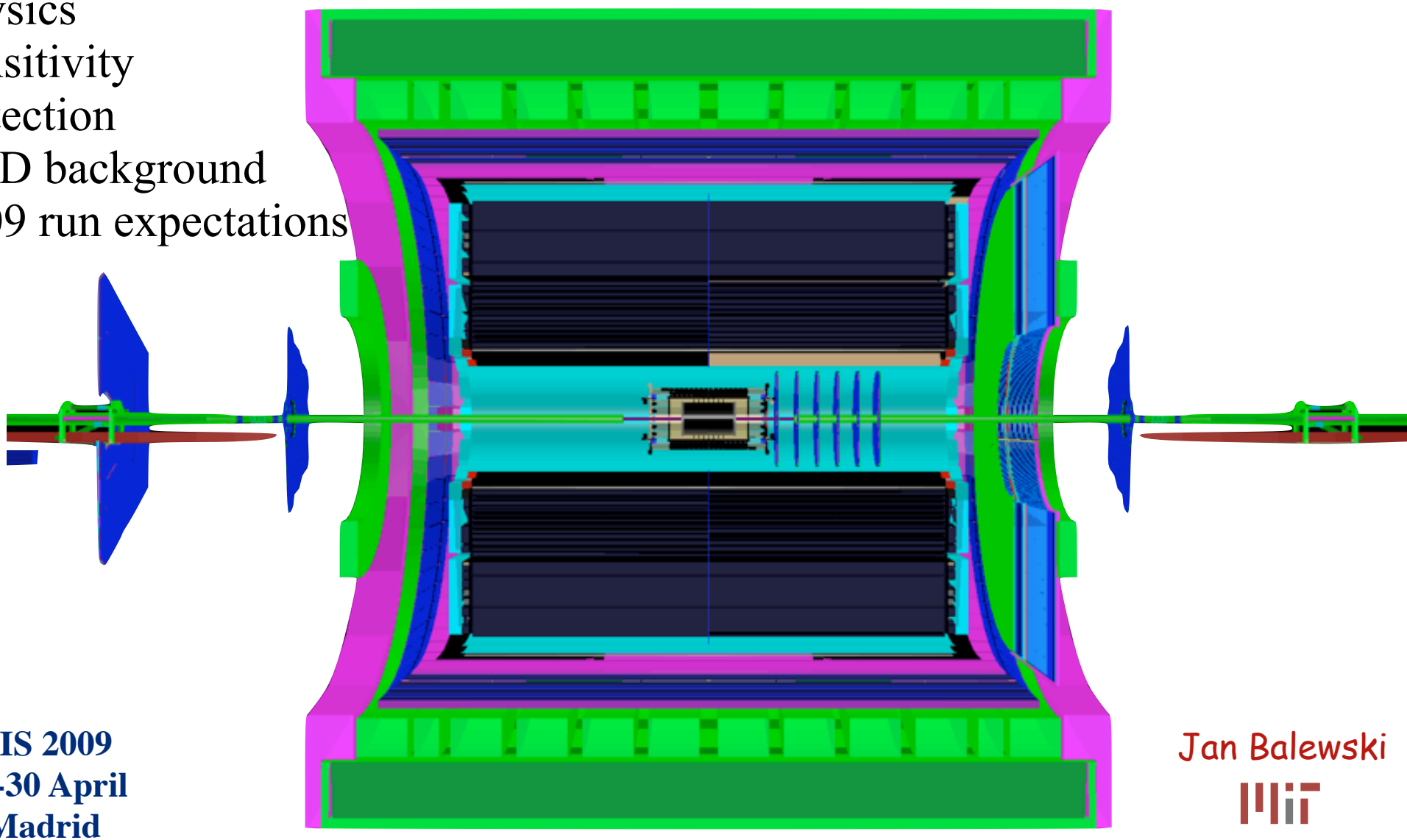
STAR W spin program in 2009 and beyond

- Physics
- Sensitivity
- Detection
- QCD background
- 2009 run expectations



DIS 2009
26-30 April
Madrid

Jan Balewski

Physics motivation - W program

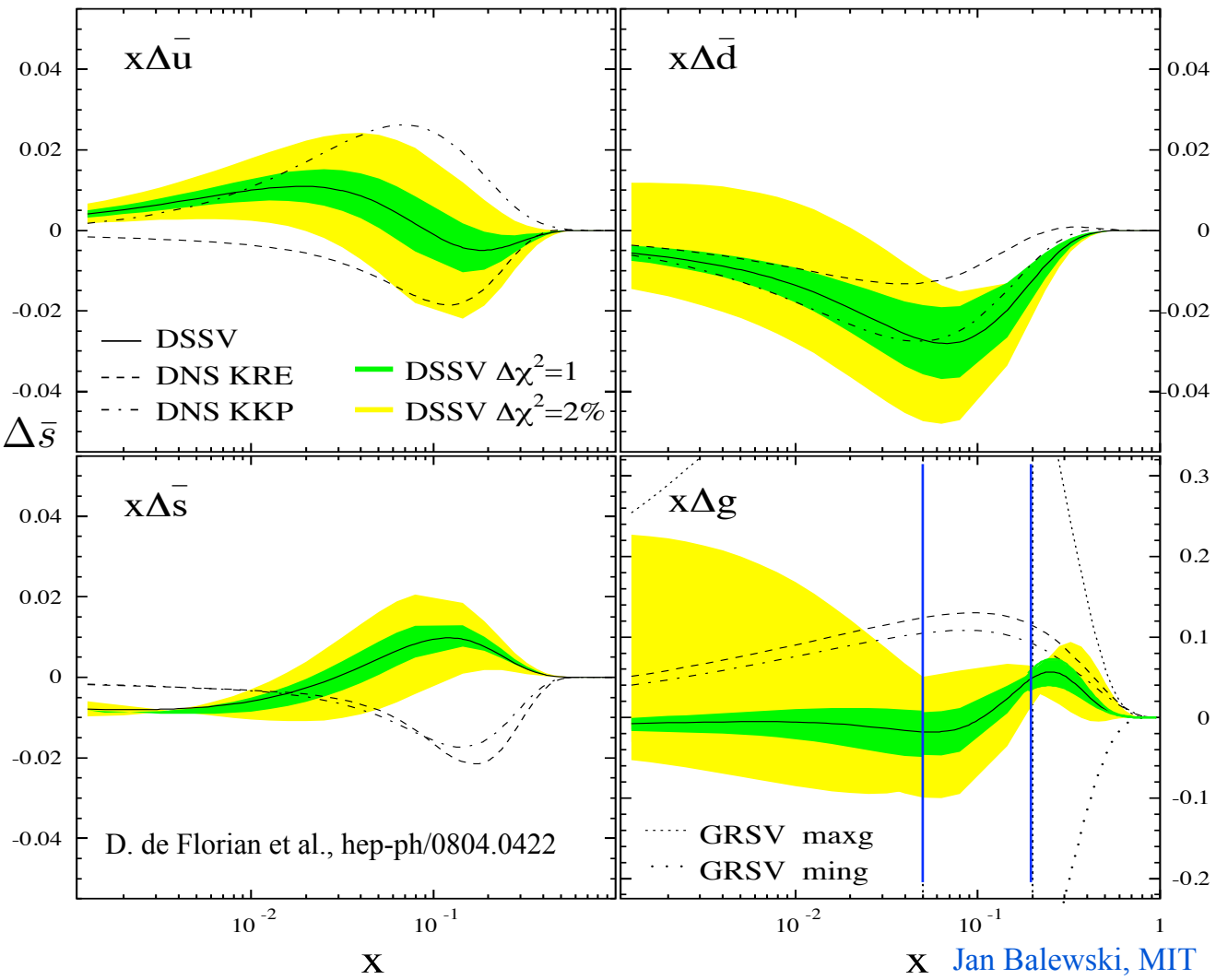
- What do we know about u/d anti-quark polarization?
  - Spin carried by quarks is very small ($\Delta\Sigma \sim 0.4$)!

$$\frac{1}{2} = \underbrace{\langle S_q \rangle}_{\frac{1}{2}\Delta\Sigma} + \langle S_g \rangle + \langle L_q \rangle + \langle L_g \rangle$$

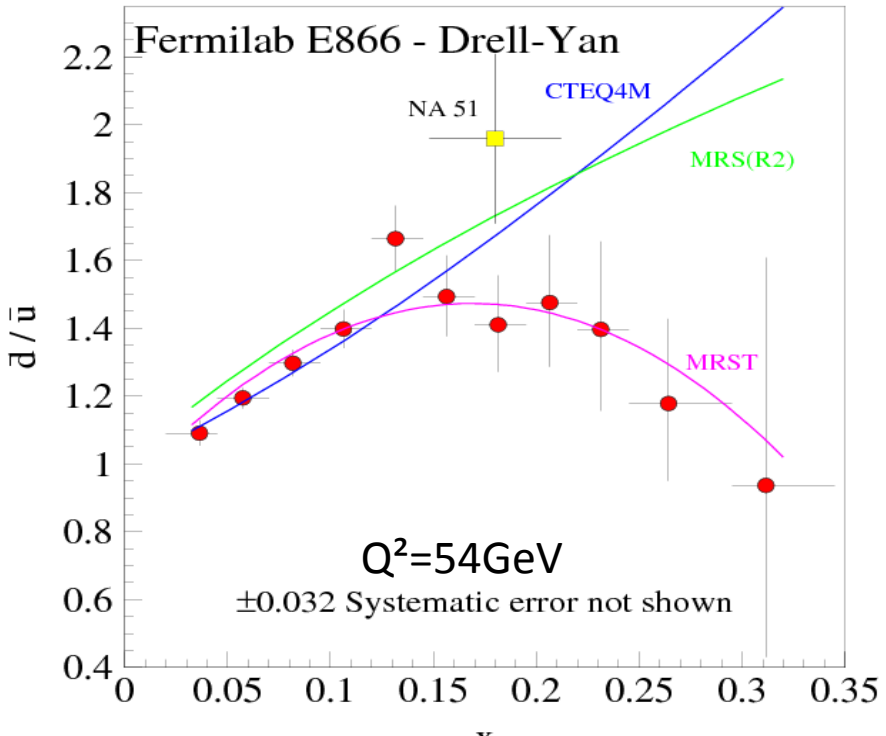
$$\Delta\Sigma = \Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} + \Delta s + \Delta\bar{s}$$

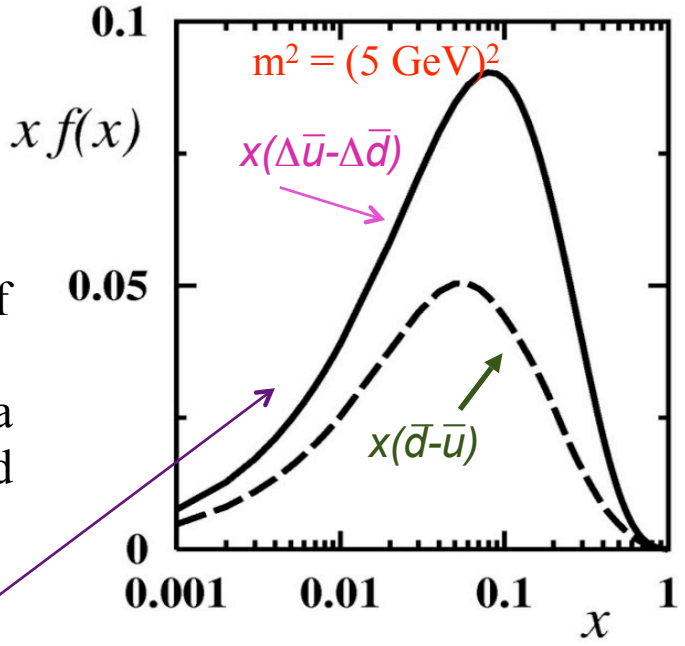
$$\Delta q_i(Q^2) = \int_0^1 \Delta q_i(x, Q^2) dx$$

polarized u/d anti-quarks distributions based on SI-DIS



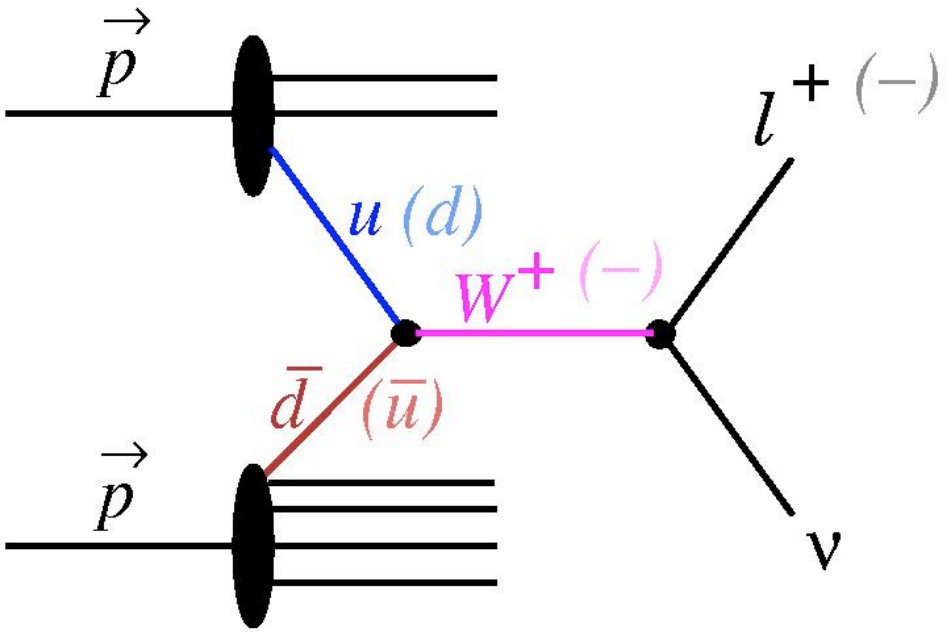
Flavor Asymmetry of the Sea





- purely perturbative mechanism would generate equal amounts of u-bar & d-bar quarks
- non-pert. mechanism seems to be necessary to generate QCD sea
- Example: E866 results are qualitatively consistent with pi0 cloud model, instanton model and chiral quark soliton model
- Difference in the polarized sector (x(Δd(x)-Δu(x))) is predicted to be even larger than difference in unpolarized sector (x(d-u))

Probing the Sea at STAR



- $u + \bar{d} \rightarrow W^+ \rightarrow e^+$
- $d + \bar{u} \rightarrow W^- \rightarrow e^-$
- In forward region:
  - W^+ gives access to $\Delta\bar{d}$
  - W^- gives access to $\Delta\bar{u}$
- V-A coupling leads to perfect spin separation
- Neutrino helicity gives preferred direction in decay

Parity violating single spin asymmetry A_L

(Helicity flip in one beam while averaging over the other)

$$A_L^{W^+} \sim \bar{d}(x_1)\,\Delta u(x_2) + u(x_1)\,\Delta\bar{d}(x_2)$$

$$A_L^{W^-} \sim \bar{u}(x_1)\,\Delta d(x_2) + d(x_1)\,\Delta\bar{u}(x_2)$$

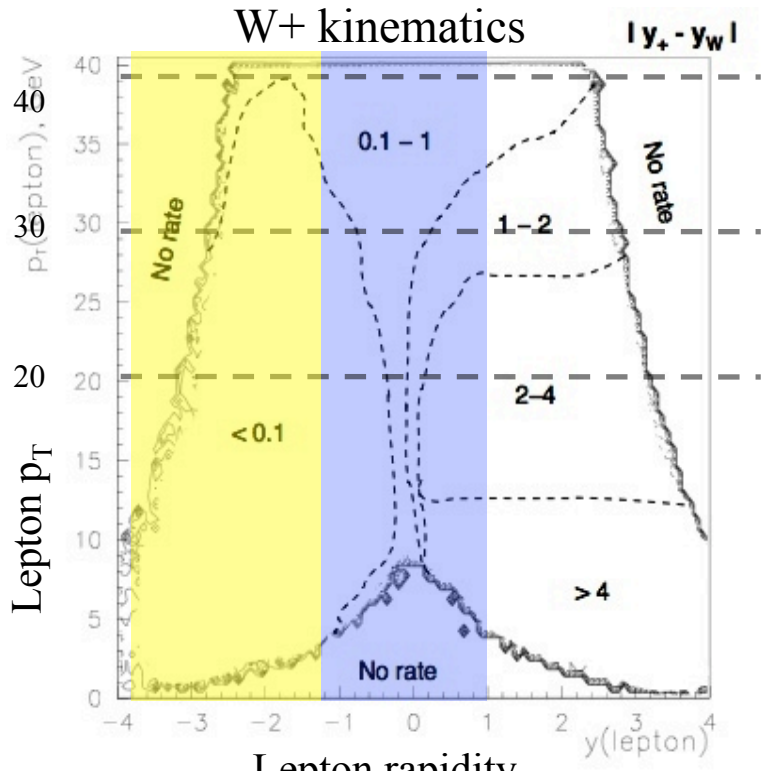
W^- preserves initial state kinematics. Decay electron emitted along W^- trajectory.

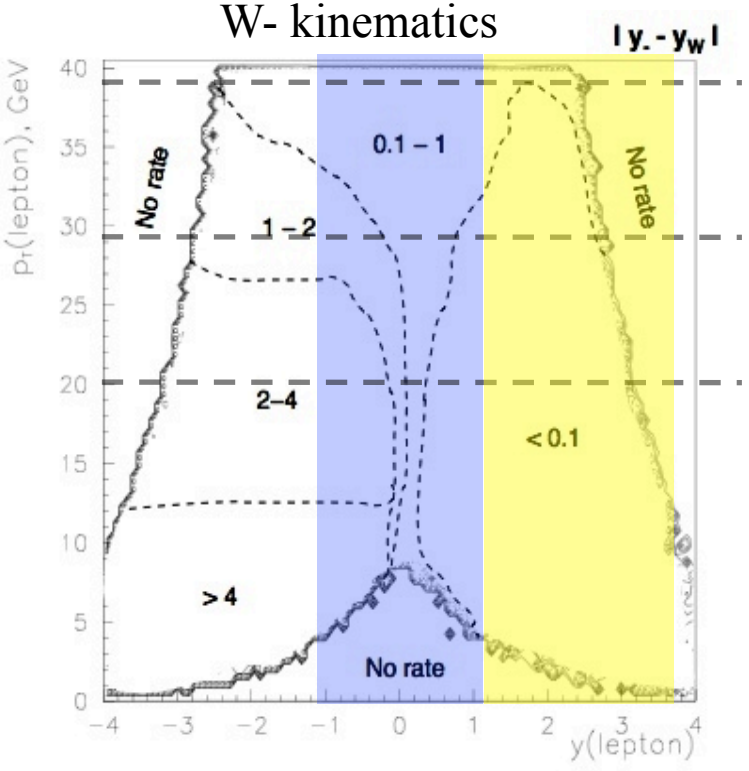
Kinematics of forward rapidity measurement

$$x_1 = \frac{M_W}{\sqrt{s}} e^{y_W} \qquad x_2 = \frac{M_W}{\sqrt{s}} e^{-y_W} \longrightarrow \text{if } q_T \text{ is small} \longrightarrow y^*_{lep} = \frac{1}{2} \ln \frac{1+\cos\theta^*}{1-\cos\theta^*} \qquad p'_{T,l} = \frac{M_W}{2} \sin\theta^*$$

$$y^{lab}_{lep} = y^*_{lep} + y_W$$

- At forward/backward rapidity q_T is small and x_1 and x_2 are calculable
- At mid-rapidity ambiguous assignment of x_1 and x_2 to polarized and unpolarized beams.



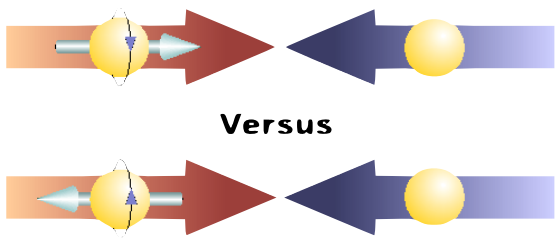


contours at constant Z=

$$|y^{lap}_{lep} - y^*_{lep} - y_W|$$

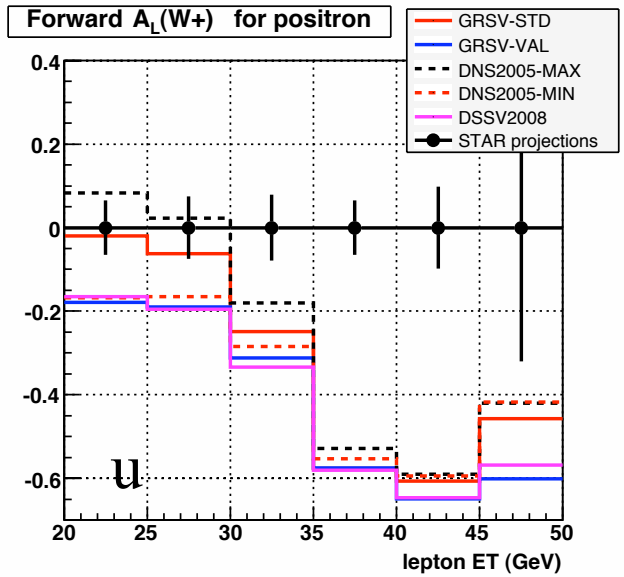
STAR Projections: q/qbar polarization at **forward rapidity**

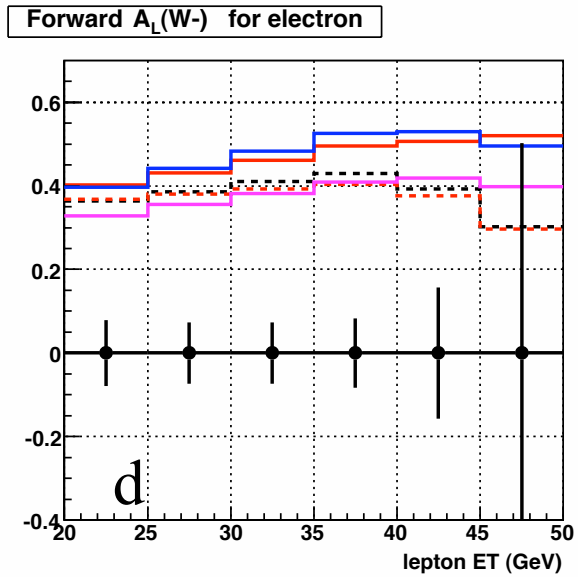
A_L

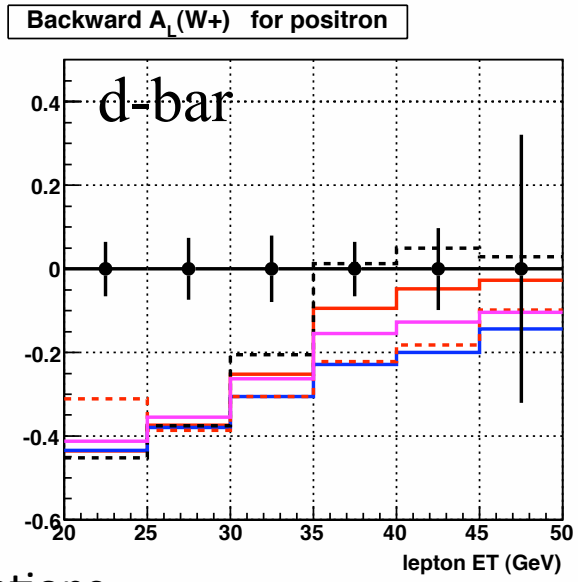


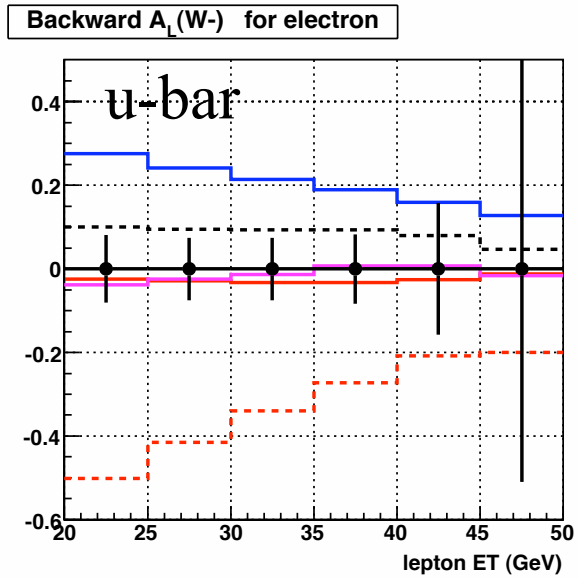
- 5 years integrated, LT=300/pb (RHIC SPIN document submitted to DOE)
- Large asymmetries dominated by quark polarization - Important consistency check to existing DIS data with 100pb^{-1} (Phase I)
- Strong impact constraining unknown antiquark polarization requires luminosity sample at the level of 300pb^{-1} for 70% beam polarization (Phase II)

STAR projections for LT=300 pb^{-1}, Pol=0.7, effi=70%, no QCD background, no vertex cut



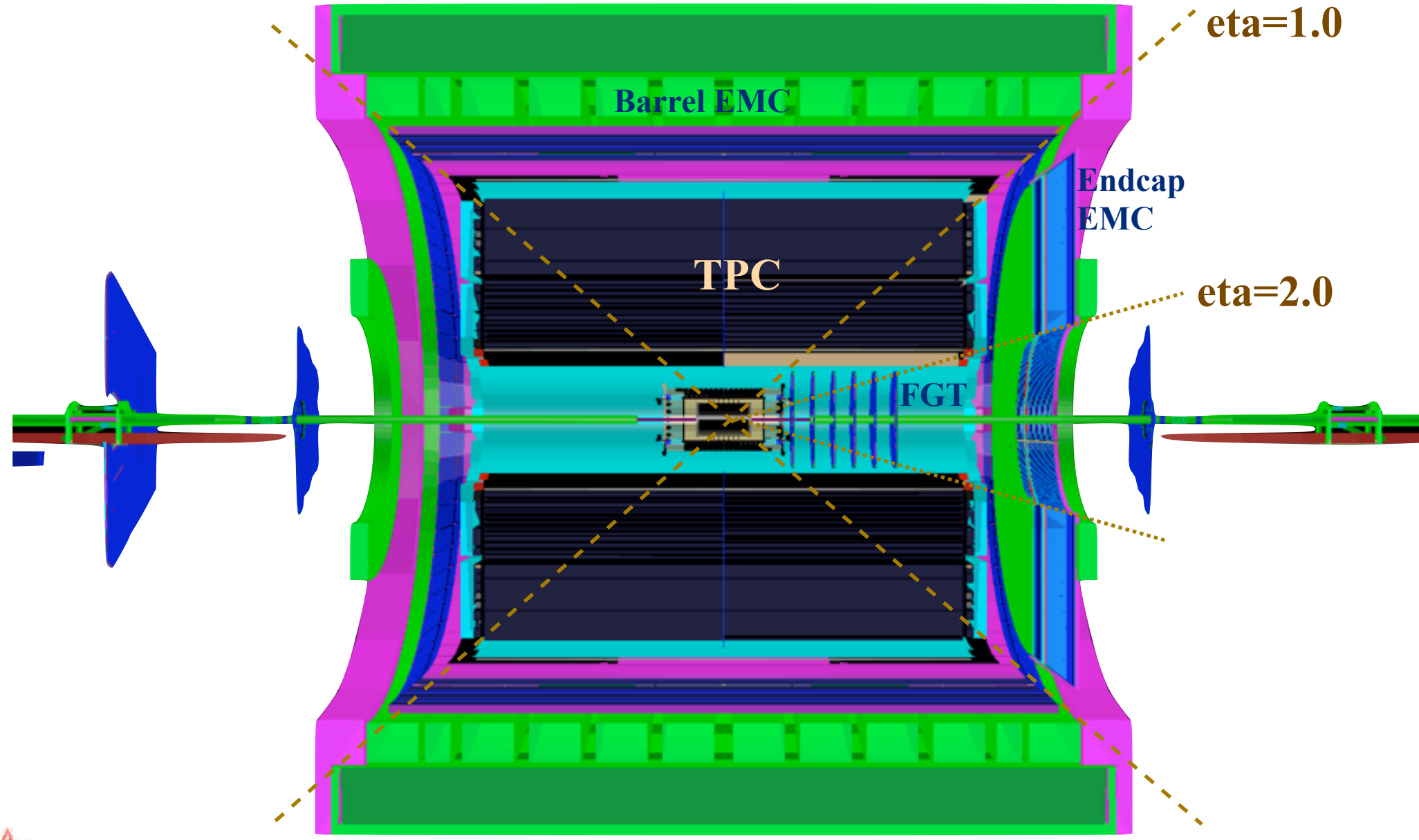






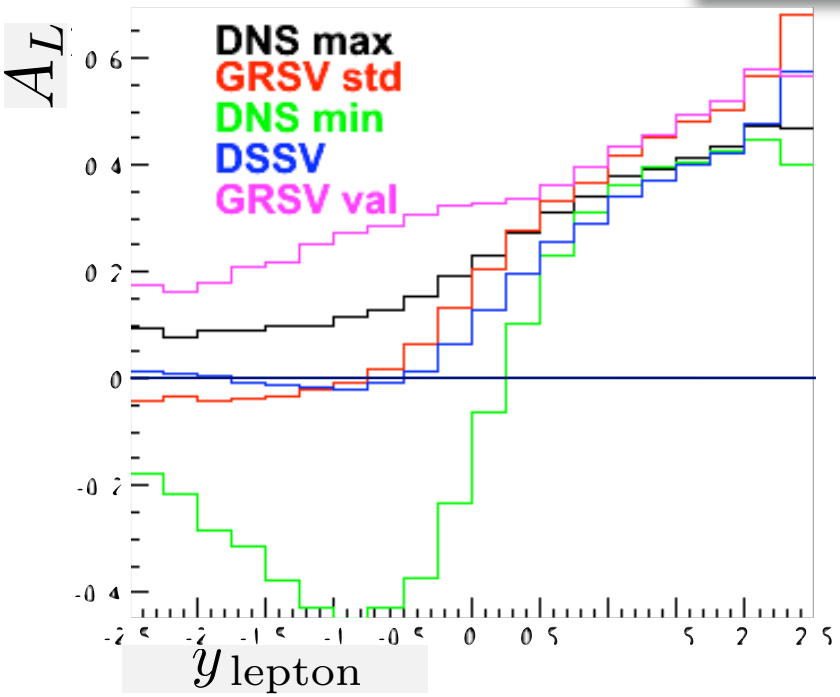
MC simulations

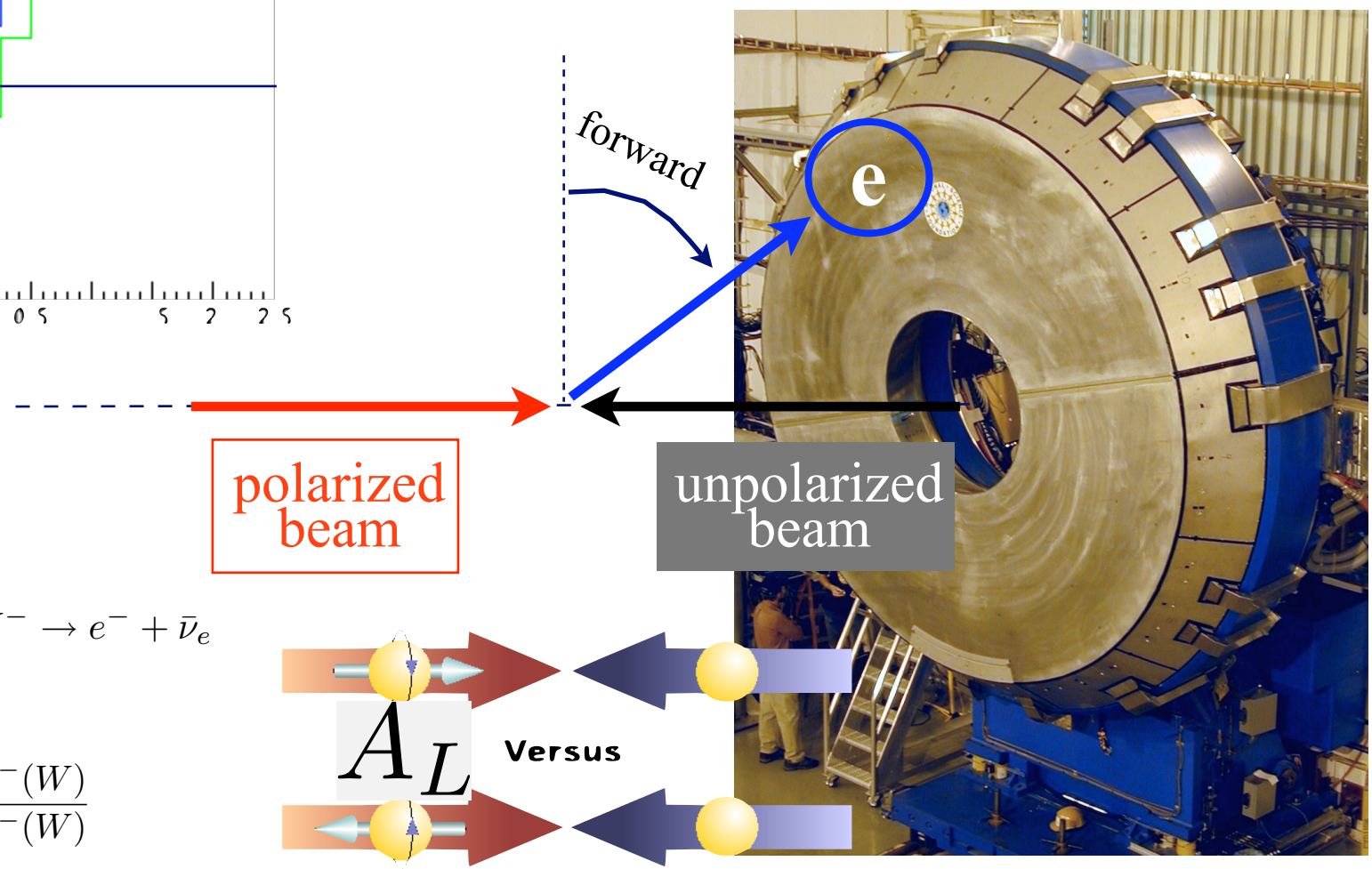
STAR Detector



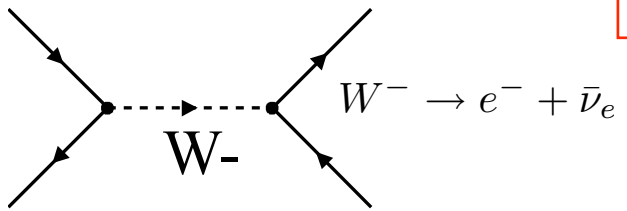
Exploring W/lepton phase space @ STAR

W^- $p_T > 20GeV/c$





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

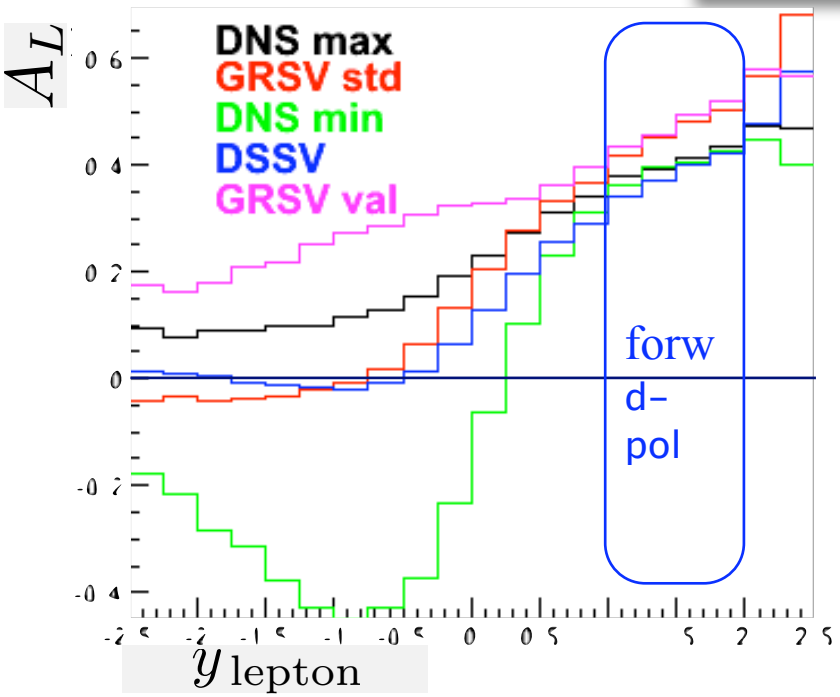


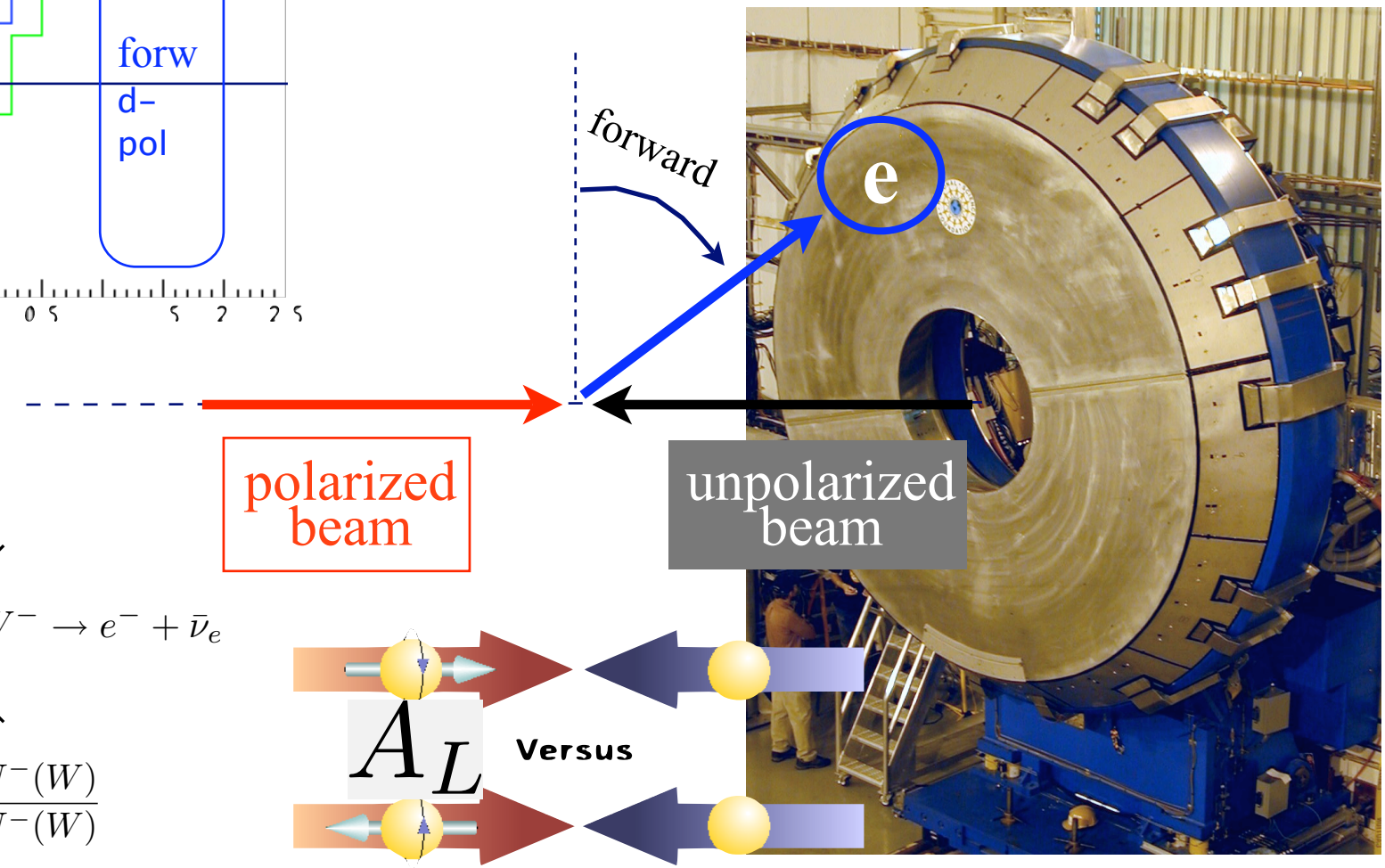
$W^- \rightarrow e^- + \bar{\nu}_e$

$$A_L^W = \frac{1}{P}\frac{N^+(W) - N^-(W)}{N^+(W) + N^-(W)}$$

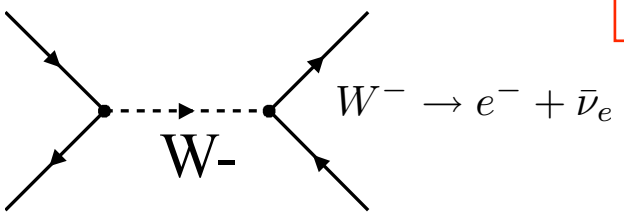
Exploring W/lepton phase space @ STAR

W^- $p_T > 20GeV/c$





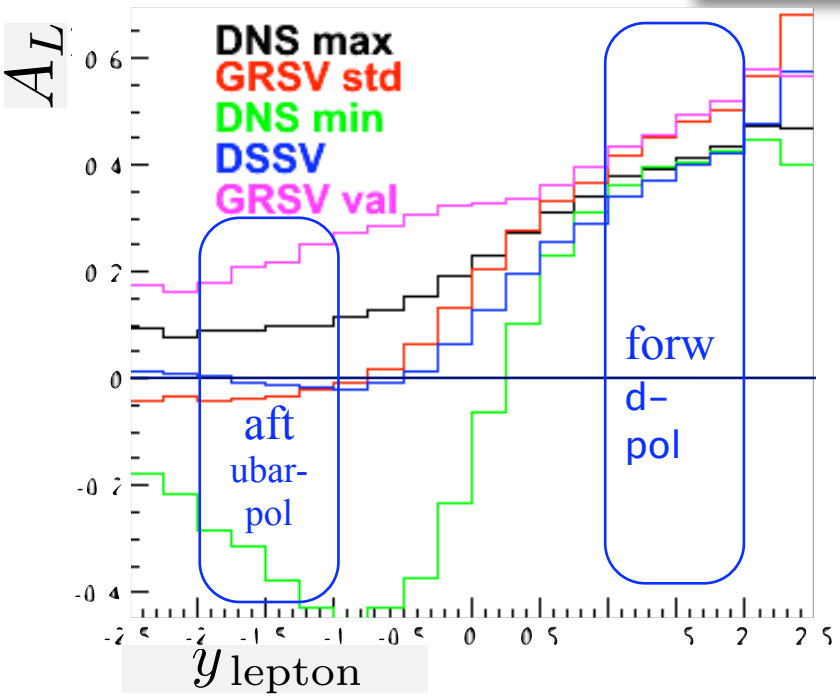
$\Delta d + \bar{u} \rightarrow W^-$
$\Delta \bar{u} + d \rightarrow W^-$

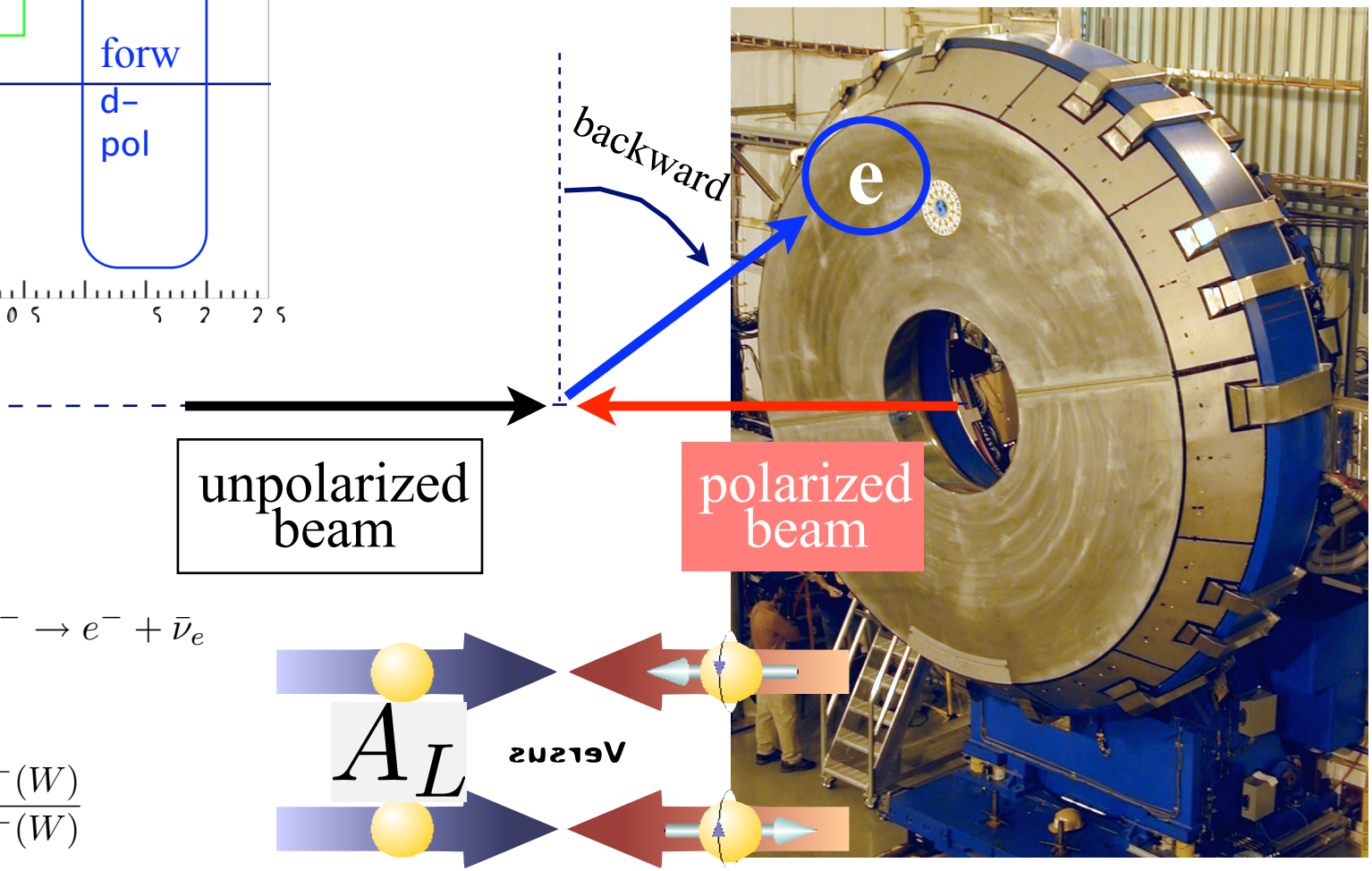


$$A_L^W = \frac{1}{P}\frac{N^+(W) - N^-(W)}{N^+(W) - N^-(W)}$$

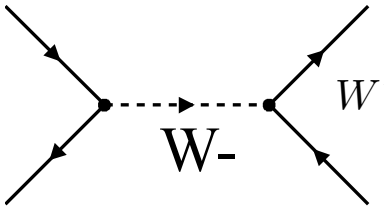
Exploring W/lepton phase space @ STAR

W^- $p_T > 20 GeV/c$





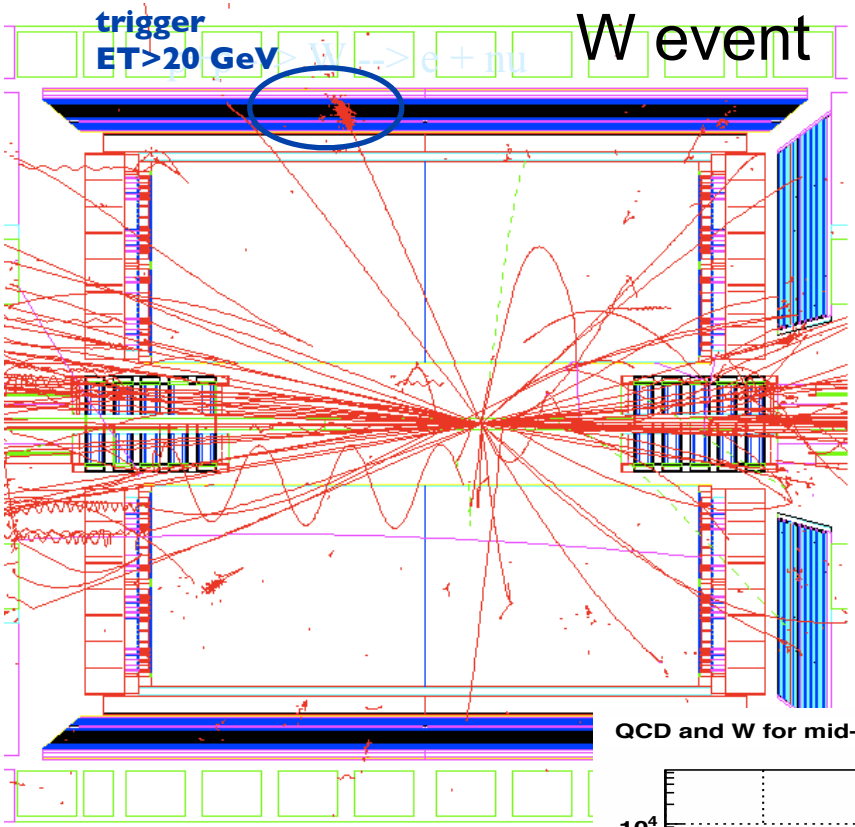
$\Delta d + \bar{u} \rightarrow W^-$
$\Delta \bar{u} + d \rightarrow W^-$



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

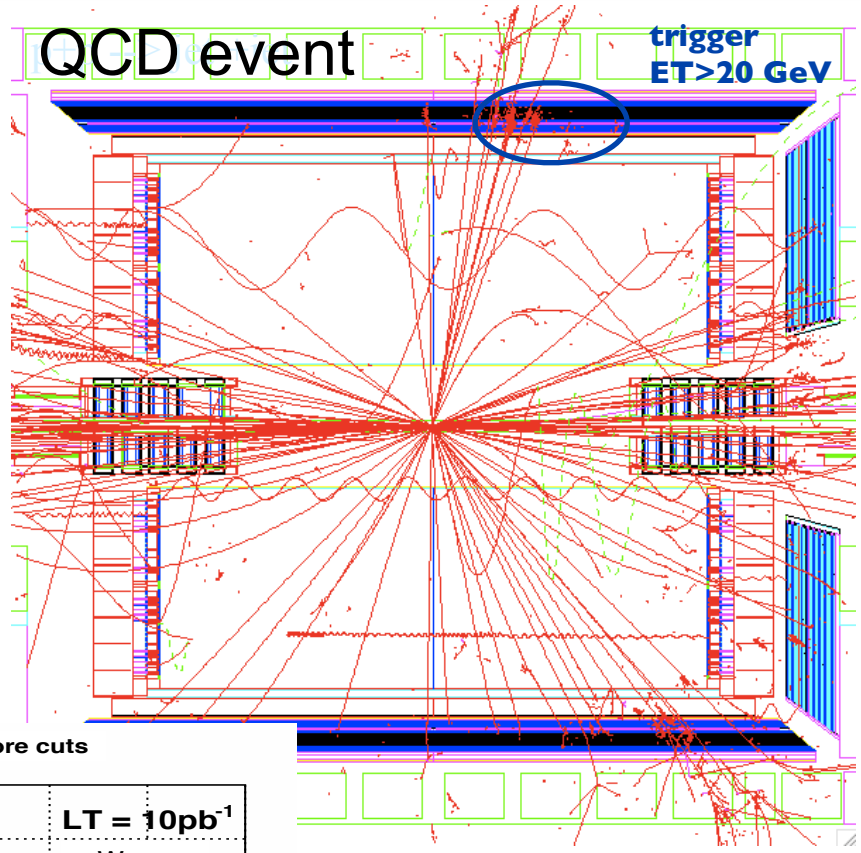
$$A_L^W = \frac{1}{P} \frac{N^+(W) - N^-(W)}{N^+(W) + N^-(W)}$$

Discriminating W-event from QCD background event

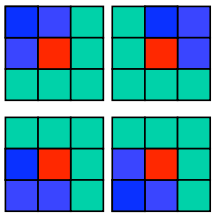


W event

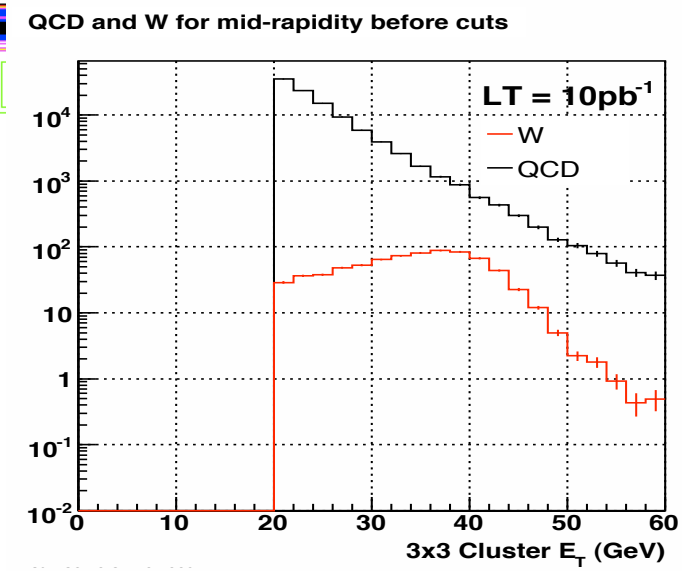
QCD event



L2 trigger:

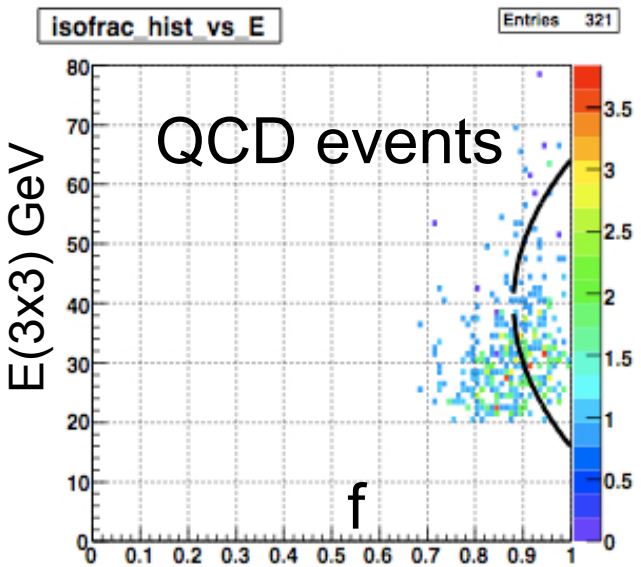


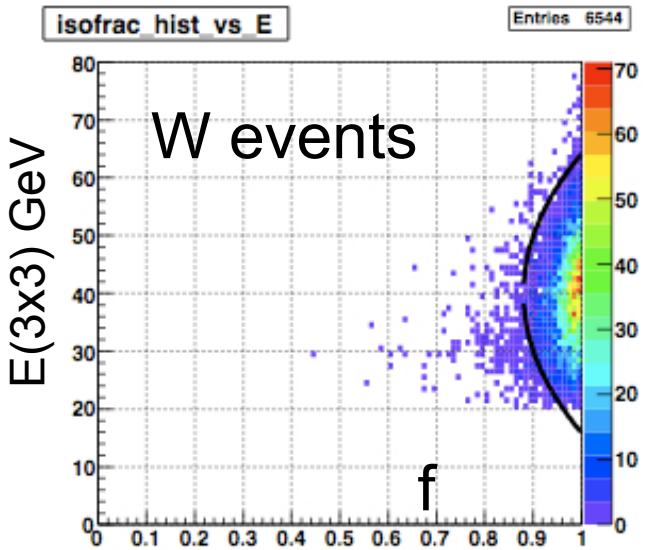
checks 4 combinations of 2x2 towers containing the seed tower



MC simulations

Example Cuts: isolation & veto away side ET

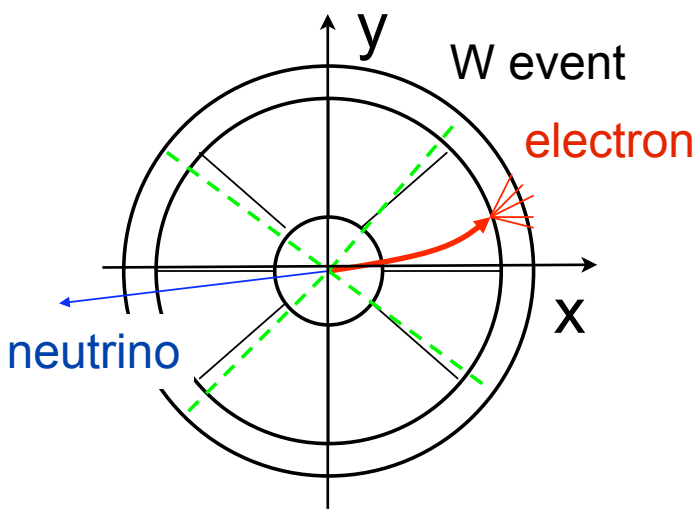




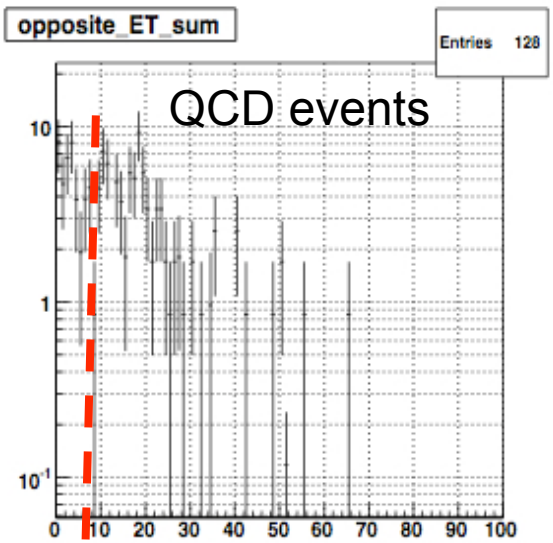
Mid rapidity MC simulations

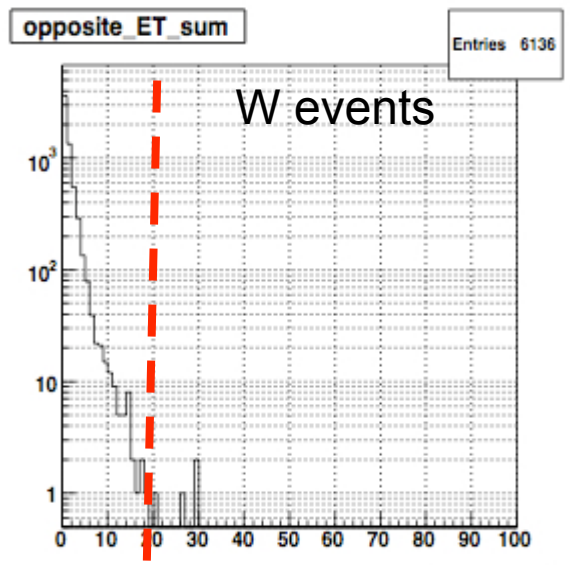
- Barrel tower isolation cut
- Look at ratio of Eт in 3x3 tower patch to Eт in 30x40 tower patch

$$f = \frac{E_T(3x3)}{E_T(40x30)} > g(E)$$



- **Away-side Eт cut**
- **Require opposite Eт < 10 GeV**

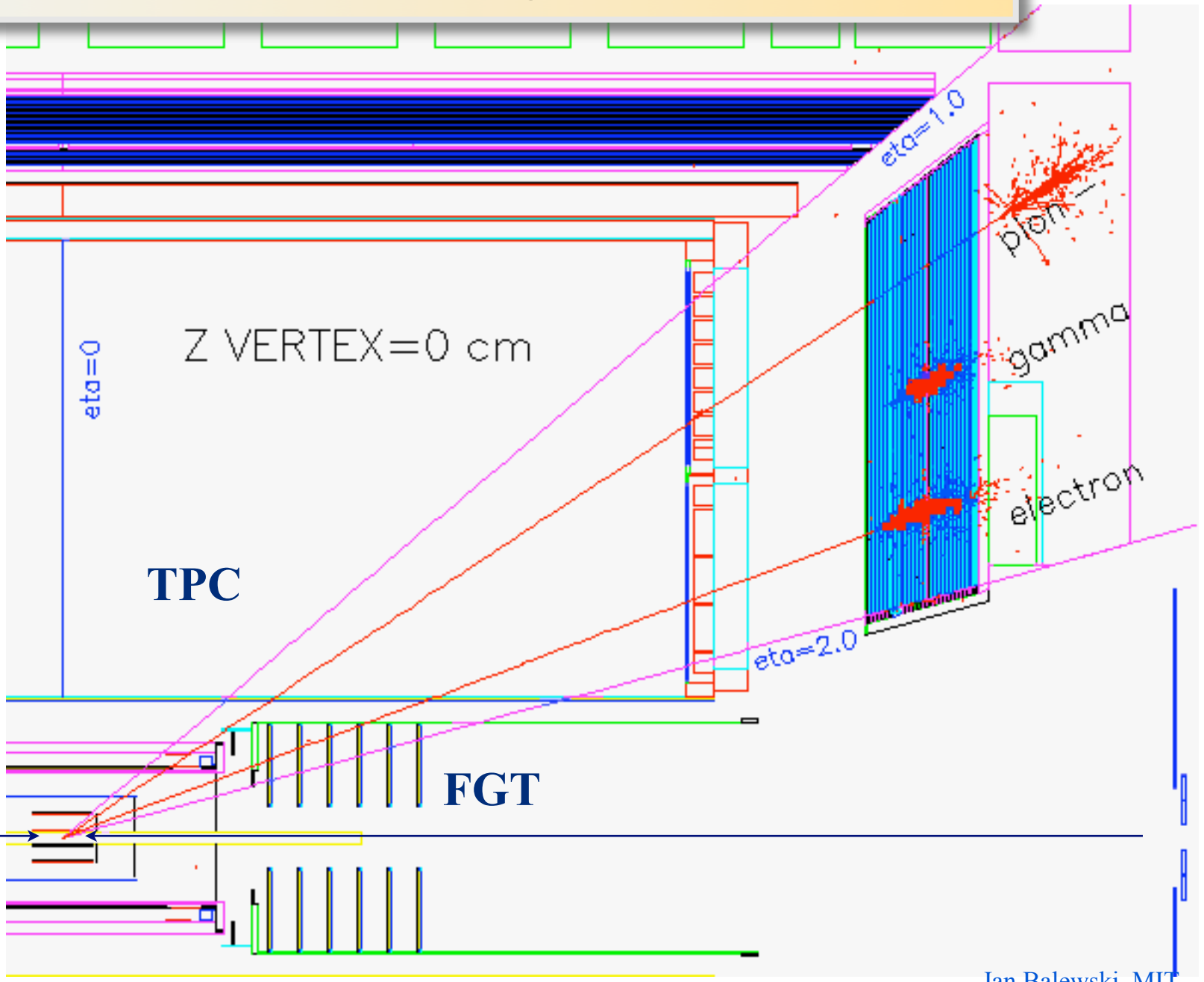




Particle ID

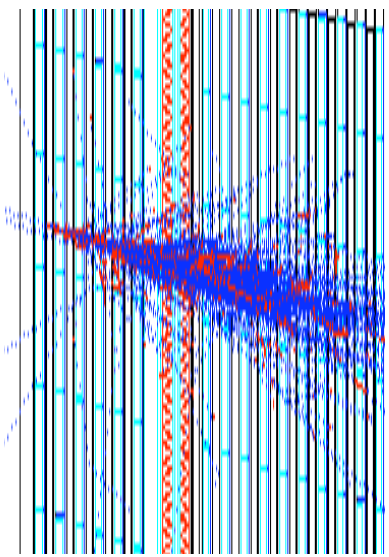
Signature of
- pi-
- gamma
- electron

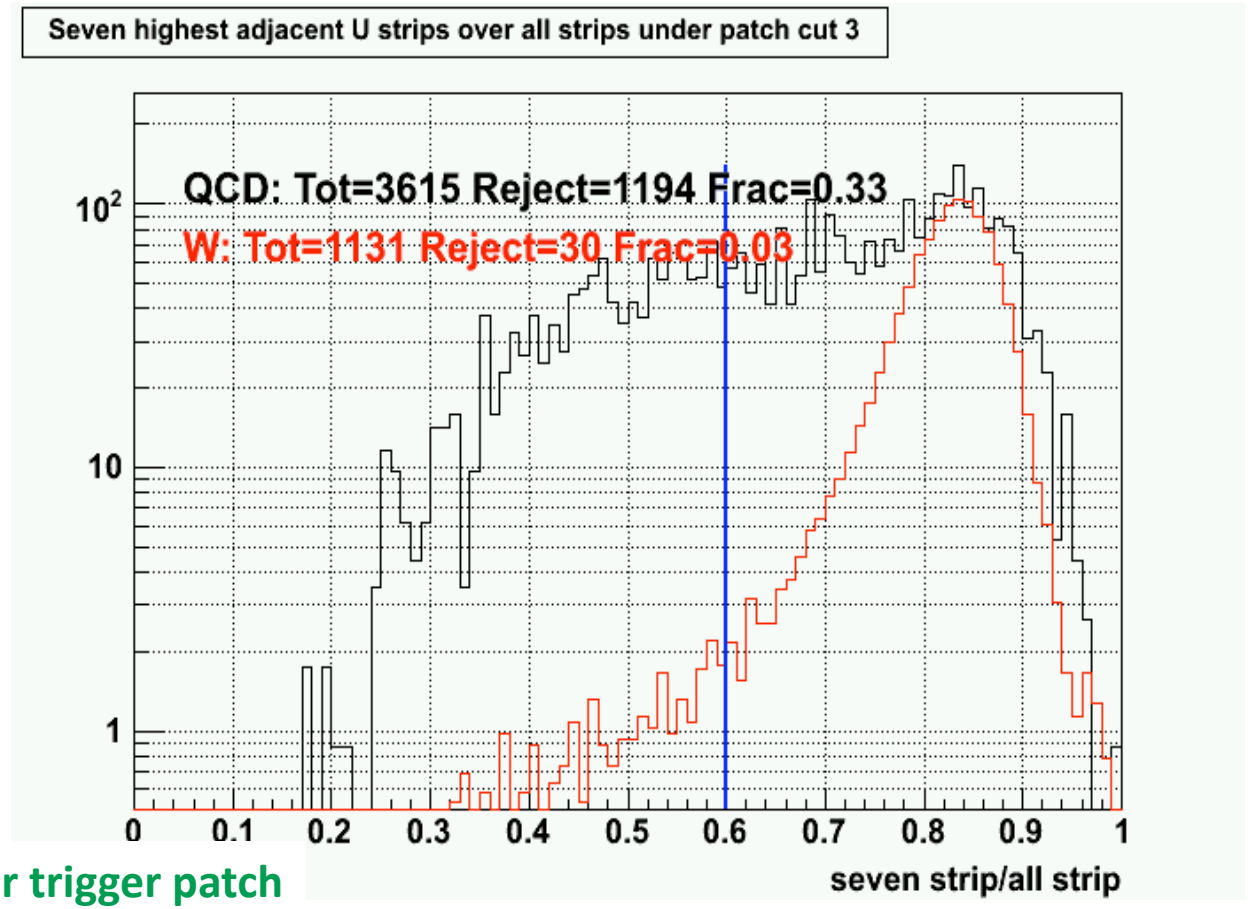
ET=20 GeV



Example Cuts: SMD isolation vs. pi0

Shower-max Detector

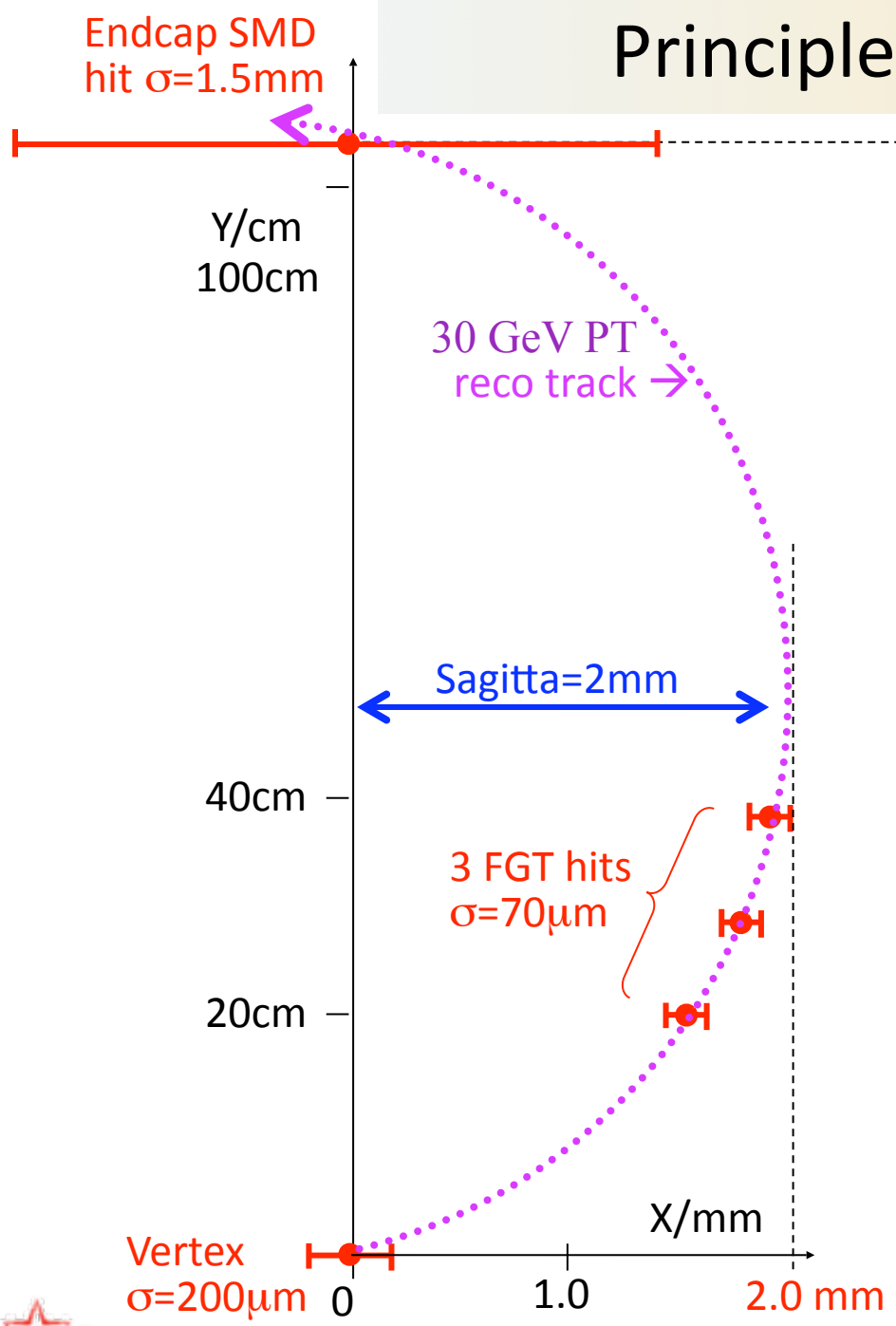


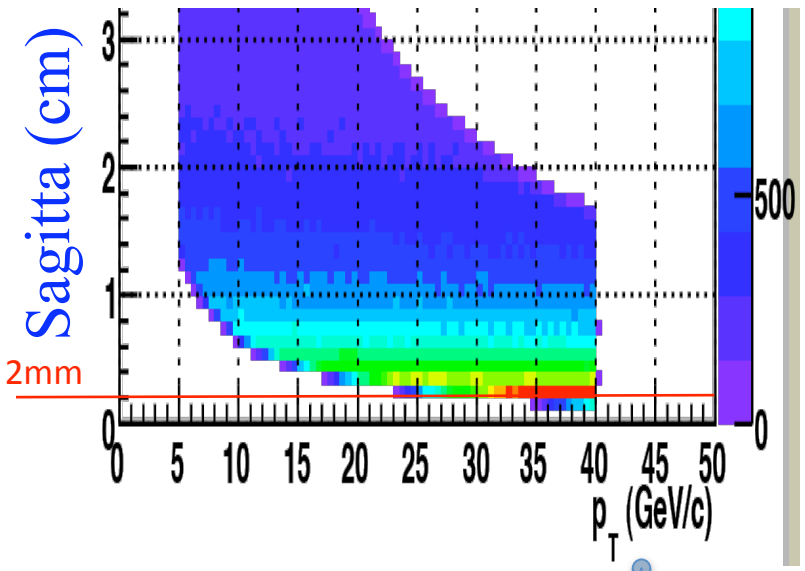


- **Find strip with highest energy under trigger patch**
- **Sum energy of highest strip and the three strips on either side**
- **Plot shows the ratio of seven strip sum to sum of energy of all strips under the trigger patch**
- **Plot shown after all other cuts applied**

Forward rapidity MC simulations

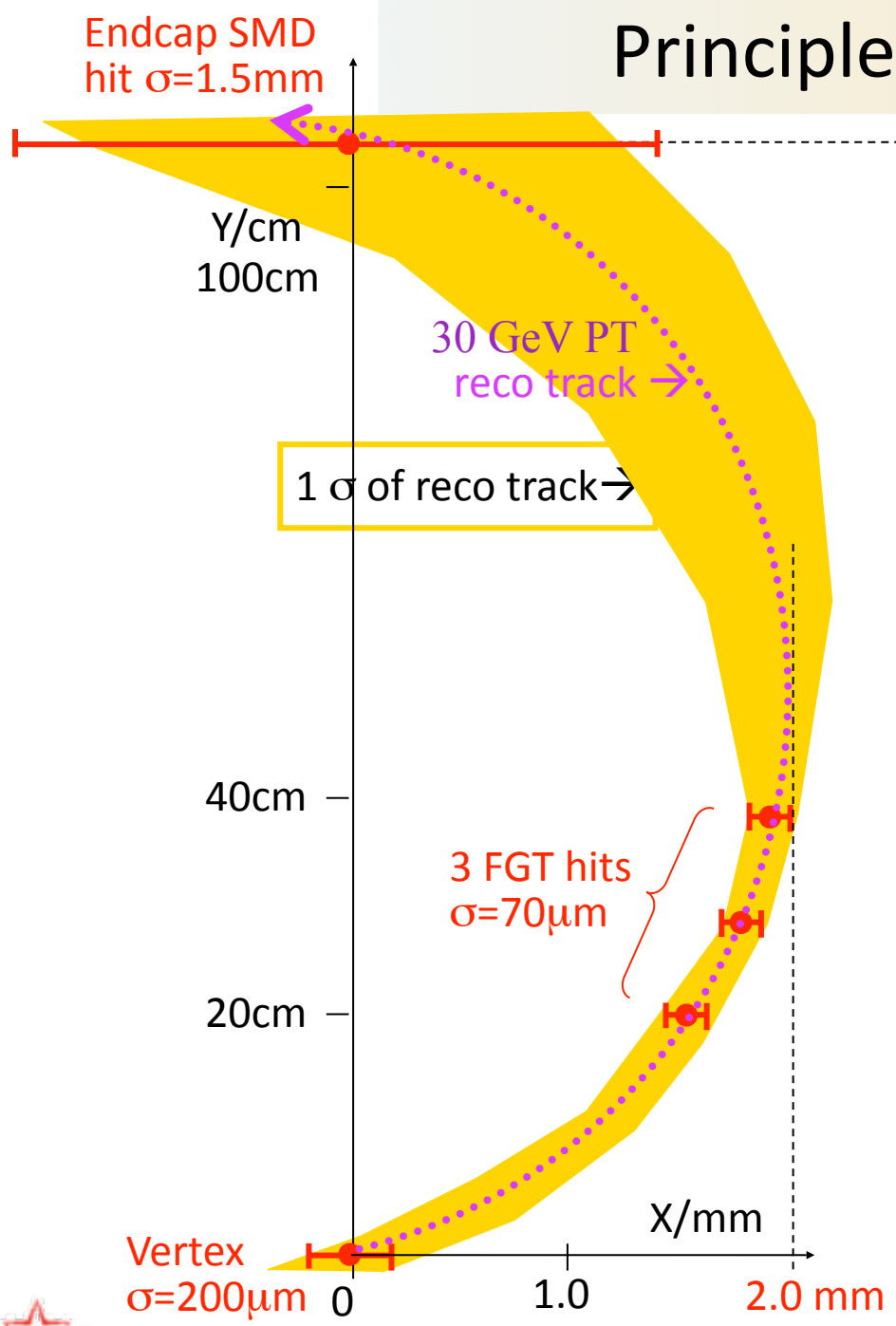
Principle of e+ vs. e- differentiation



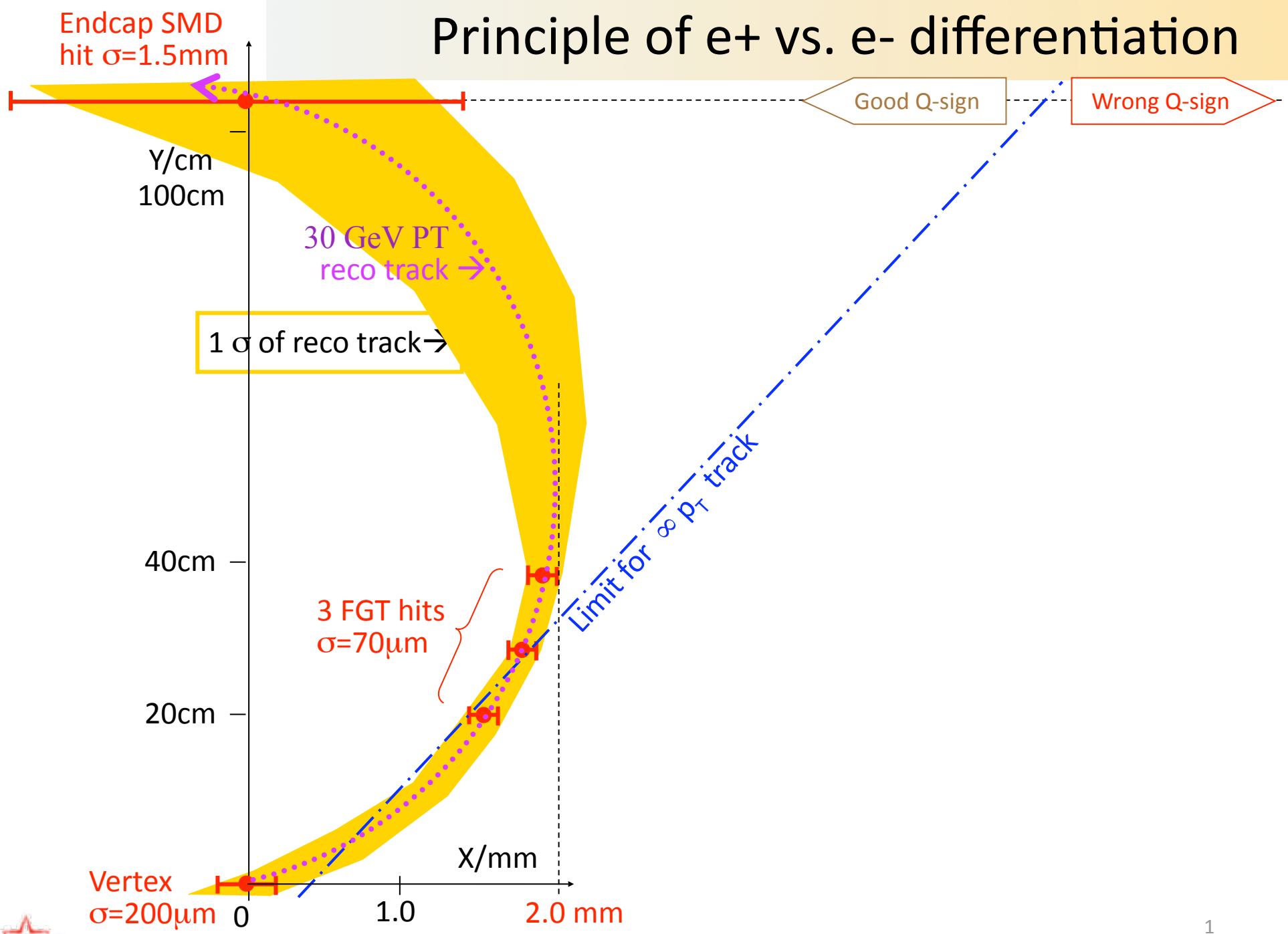


Include vertex & Esmd

Principle of e+ vs. e- differentiation

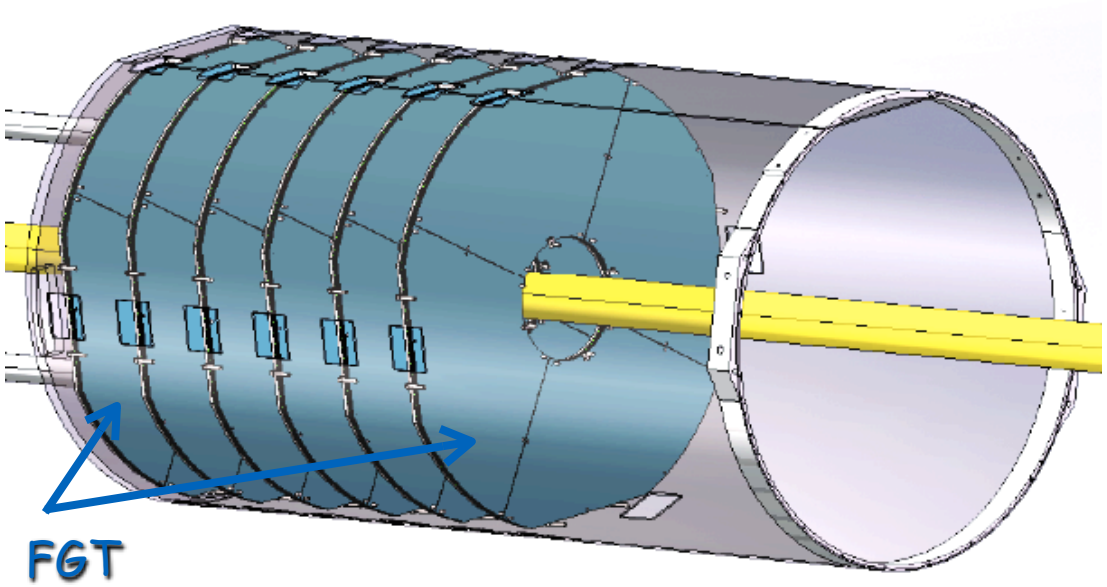


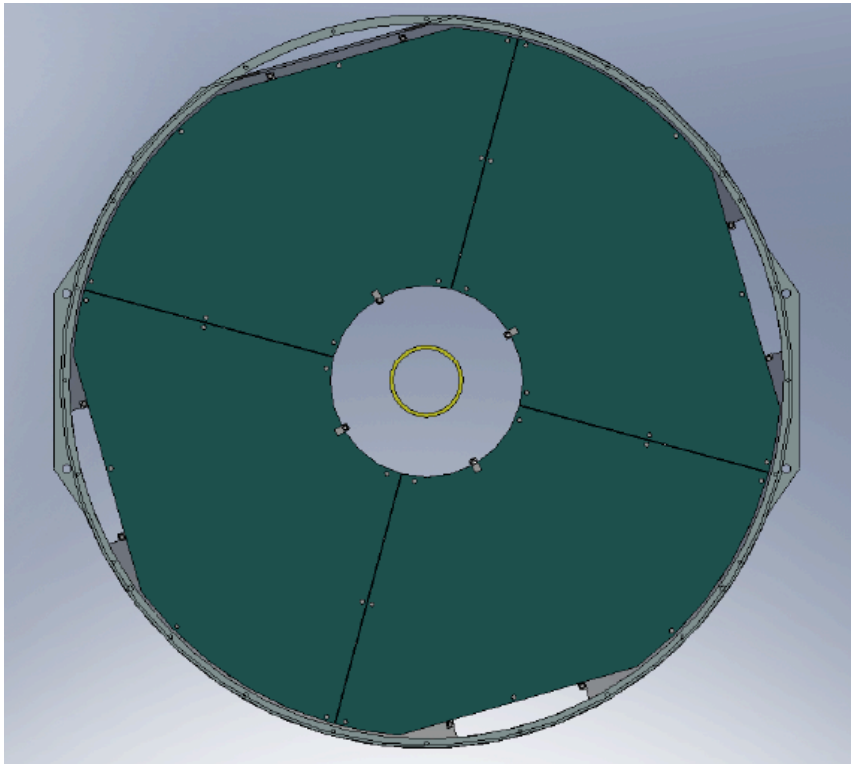
Principle of e+ vs. e- differentiation



FGT Technical realization

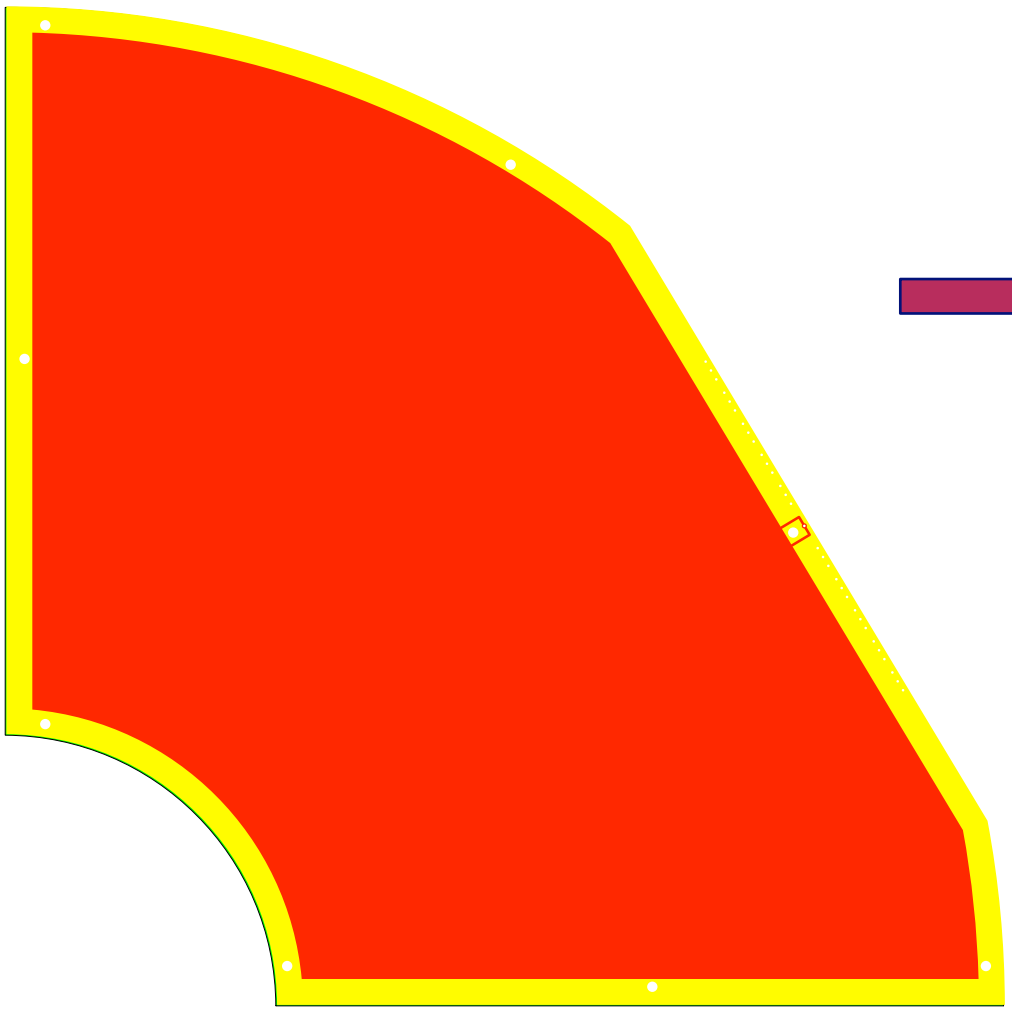
- Mechanical design

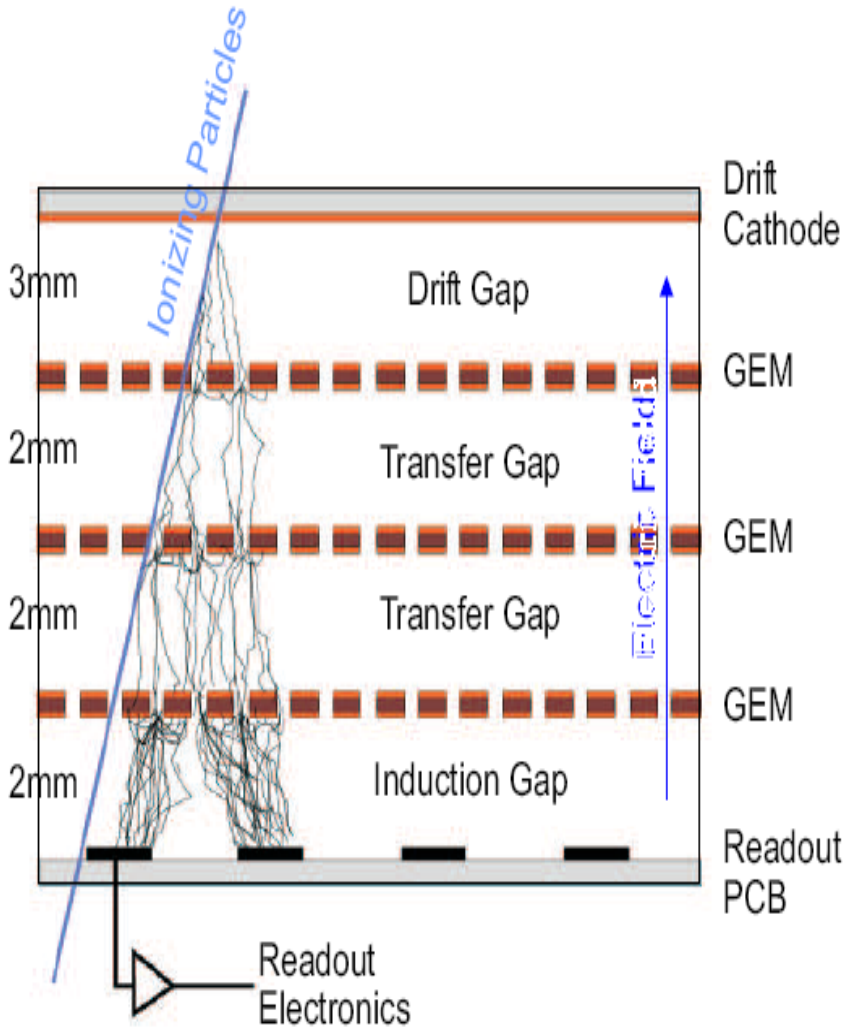




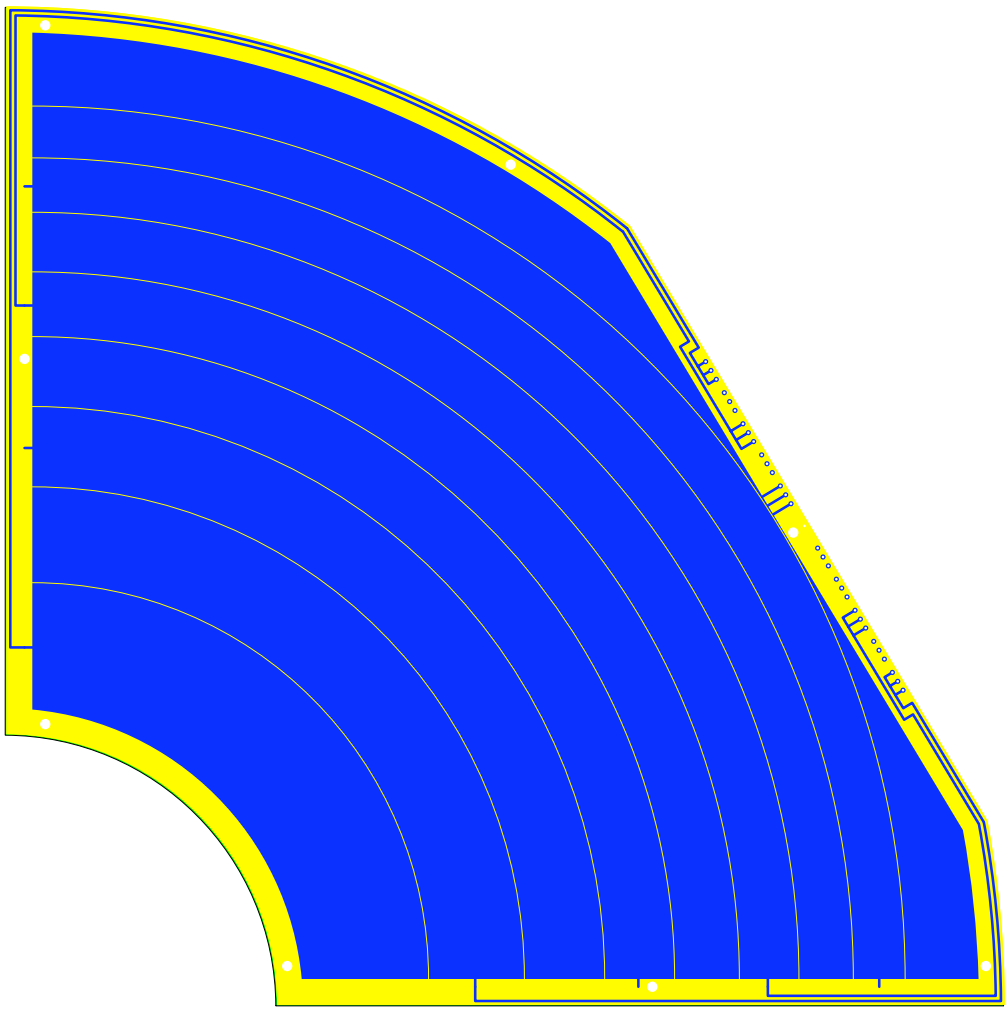
- FGT: 6 light-weight disks
- Each disk consists of 4 triple-GEM chambers (Quarter sections)
- Procurement and assembly of full quarter section prototype in preparation

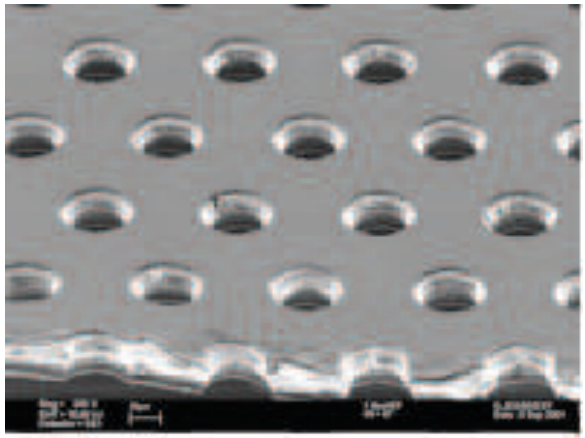
FGT Technical realization

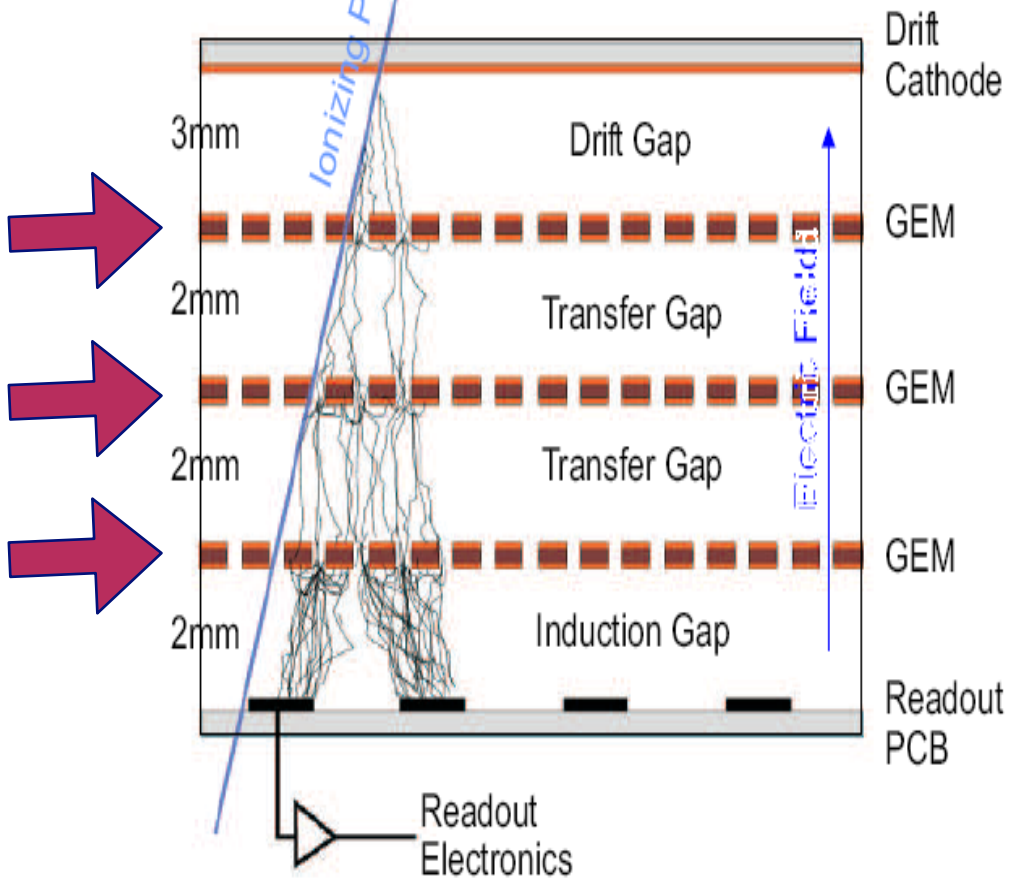




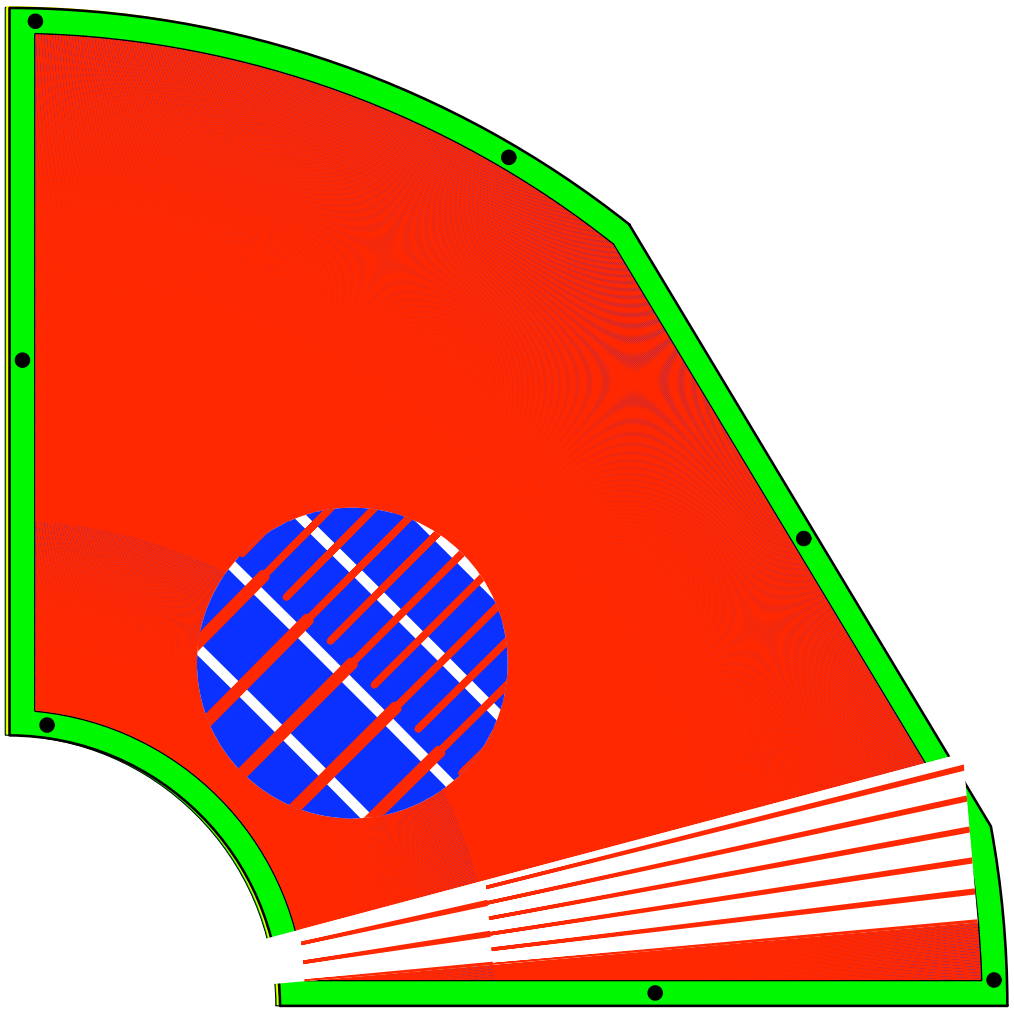
FGT Technical realization

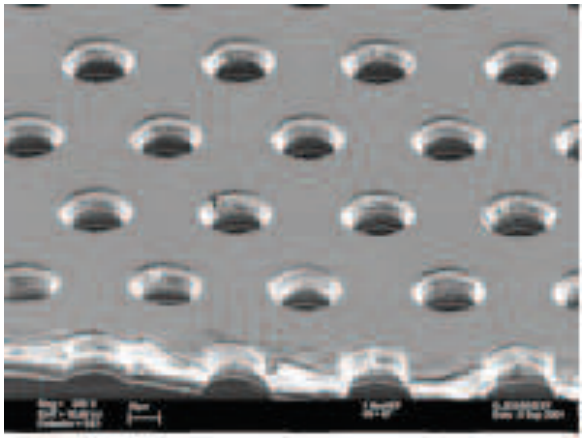


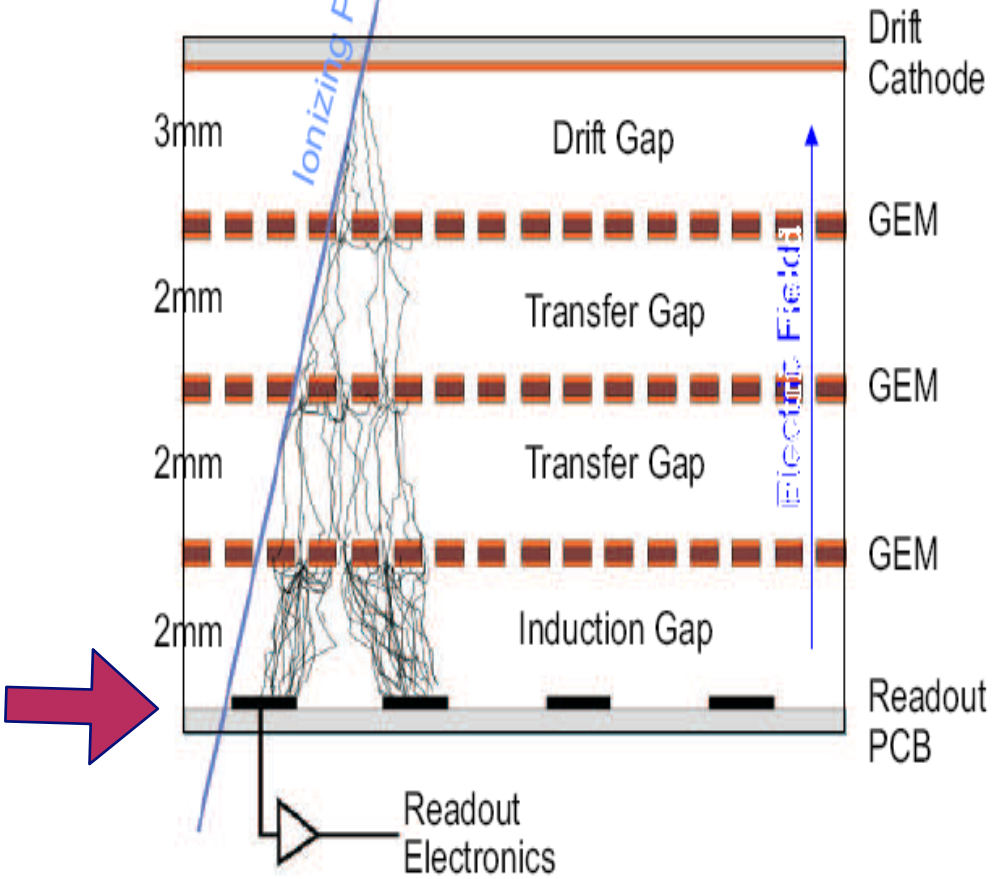




FGT Technical realization







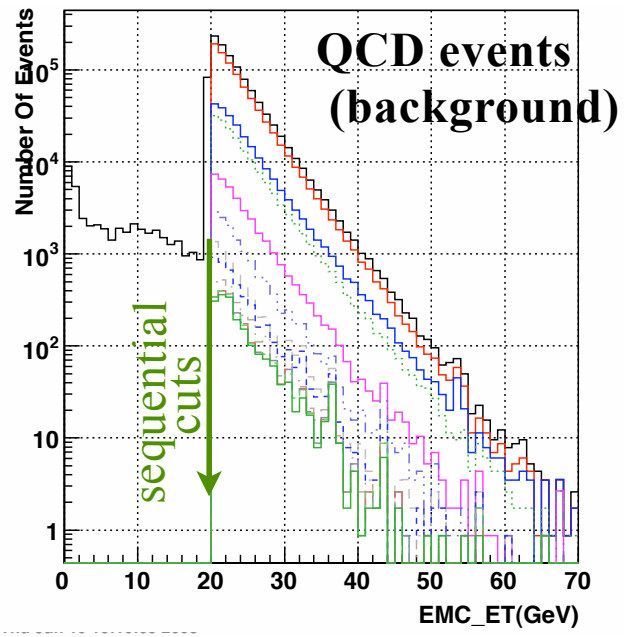
QCD Physics Background Suppression at Forward Rapidity

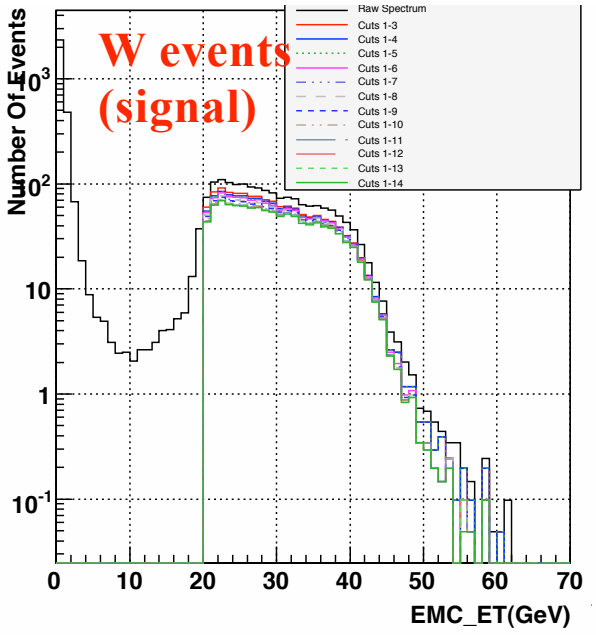
- generated 10e10 QCD pythia events w/ full detector response

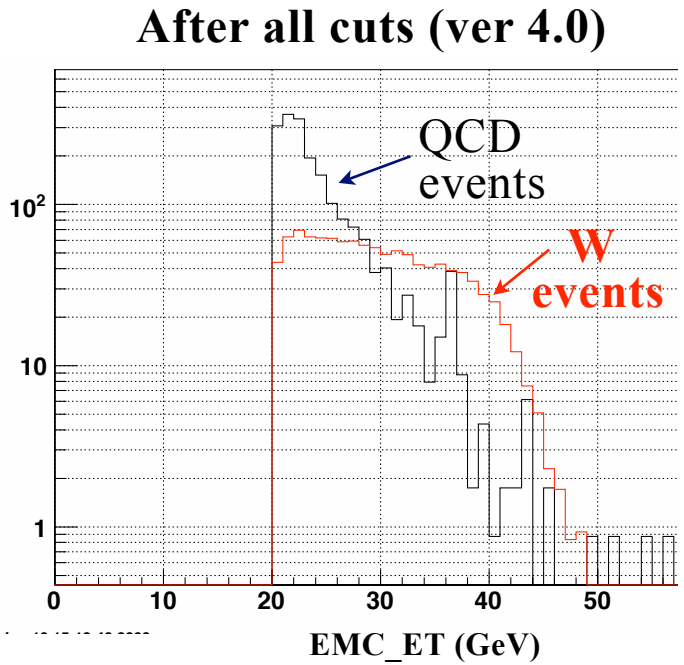
MC simulations

- e/h separation: Full PYTHIA QCD background and W signal sample including detector effects

All simu scaled to LT=300/pb





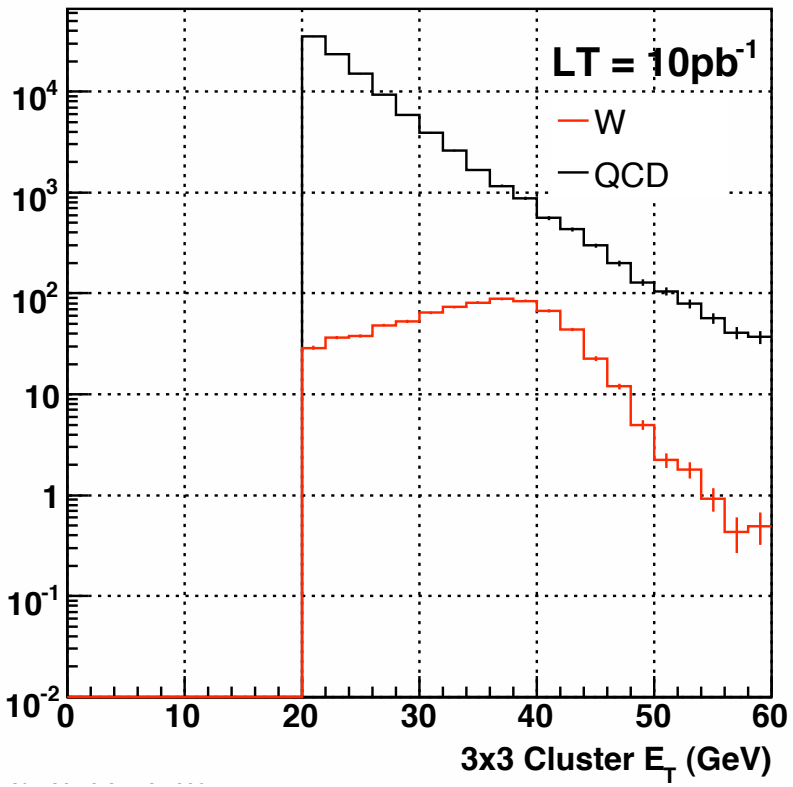


- e/h separation based on global cuts (isolation/missing E_T) and EEMC specific cuts
- With current algorithm: E_T > 30GeV yields S/B > 1
  - (tmp: 70% of Geant tracks used isolation cut)

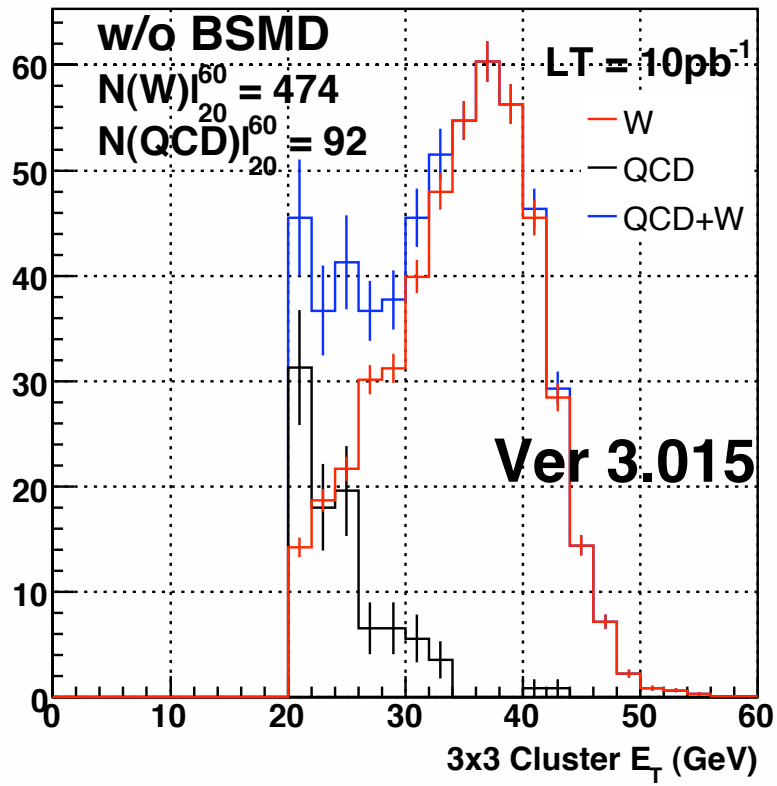
QCD Physics Background Suppression at Mid Rapidity

MC simulations

QCD and W for mid-rapidity before cuts



QCD and W for mid-rapidity after cuts



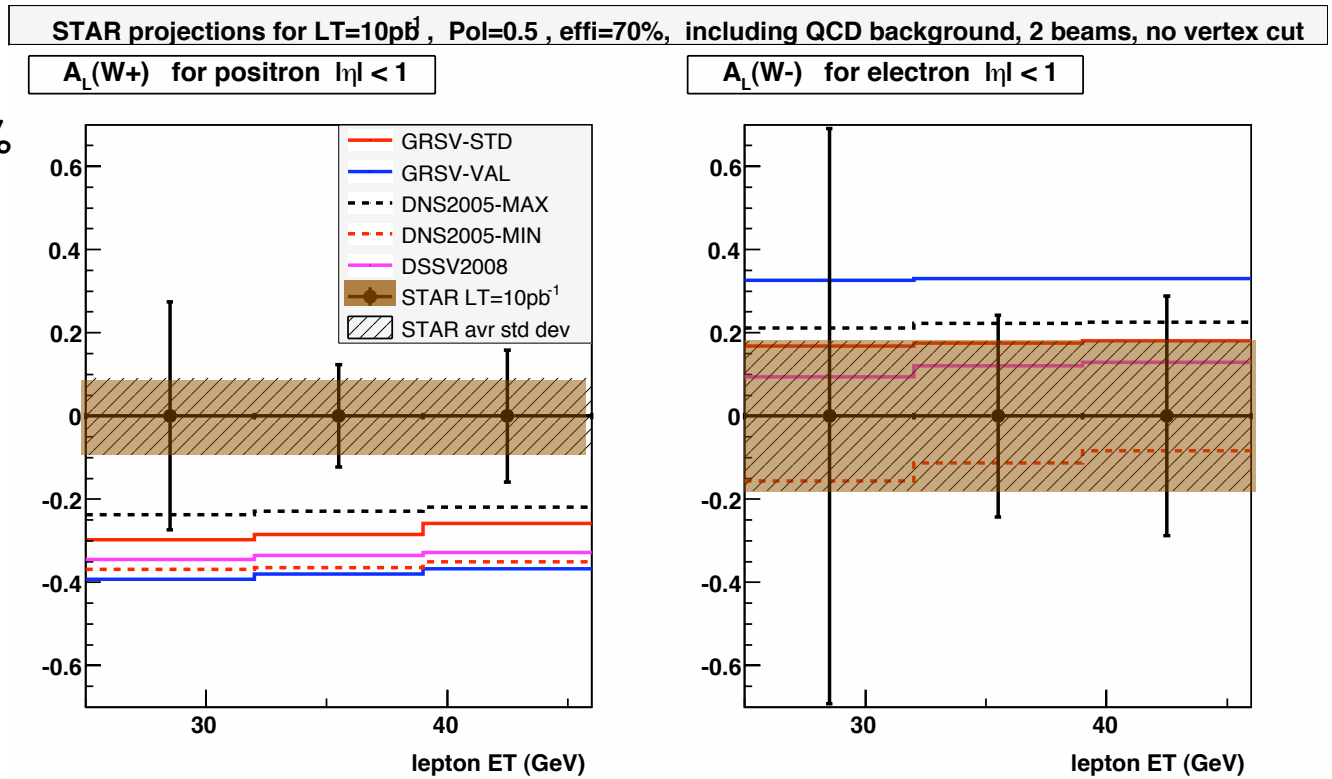
500 GeV longitudinal running in 2009

Goal : First measurement of A_L for W

MC simulations

Effective signal ~250 (W^+) ~60 (W^-) with 10 pb^{-1}

- Longitudianl Polarization = 50%
- Luminosity: 10pb^{-1}
- FOM = 2.5pb^{-1}



(assuming W-reco algo at mid rapidity yields S/B >1 for lepton ET>30 GeV)

Status on April 12, 2009

- recorded ~4 weeks of data with well working detector
- average beams pol of about 35%
- sampled luminosity of ~10pb^{-1}

Summary and Outlook

- Exciting program of W production in polarized proton-proton collisions at RHIC constraining polarized u/d anti-quark distributions - Clear sensitivity in particular at forward rapidity
- STAR experiment requires upgrade of forward tracking system for charge sign discrimination of electrons/positrons
- Triple-GEM technology provides a cost effective way for a forward tracking upgrade solution
- Goal: Full installation summer 2011 to be ready for Run 12
- 2009 run data expected to yield W xsection at mid rapidity
- Awaiting forward rapidity A_L measurement in next few years