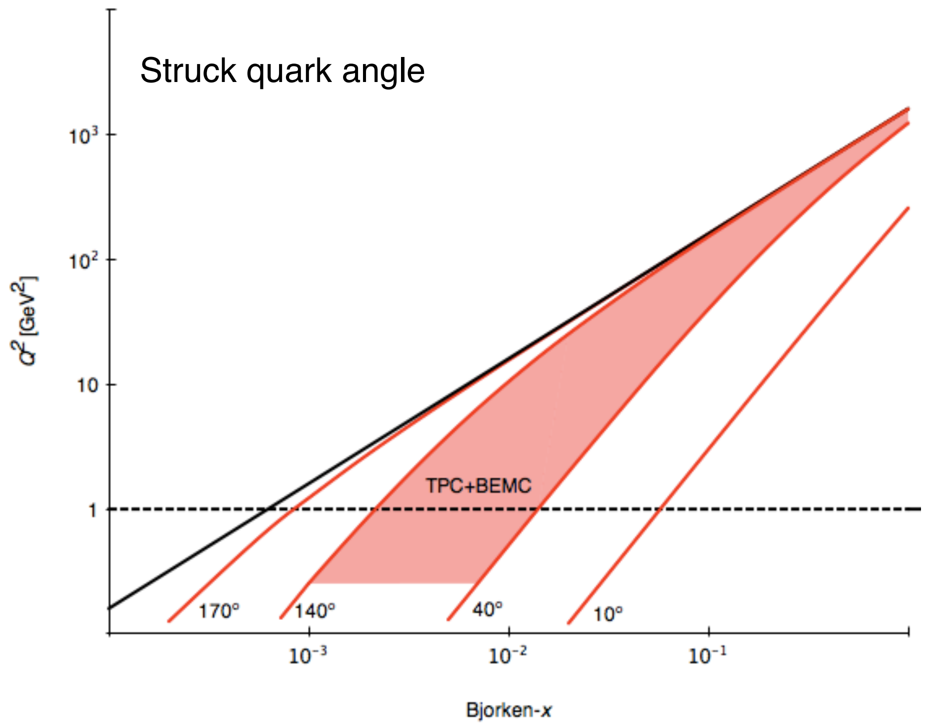
Expect meaningful extensions of inclusive measurements of $g_1(x,Q^2)$, $g_2(x,Q^2)$ to smaller-*x;*
limited mostly by electron energy,

Expect better precision and reach in Q^2 for semi-inclusive measurements;
main limitation will likely be forward particle identification (and measurement),

Electroweak (interference) measurements are likely beyond the reach of a MeRHIC;
limited by electron energy and acceptance,

Roman Pots are clearly *essential* for exclusive measurements, DVCS. Their impact remains to be estimated/quantified.

Collisions with polarized deuterons in combination with tagged spectators would allow *simultaneous* proton and neutron measurements; conceptually quite attractive, and technically hard (infeasible?).



Questions for C-AD

- What are constraints on direction of electron?
  - Electron in Blue Beam
    - Better matched to existing asymmetric detector, no conflict with HFT
    - HOWEVER
      - Existing Endcaps not well matched to energy of electron
      - High energy jets for energy loss study go to the other side
  - Electron in Yellow Beam
    - Would need to shift the FMS and associated upgrades to the other side
    - Allows for different Endcaps better matched to energy of the electron
    - Serious conflict with the HFT services: loss of charm sector?
- What are constraints on additional forward magnets?
  - May be necessary to take advantage of the FMS region
- Are polarized deuterons possible?