W physics at RHIC –

Physics case and preparations in STAR and PHENIX

RHIC Spin Collaboration Meeting,
April 21

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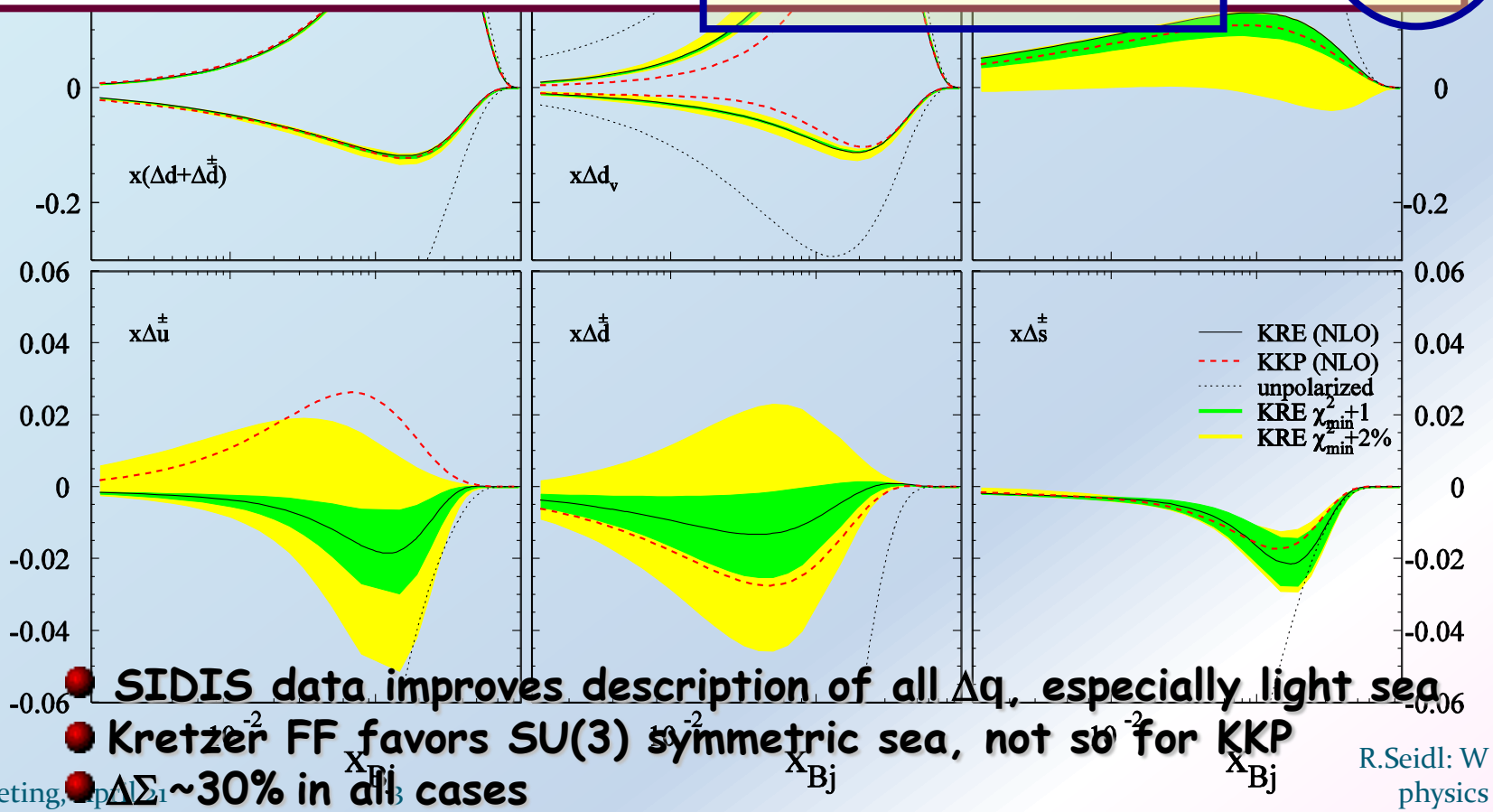
Outline

- Introduction, Theory:
  - Current knowledge of quark helicity distributions
  - Real W production as high-scale access to (anti)quark helicities
  - Inclusive W→lepton Single spin asymmetries theoretically well understood
- Experimental preparedness for W-physics
  - STAR: EEMC + Forward Gem Tracker (FGT) upgrade :
    - Technology under control
    - Installation schedule
  - PHENIX
    - Central Arm: EMCal + DCs , expected asymmetries
    - Muon arms: RPC and and Muon Tracker FEE upgrades:
      - Backgrounds: Simulation and reduction , Absorber
      - Installation schedule
      - Expected asymmetries

Current knowledge of helicity distributions: NLO FIT to DIS & SIDIS data

D. De Florian et al. PRD71:094018,2005 NLO @ Q^2=10 GeV^2

	χ^2_{DIS}	χ^2_{SIDIS}	Δu_v	Δd_v	$\Delta\bar{u}$	$\Delta\bar{d}$	Δs	Δg	$\Delta\Sigma$
Kretzer	206	225	0.94	–0.34	–0.049	–0.055	–0.051	0.68	0.28
KKP	206	231	0.70	–0.26	0.087	–0.11	–0.045	0.57	0.31



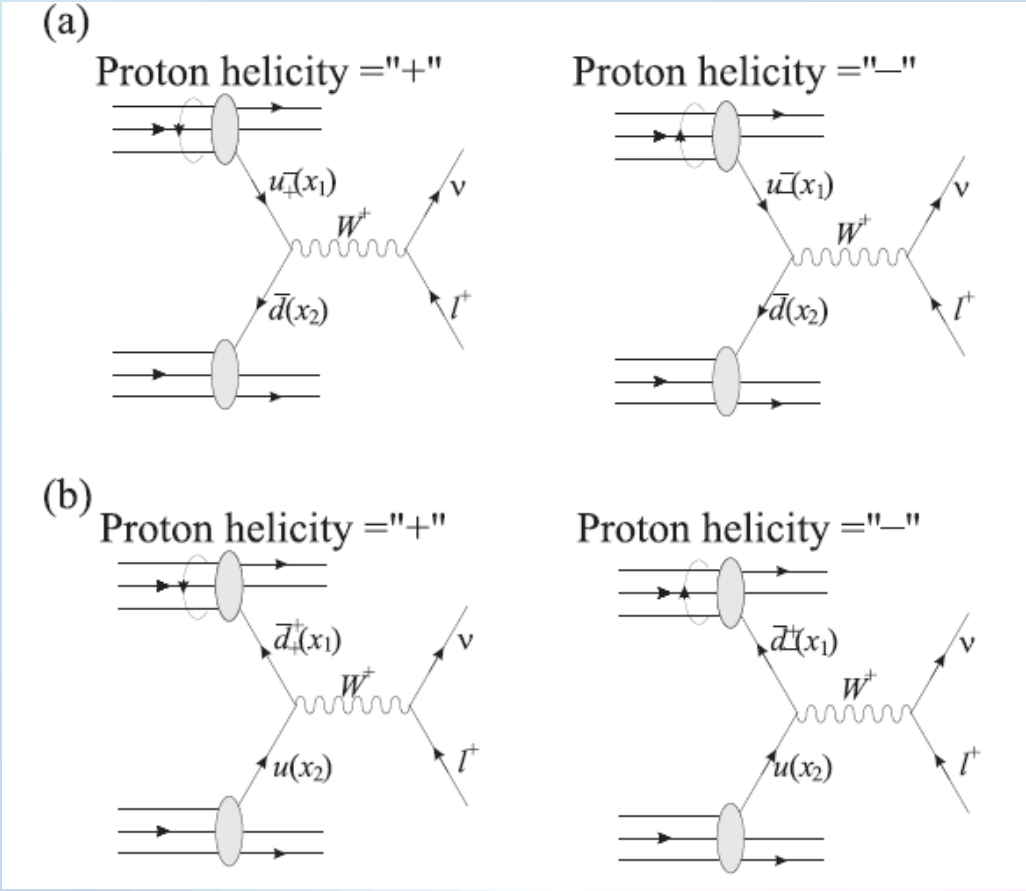
- SIDIS data improves description of all Δq, especially light sea
- Kretzer FF favors SU(3) symmetric sea, not so for KKP
- ΔΣ~30% in all cases

Real W production as access to quark helicities

- Maximally parity violating V-A interaction selects only lefthanded quarks and righthanded antiquarks:

➔Having different helicities for the incoming proton then selects spin parallel or antiparallel of the quarks

➔Difference of the cross sections gives quark helicities $\Delta q(x)$



Quark and antiquark helicities probed in W production

- Building single spin asymmetries of decay lepton

$$A_L = \frac{\vec{N} - \overleftarrow{N}}{\vec{N} + \overleftarrow{N}}$$

- Positive lepton asymmetries sensitive to $\Delta u\,(x)$ and $\Delta\,\bar{d}\,(x)$

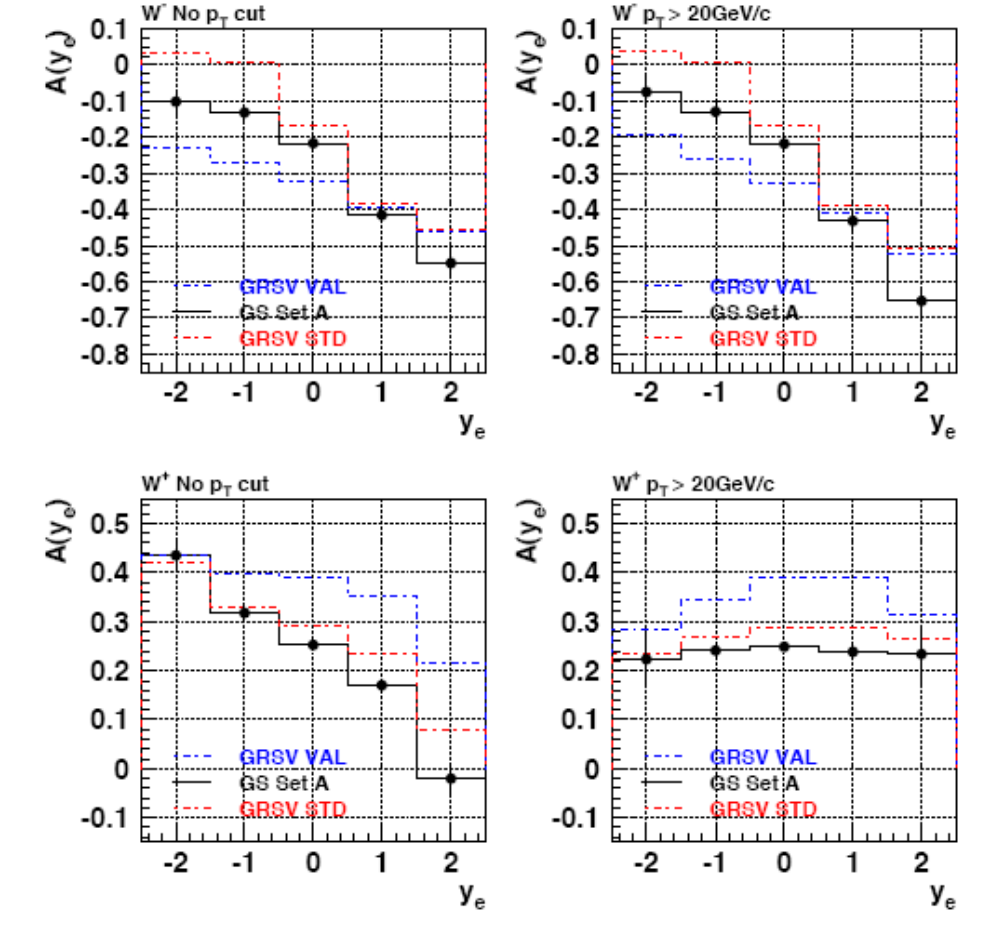
$$A_L^{W^+} \approx -\frac{\Delta u(x_1)\bar{d}(x_2) - \Delta\bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) - \bar{d}(x_1)u(x_2)}$$

- Negaitv lepton asymmetries sensitive to $\Delta d\,(x)$ and $\Delta\,\bar{u}\,(x)$

$$A_L^{W^-} \approx -\frac{\Delta d(x_1)\bar{u}(x_2) - \Delta\bar{u}(x_1)d(x_2)}{d(x_1)\bar{u}(x_2) - \bar{u}(x_1)d(x_2)}$$

Asymmetries and sensitivities

- Large asymmetries in the forward regions due to the u and d quark polarizations
- Very different parameterizations in the backward regions due to sea polarizations
- Large scale way to test quark polarizations
- Pin down sea



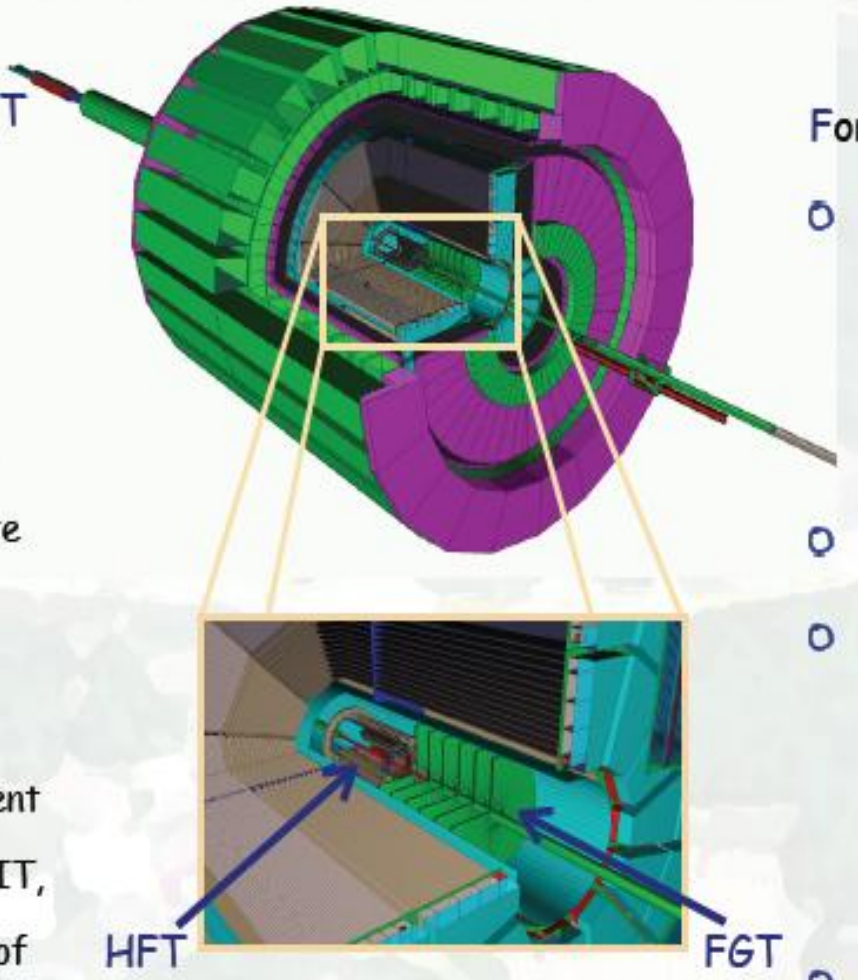
STAR - Tracking Upgrade

Overview

Heavy Flavor Tracker: HFT

- Precision vertexing for charm and bottom reconstruction
- Silicon pixel (PIXEL) and silicon strip (Intermediate Silicon Tracker - IST)
- HFT project:

  BNL, UC Irvine, UCLA, Kent State University, LBL, MIT, IPHC-Strasbourg, Univ. of Washington
- CD0 review: February 2008



DAC review, BNL, 01/07: Science well established / Configuration well motivated technologically!

Forward GEM Tracker: FGT

- Charge sign identification for high momentum electrons from $W^{\pm}$ decay (Energy determined with EEMC)
- Triple-GEM technology
- FGT project:

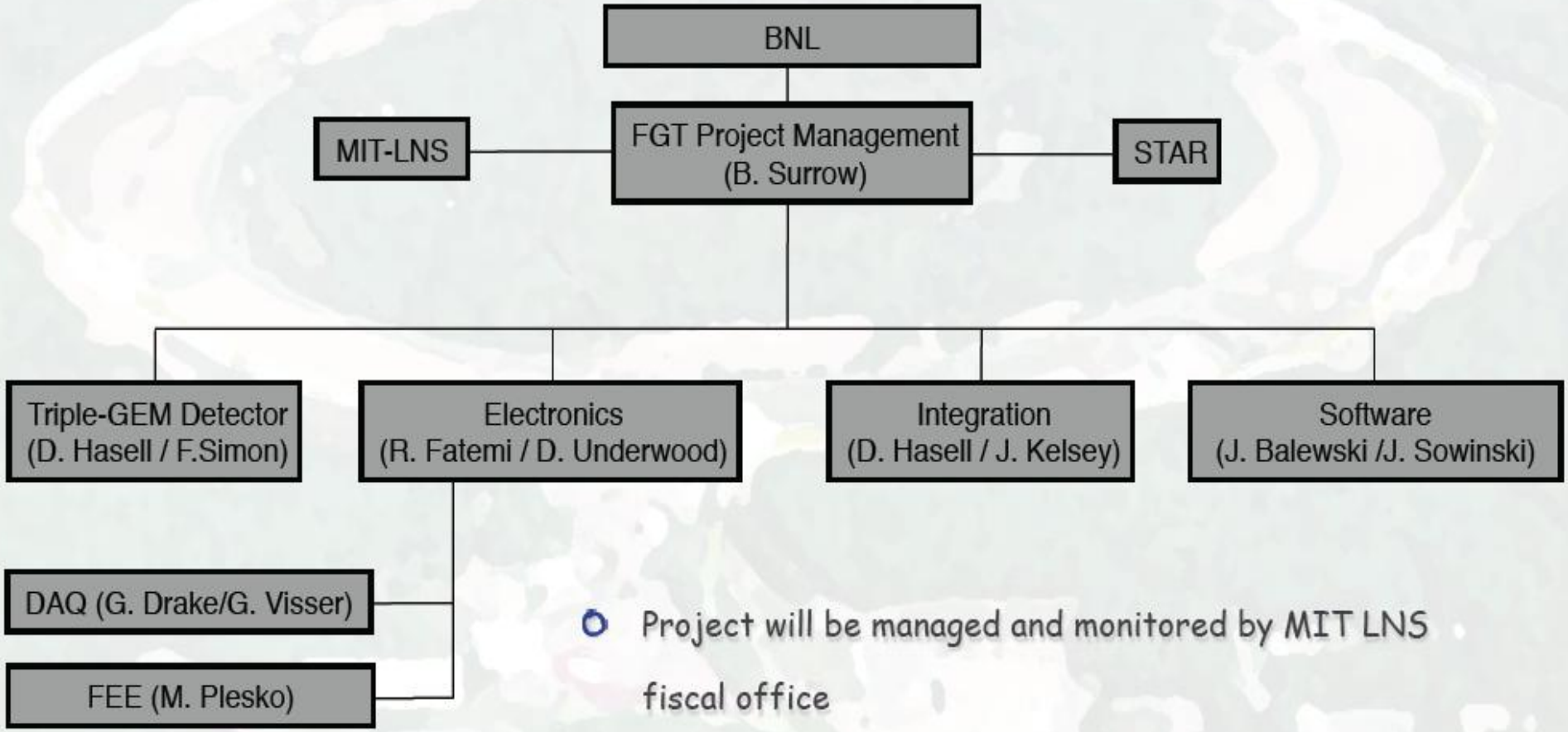
  ANL, IUCF, LBL, MIT, University of Kentucky, Valparaiso University, Yale
- Successful project review (Capital equipment funding): January 2008

STAR - Forward GEM Tracker

- STAR FGT project
  - Argonne National Laboratory: H. Spinka, D. Underwood, G. Drake, T. Kasprzyk (technician), post-doc
  - Indiana University Cyclotron Facility: W. Jacobs, J. Sowinski, G. Visser, S. Wissink, B. Page (student)
  - Lawrence Berkeley National Laboratory: H.G. Ritter, E. Sichtermann
  - Massachusetts Institute of Technology: J. Balewski, D. Hasell, J. Kelsey, K. Dow, R. Milner, M. Plesko, R. Redwine, D. Ross (technician), T. Sakuma (student), B. Surrow, G. van Nieuwenhuizen, students + post-doc
  - Max-Planck Institut fur Physik, Munich: F. Simon, students + post-doc
  - University of Kentucky: R. Fatemi, electronics technician, students
  - Valparaiso University: D.D. Koetke et al., students
  - Yale University: R. Majka, N. Smirnov

STAR - Forward GEM Tracker

- Organizational chart



- Project will be managed and monitored by MIT LNS fiscal office
- Quarterly reports to BNL management
- Contingency controlled by project management team

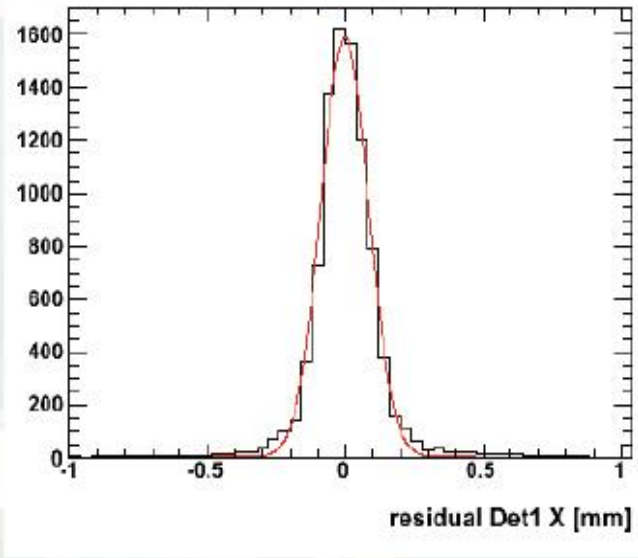
STAR - Forward GEM Tracker

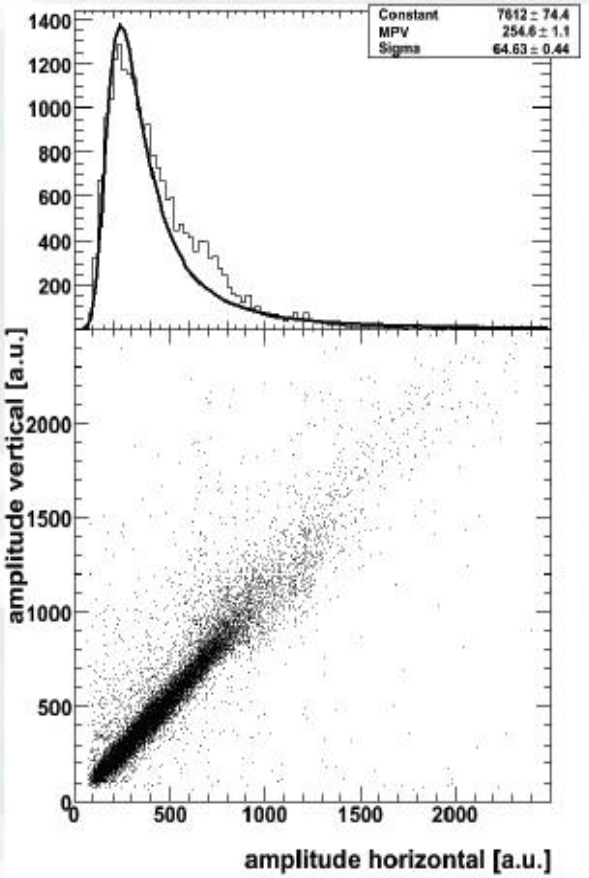
- Overview - Planing
  - Goal: Installation in summer 2010 ⇒ Ready for anticipated first long 500GeV polarized pp run in FY11 consistent with STAR 5-year Beam Use Request
  - Review: Successful review January 2008 / Beginning of construction funds FY08
  - Cost estimate and planing relies on the R&D and pre-design work:
    - Triple-GEM Detector: Complete prototype tested on the bench and during FNAL testbeam experiment with extensive experience in mechanical design work (MIT-Bates) and assembly including previous experience at COMPASS
    - Front-End Electronics (FEE) System: Complete prototype tested on the bench and during FNAL testbeam experiment based on existing APV25-S1 readout chip (MIT-Bates)
    - Data Acquisition (DAQ) System: Conceptual layout is based on similar DAQ sub-detector systems with extensive experience (ANL/IUCF)
    - GEM foil development: Successful development of industrially produced GEM foils through SBIR proposal in collaboration with Tech-Etch Inc. (BNL, MIT, Yale University)

STAR - Forward GEM Tracker

GEM technology development

- SBIR proposal (Phase I/II): Established commercial GEM foil source (Tech-Etch Inc.)
- FNAL testbeam of three prototype triple-GEM chambers including APV25 chip readout
- Performance meets requirements!

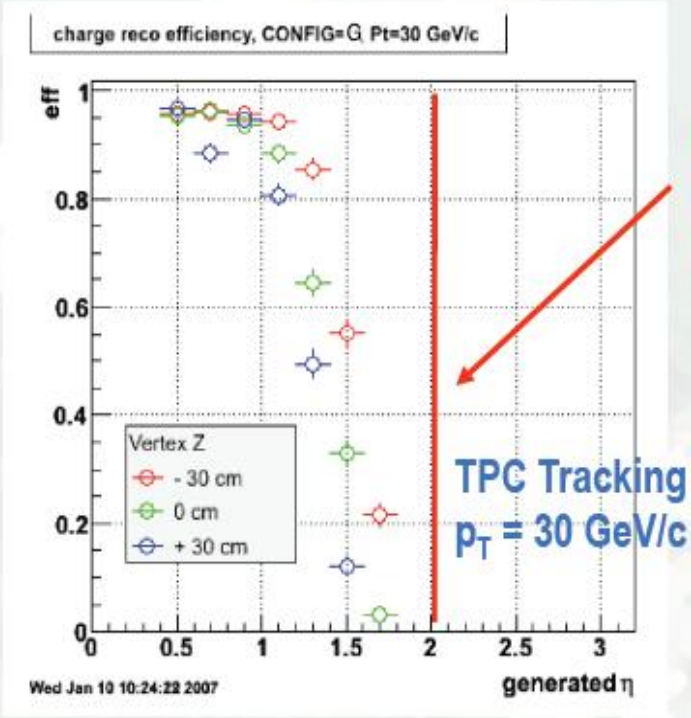




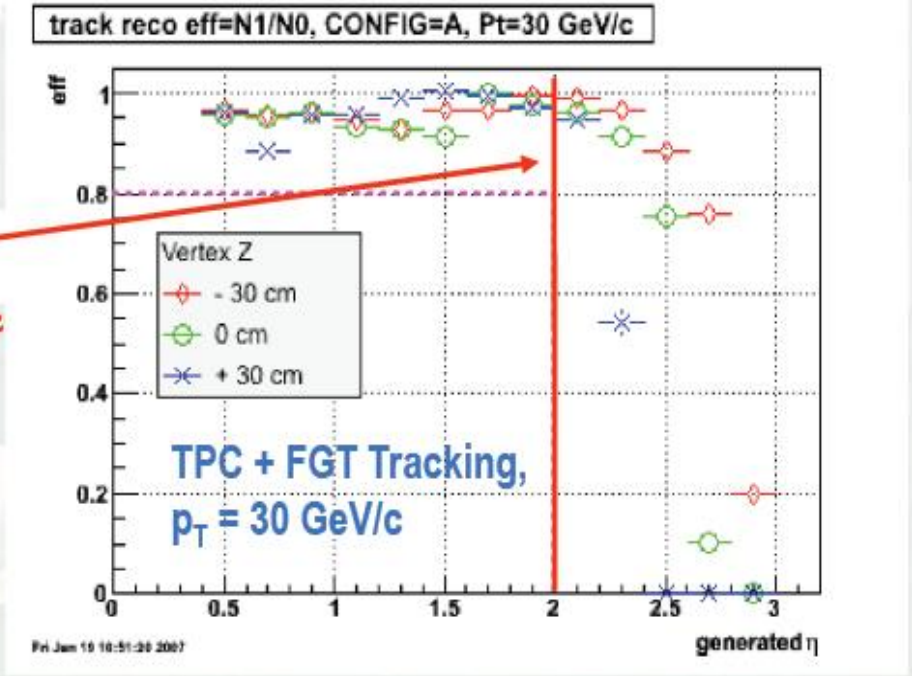
- Hit resolution: ~60 μm
- Good charge sharing!

STAR - Forward GEM Tracker

- e^+/e^- separation - Simulation work



Reach of EEMC Acceptance



Conclusion:

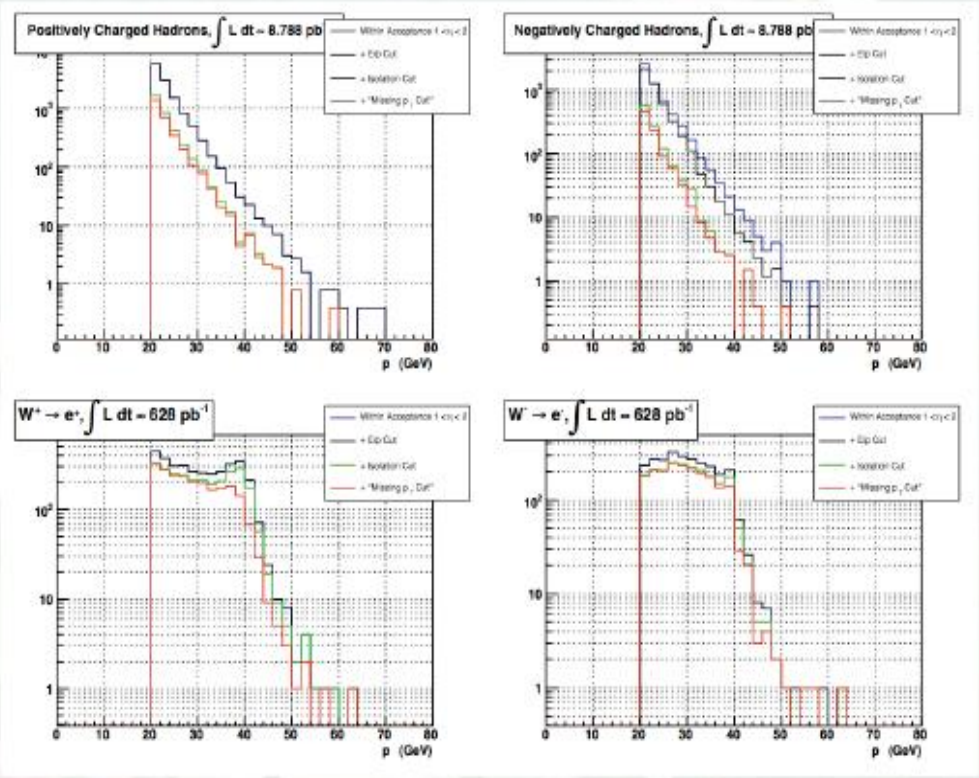
Charge sign reconstruction impossible beyond η = ~1.3

Conclusion: for 6 triple-GEM disks, assumed spatial resolution 60 μm in x and y (Fairly insensitive for 60-100 μm)

Charge sign reconstruction probability above 90% for 30 GeV p_T over the full acceptance of the EEMC for the full vertex spread

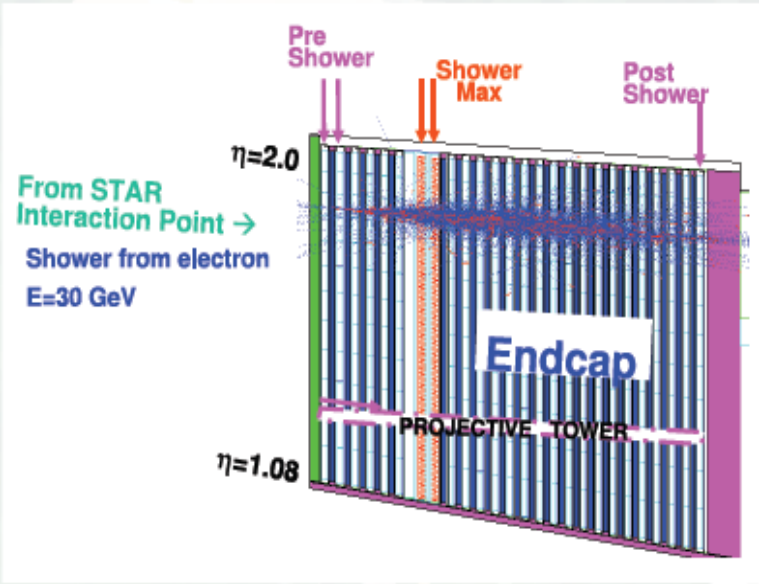
STAR - STAR Forward GEM Tracker

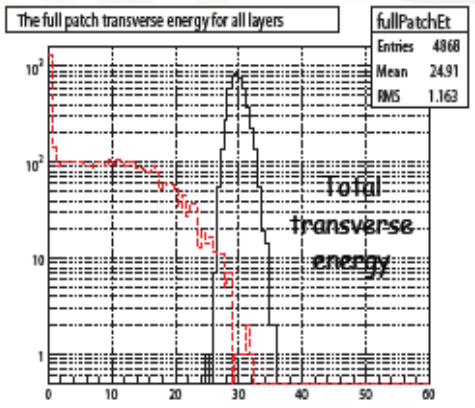
- e/h separation - Simulation work
  - Extensive full PYTHIA QCD background and W event simulations started
  - Strategy: Global cuts such isolation together with STAR EEMC specific cuts focusing on transverse / longitudinal shower shape discrimination
  - Expect e/h discrimination at the level of more than two orders of magnitude

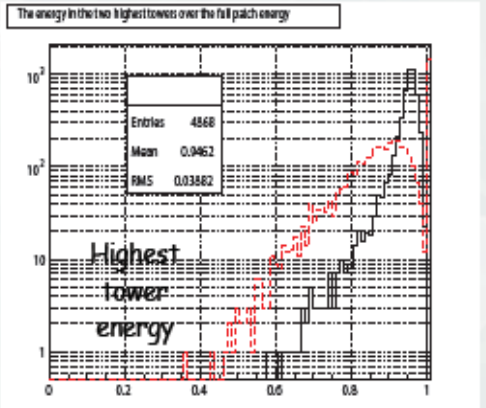


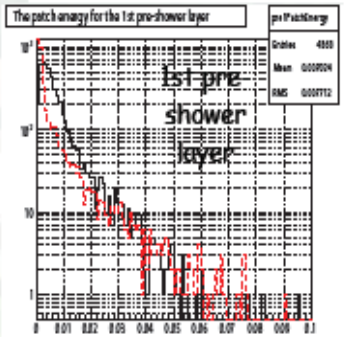
STAR - STAR Forward GEM Tracker

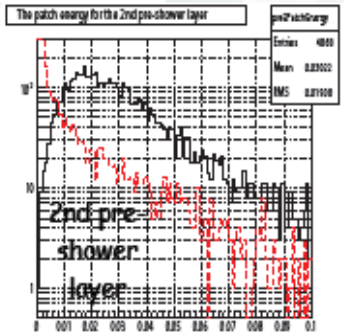
- e/h separation - Simulation work
  - EEMC distributions for different EEMC sub-systems for 30GeV electron and pion

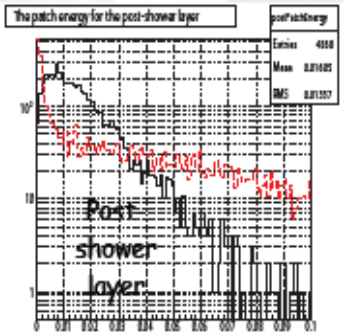


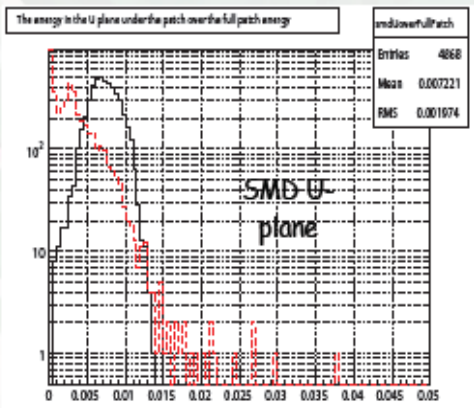


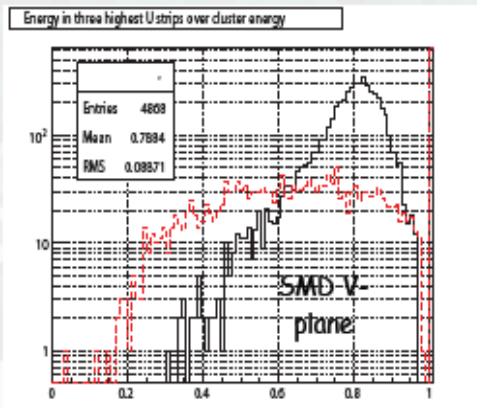






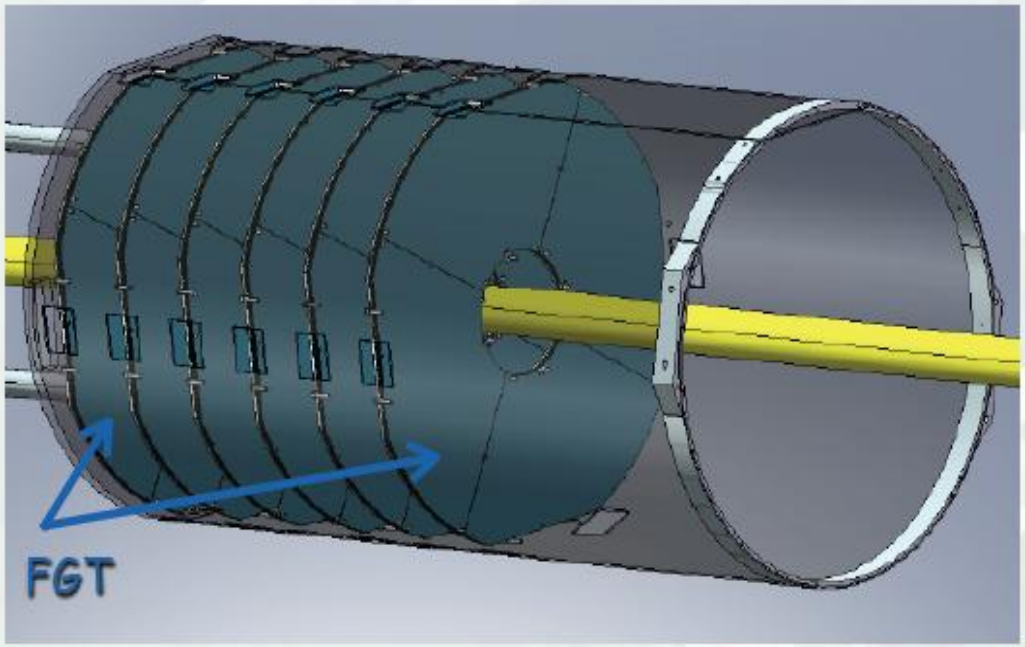


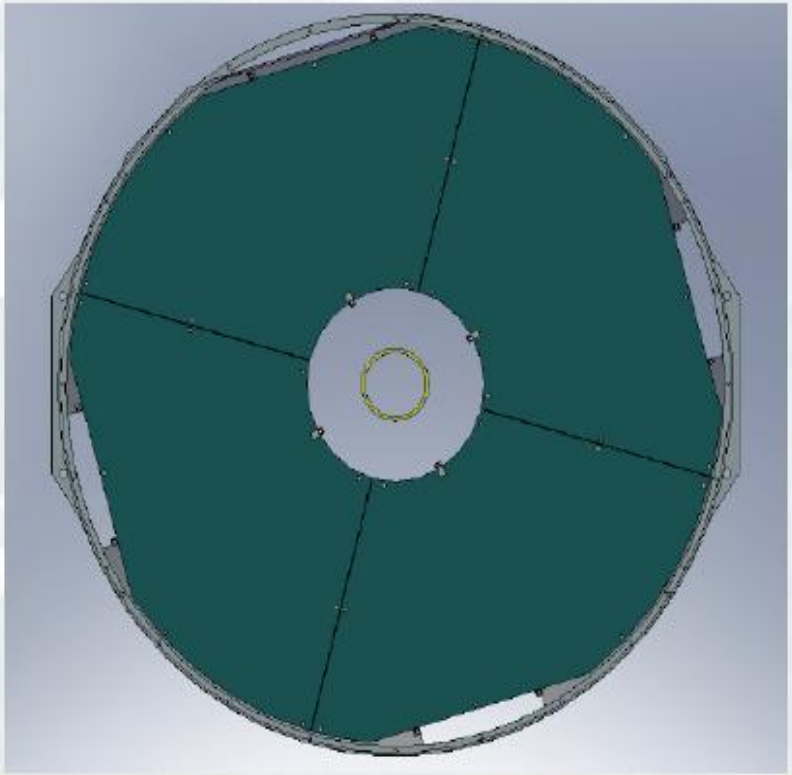




STAR - Forward GEM Tracker

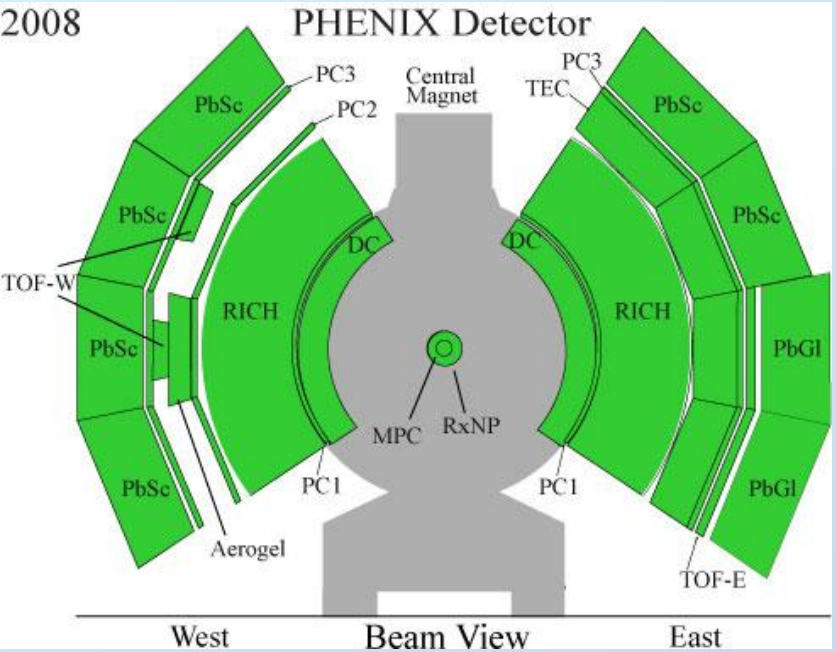
- Technical realization

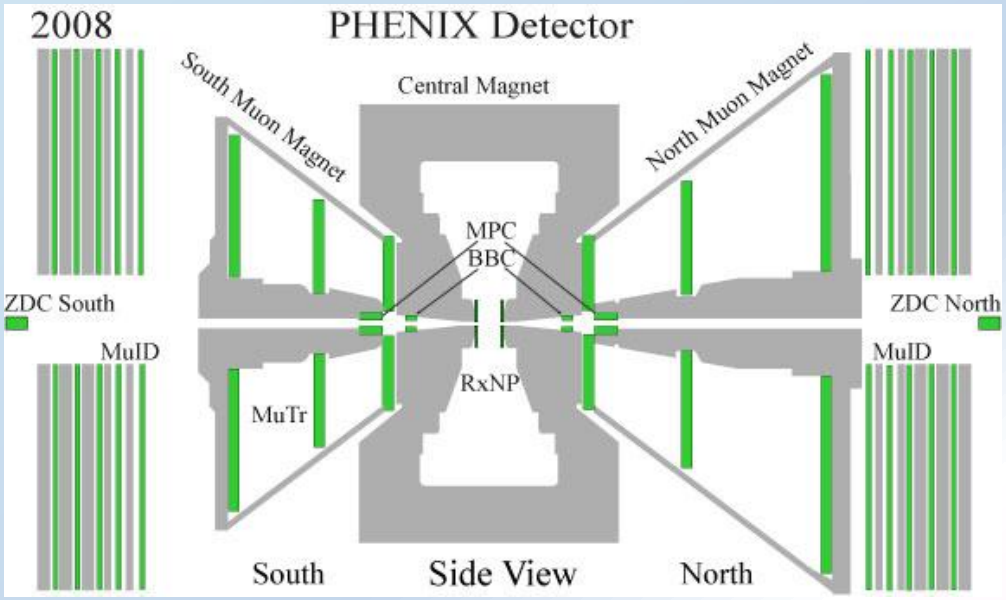




- FGT: 6 light-weight disks
- Each disk consists of 4 triple-GEM chambers (Quarter sections)
- Procurement and assembly of full quarter section prototype in preparation

PHENIX



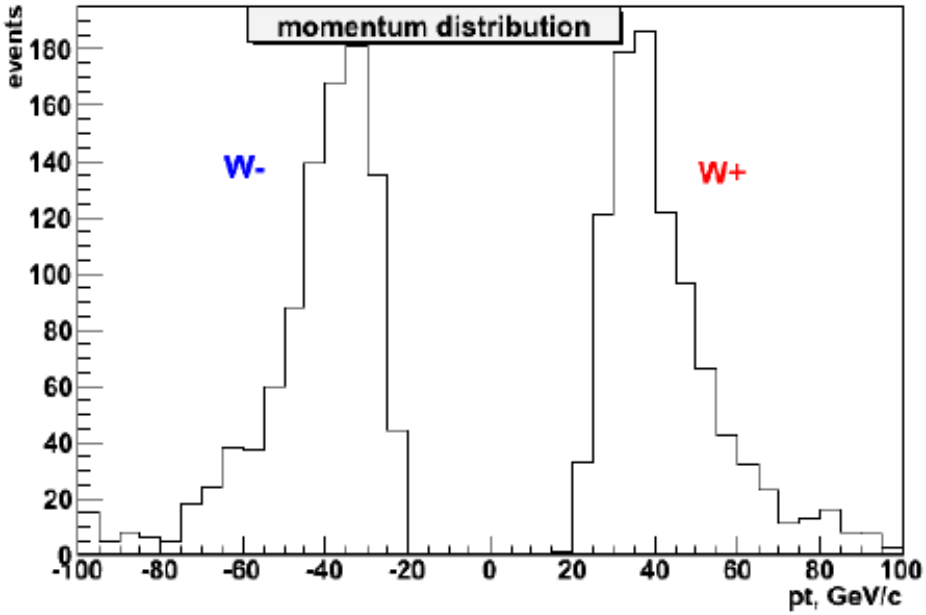


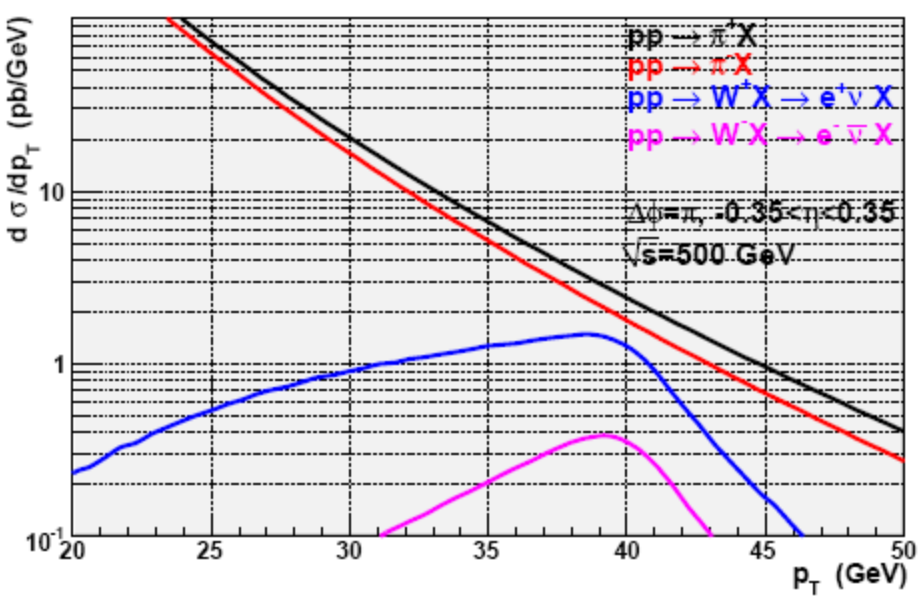
Central arm

Forward/ Backward Muon arms

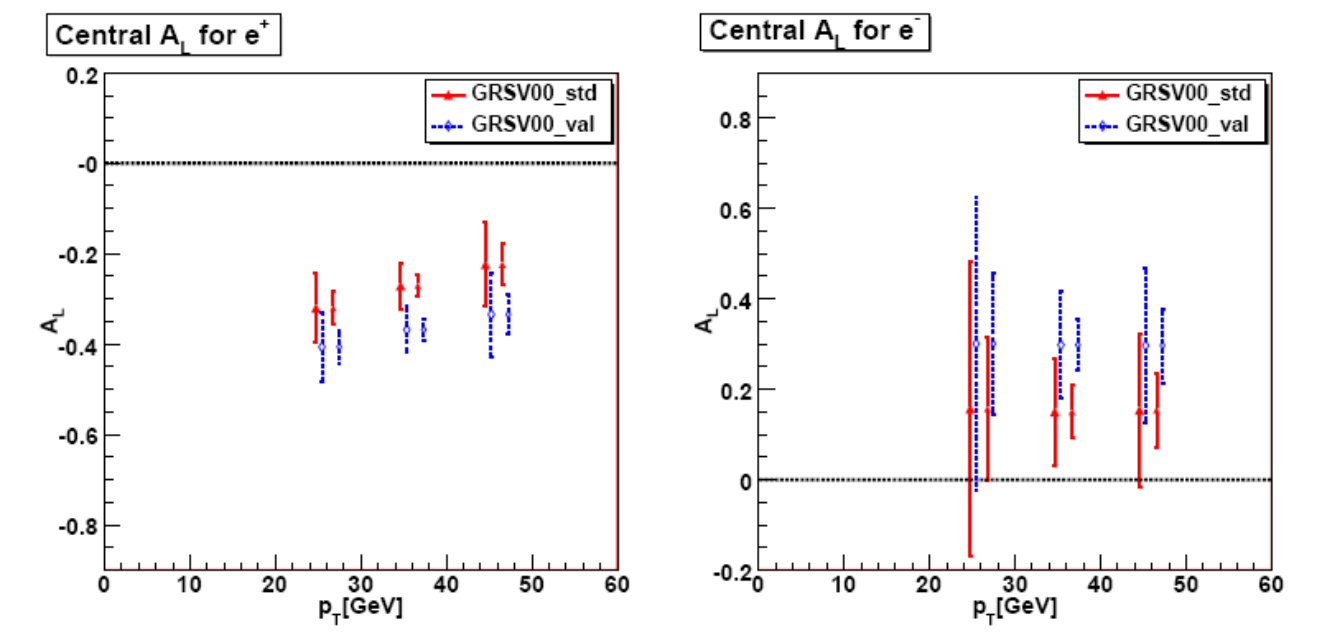
Central arm W measurememements

- Existing EMCal and DCs are adequate to detect electrons from W decays
- W momentum resolution about 8-9 GeV
- Charge reconstruction efficiency ~95%
- Deposited energy in EMCal and W isolation reduces hadron background by several orders of magnitude
- Clean measurements already possible now





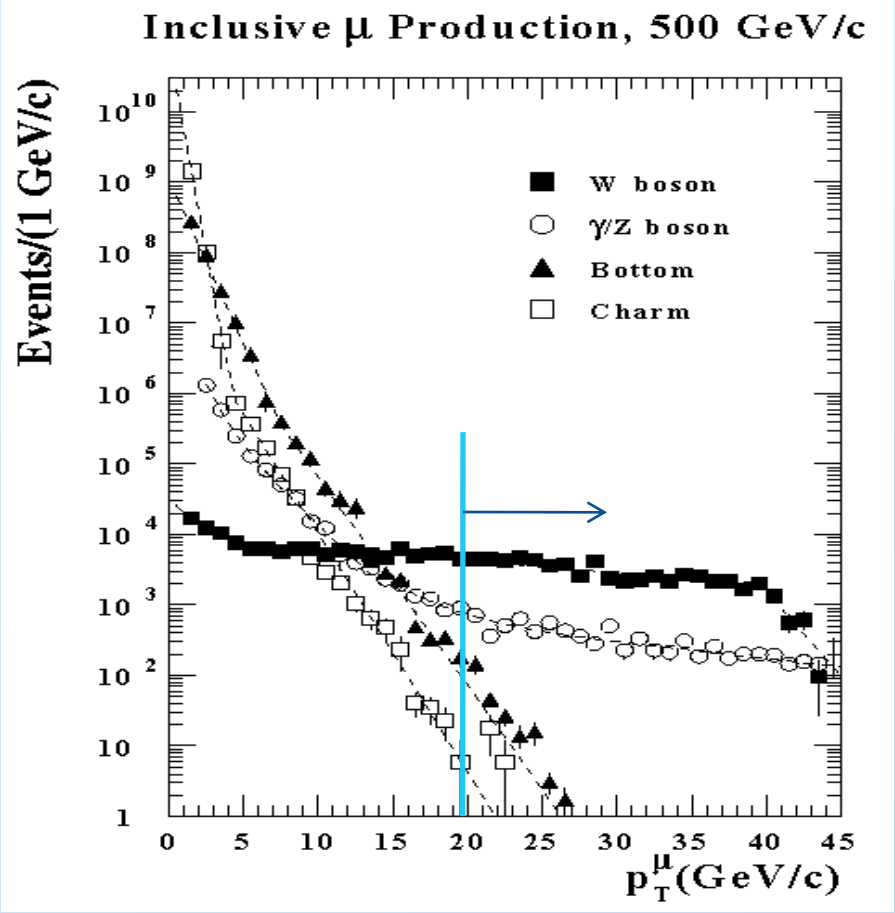
Expected Central arm asymmetries



Assumed luminosity:
319 pb^{-1} and 1320 pb^{-1}

- For central detector, still generated asymmetries
- Large asymmetries to be seen
- Even in central part distinction power between Sea scenarios

Forward/Backward arms: Trigger needs



- Hadronic decays dominate muon rates
- W dominate only above 20-25 GeV
- DAQ cannot take full rate @500GeV
- Current muon trigger momentum "blind"

➔ Need for a momentum sensitive muon trigger

➔ Add Resistive Plate Counters(RPCs)

➔ Add fast readout electronics for Muon tracker

Trigger Upgrade Group in PHENIX: RPCs

A. Basye, D. Isenhower, D. Jumper, N. Sparks, R. Towell, C. Watts, J. Wood and R. Wright
Abilene Christian University, Abiline

K. Barish and R. Seto
University of California, Riverside

S. Hu, X. Li, F. Zhou and S. Zhou
CIAE, Beijing, China

A. Linden-Levy, E. Kinney, J. Nagle
University of Colorado, Boulder

C.Y. Chi, W. Sippach and W. Zajc
Columbia University and Nevis Laboratory, New York

C. Butler, K. Dayana, X. He, C. Oakley and J. Ying
Georgia State University, Atlanta

J. Blackburn, M. Grosse Perdekamp, C. Lee, Y.-J. Kim, B. Meredith, T. Natoli, N. Mucia, D. Northacker, J.-C. Peng, E. Thorsland, A. Veicht, A. Vossen and R. Yang
University of Illinois, Urbana Champaign

J. Hill, T. Kempel, J. Lajoie, G. Sleege, C. da Silva and F. Wei
Iowa State University, Ames

J.H. Bae, B. Hong, B. D. Kim, B. I. Kim, K. B. Lee, K. S. Lee, C. S. Park, S. Park and K.-S. Sim
Korea University, Seoul, Korea

B. Fadem, J. Herstoff and P. Lichtenwalner
Muhlenberg College, Allentown, PA 18104, USA

Y. Mao and R. Han
Peking University, Beijing, China

G. Bunce and R. Seidl
RIKEN BNL Research Center

Trigger Upgrade Group in PHENIX: muTr FEE

T. Mibe, N. Saito
KEK, Tsukuba, Japan

K. Aoki, S. Dairaku, K. Imai, K. Karatsu, T. Murakami, A. Sato, K. Senzaka, K. Shoji, K. Tanida
Kyoto University, Kitashirakawa-Oiwakecho, Kyoto, Japan

M. Brooks and M. Leitch
Los Alamos National Laboratory, Los Alamos

D. Fields
University of New Mexico, Albuquerque

Y. Fukao and A. Taketani
RIKEN Institute, Hirosawa, Wako, Saitama, Japan

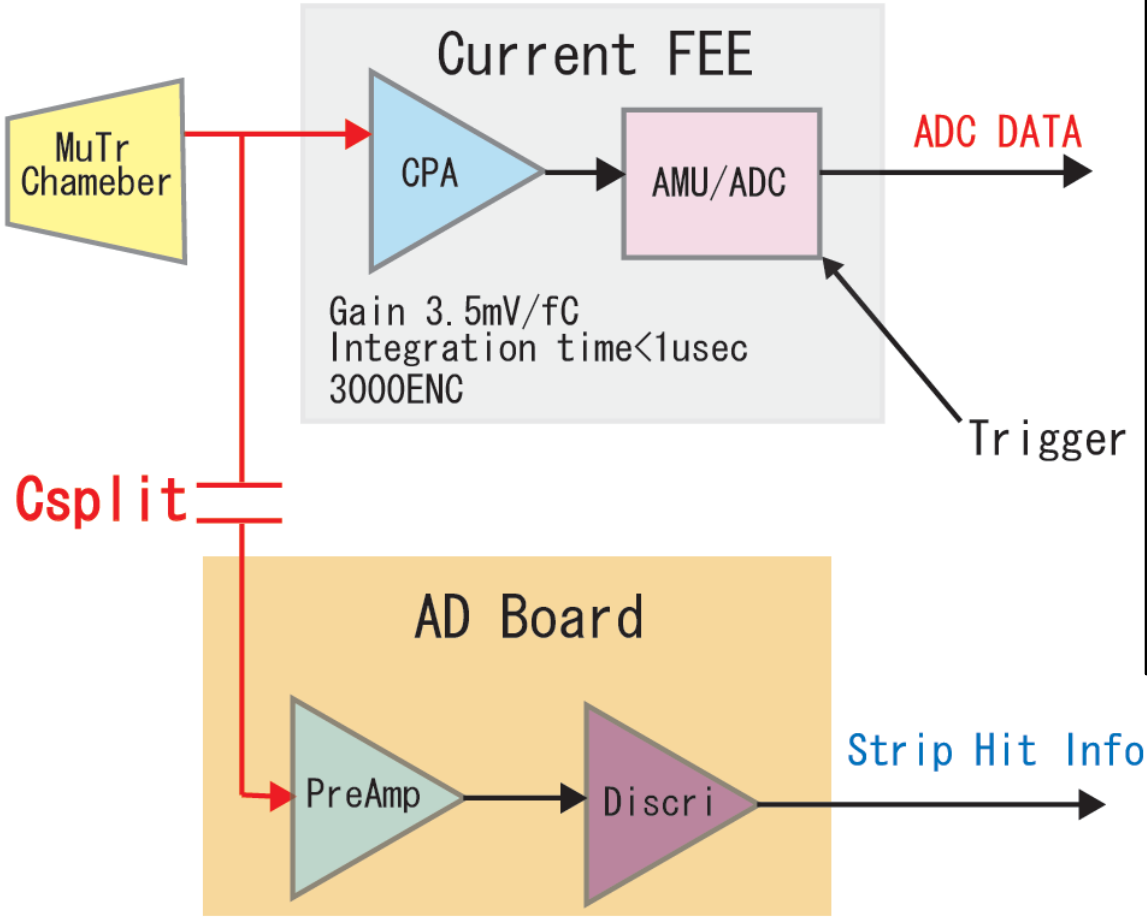
K. Kurita and J. Murata
Rikkyo University, Tokyo, Japan

78 collaborators from 18 institutions in the US, Japan, Korea and China

Funding:

muTr → $2.6 Million from JSPS
RPCs → $2.0 Million from NSF, $300k institutional

MuTr Front End Electronics (FEE) upgrade

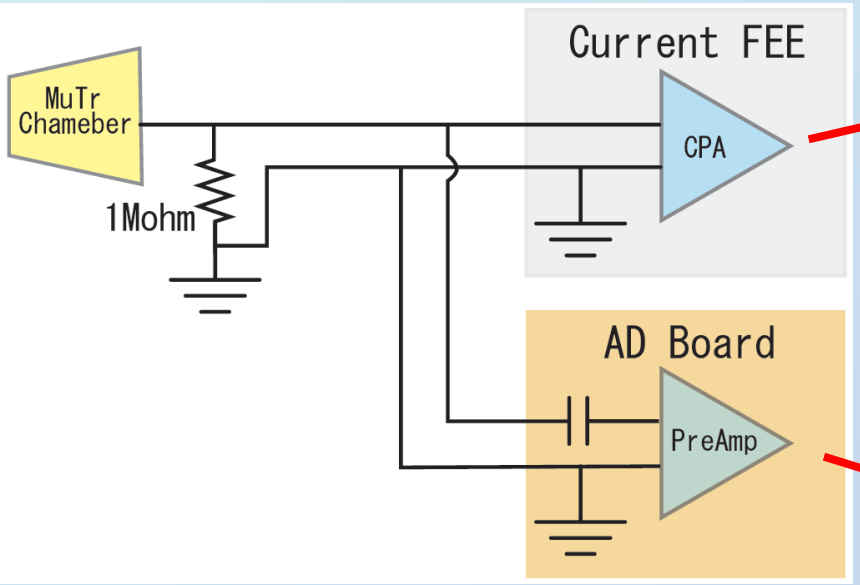


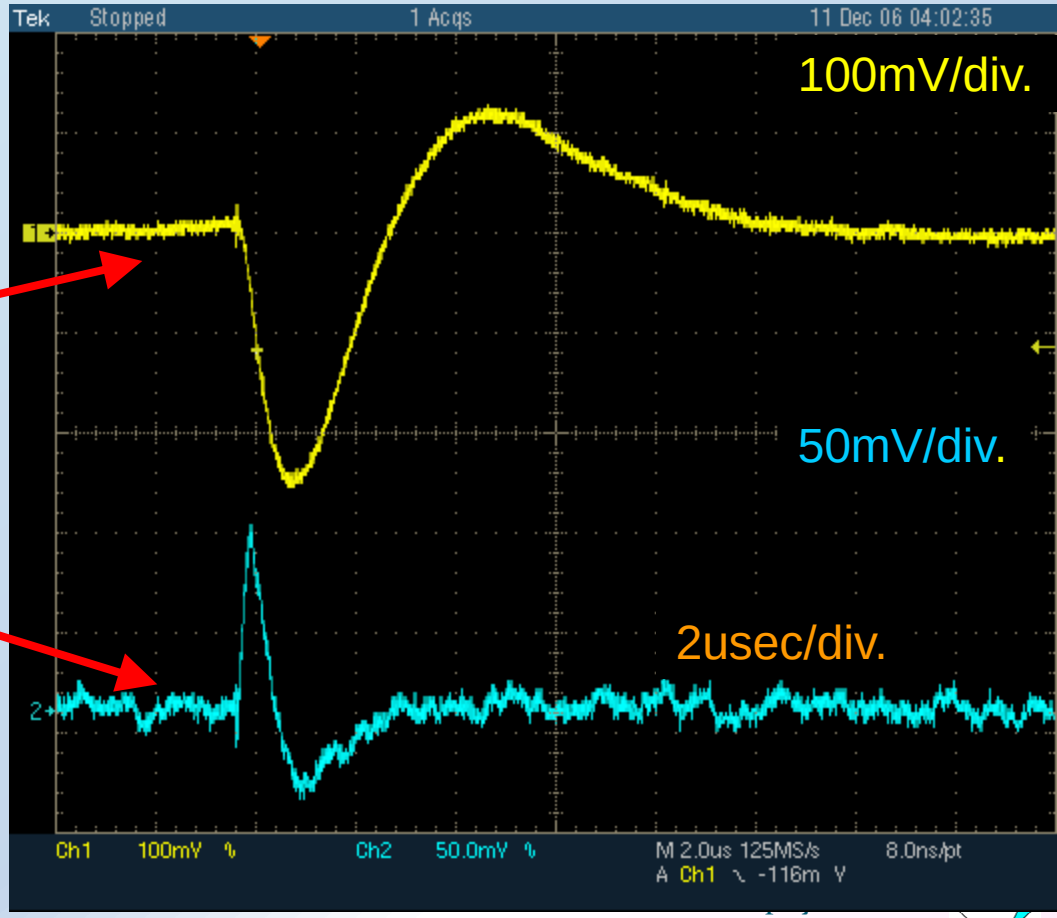
- AD board steals charge from FEE
  - Does Csplit work well ?
- Efficiency of strip hit information?
- Instrument MuTr Stations 1-3

Collaborative effort between KEK,RIKEN, Kyoto, Rikkyo and LANL

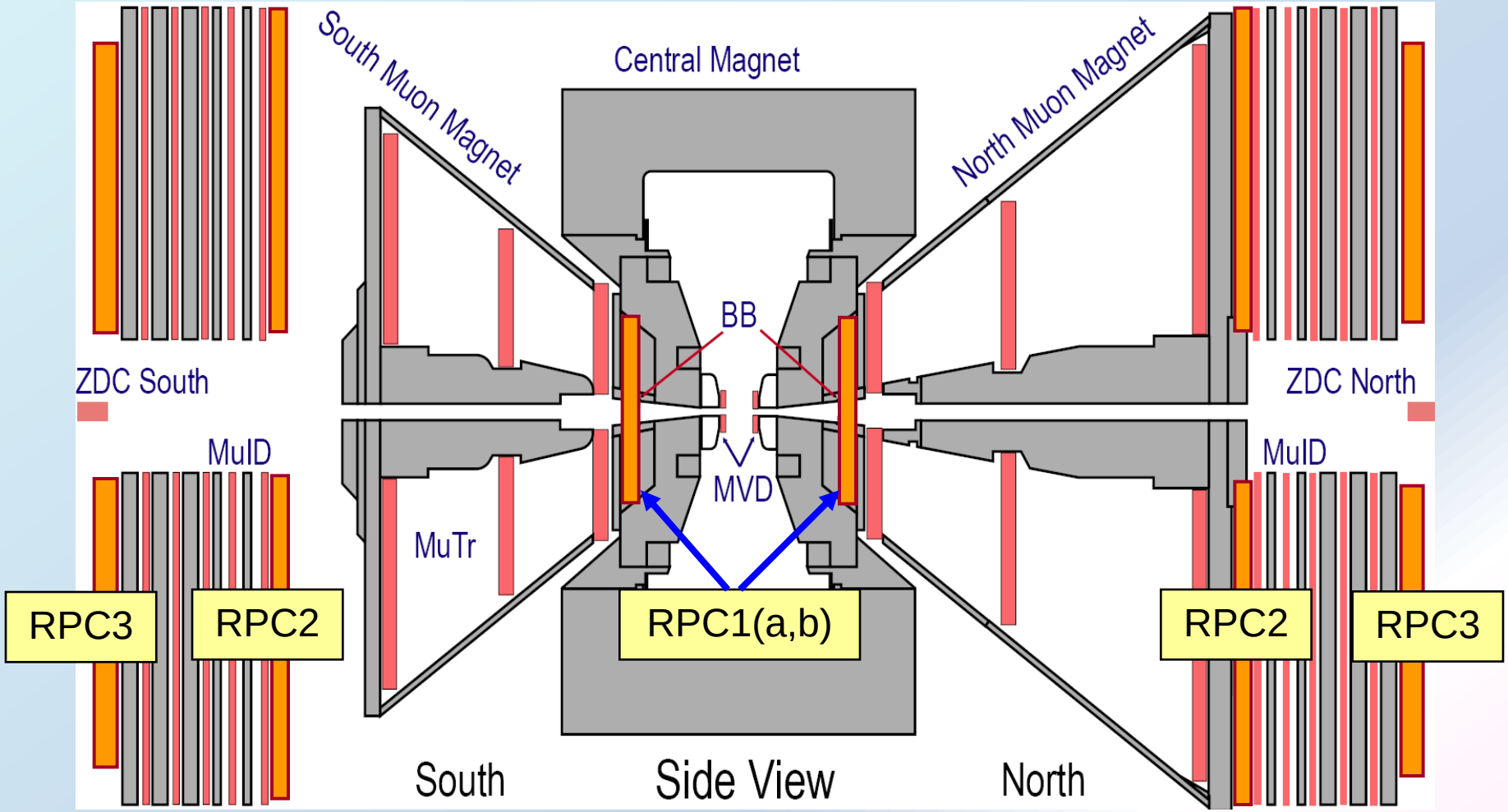
Test Pulse Input to Chamber

- Pulse Shape of CPA output on FEE & Amp. output on AD Board



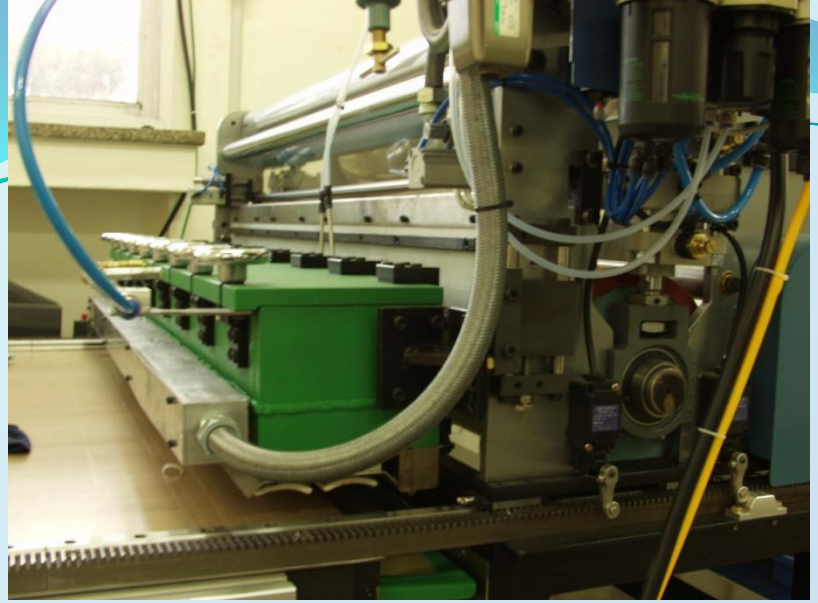


Overall Layout of the PHENIX RPC Muon Trigger Spectrometer



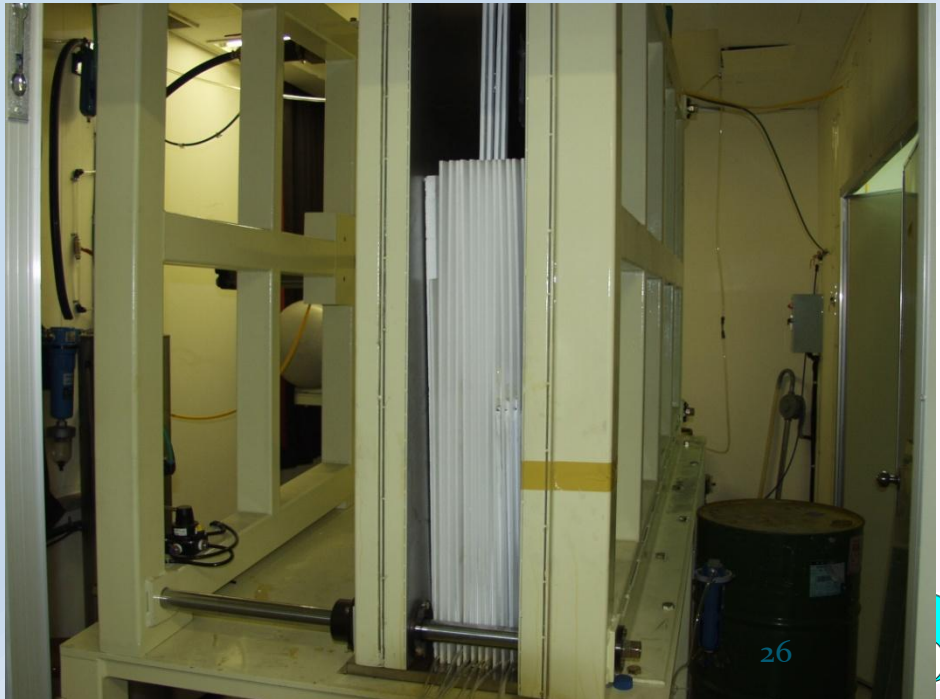
Manufacturing of RPC Gaps and Parts for PHENIX → Tested Successfully with Prototype C

►Bakelite produced and cut in Italy ►Gas gaps are produced at Korea University
►RPC frame & parts are procured in China (CIAE) ►Final assembly done at BNL.

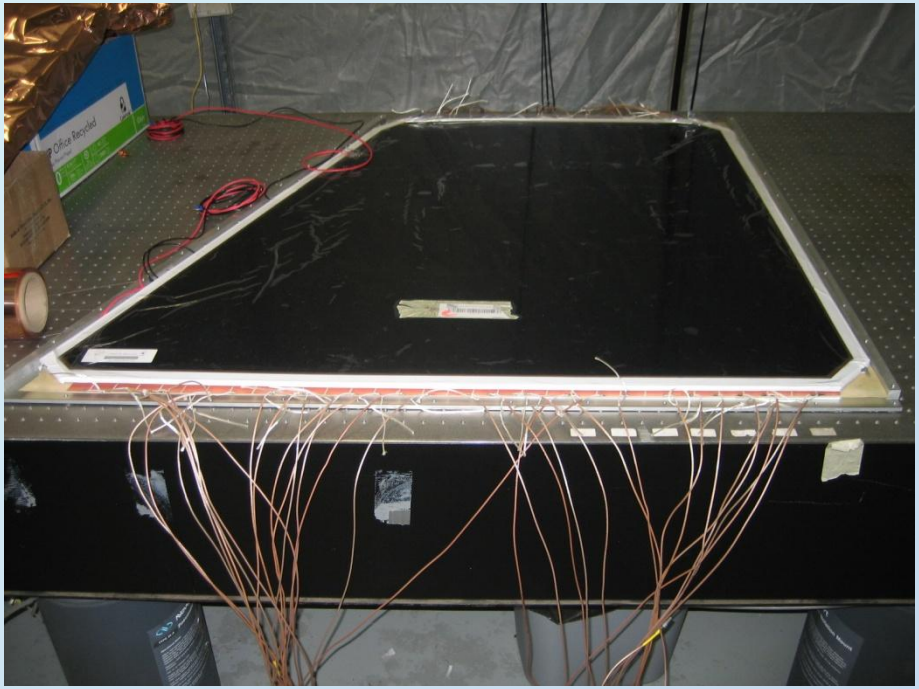


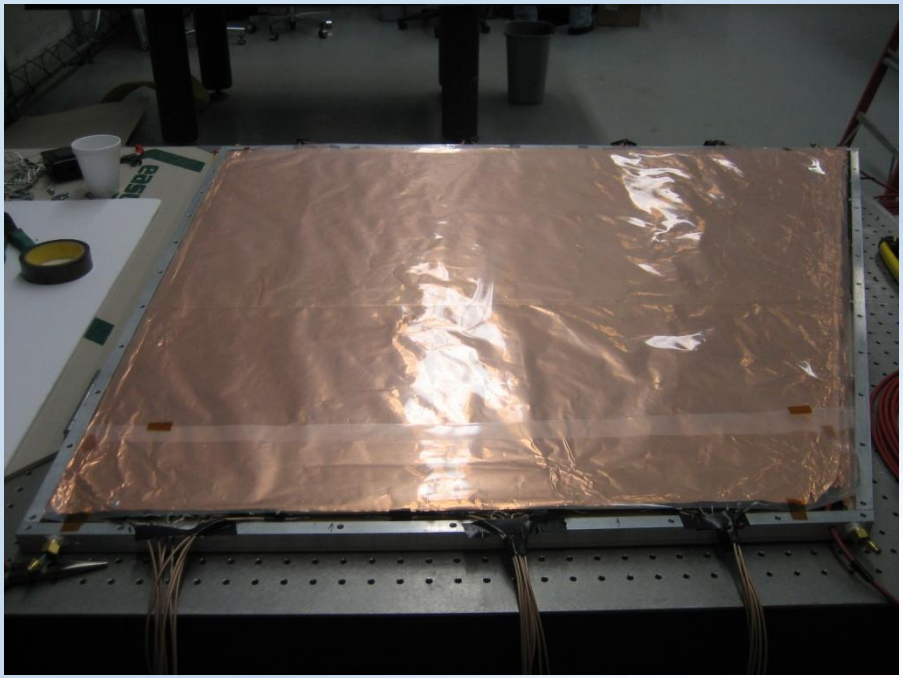
Gas Gap Production at Korea University

(prototype C, presently prototype D)



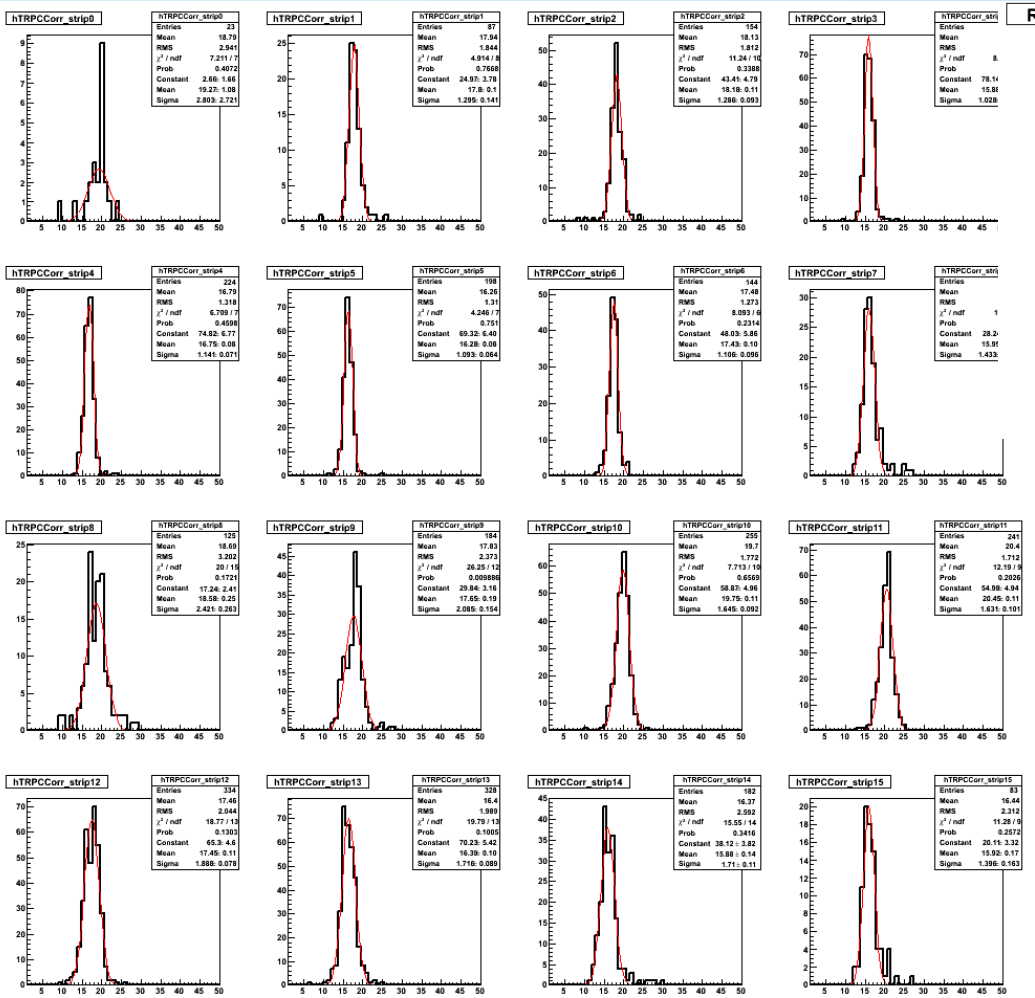
Assembly of the first (of three) Prototype C



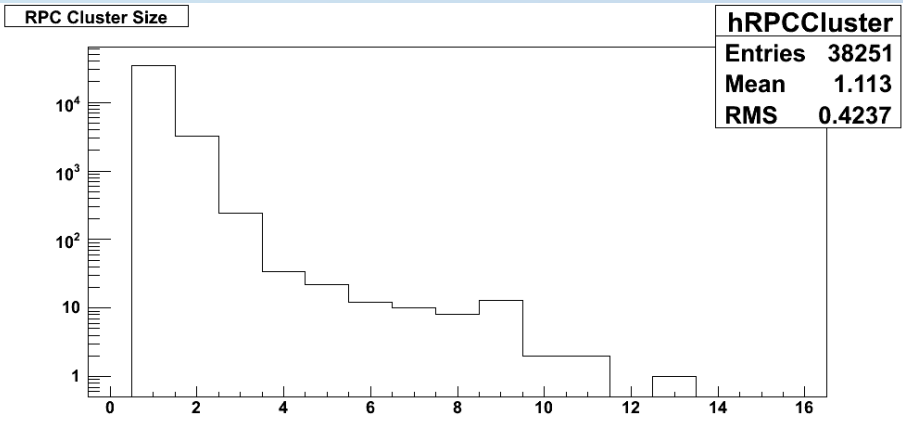


First RPC Prototype C Test Results

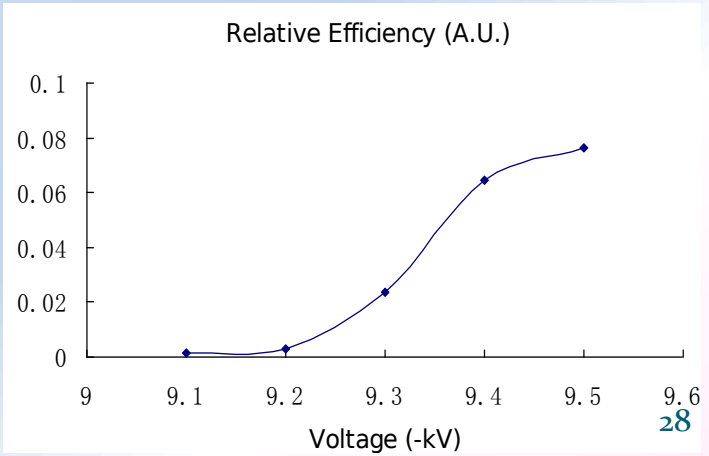
All TDC widths are less than 3 ns.



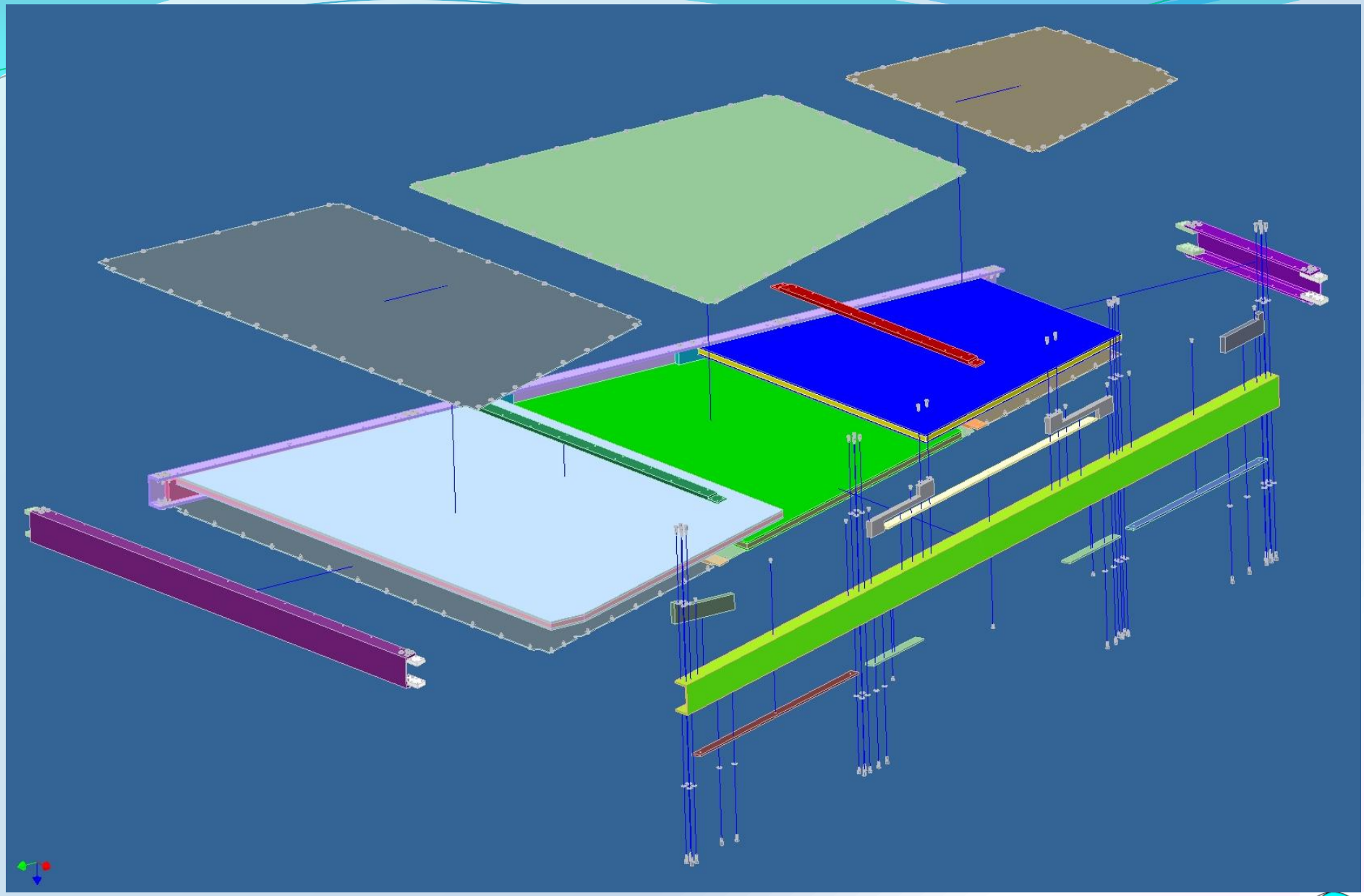
Cluster size seems constant from 9.3 to 9.5 kV.



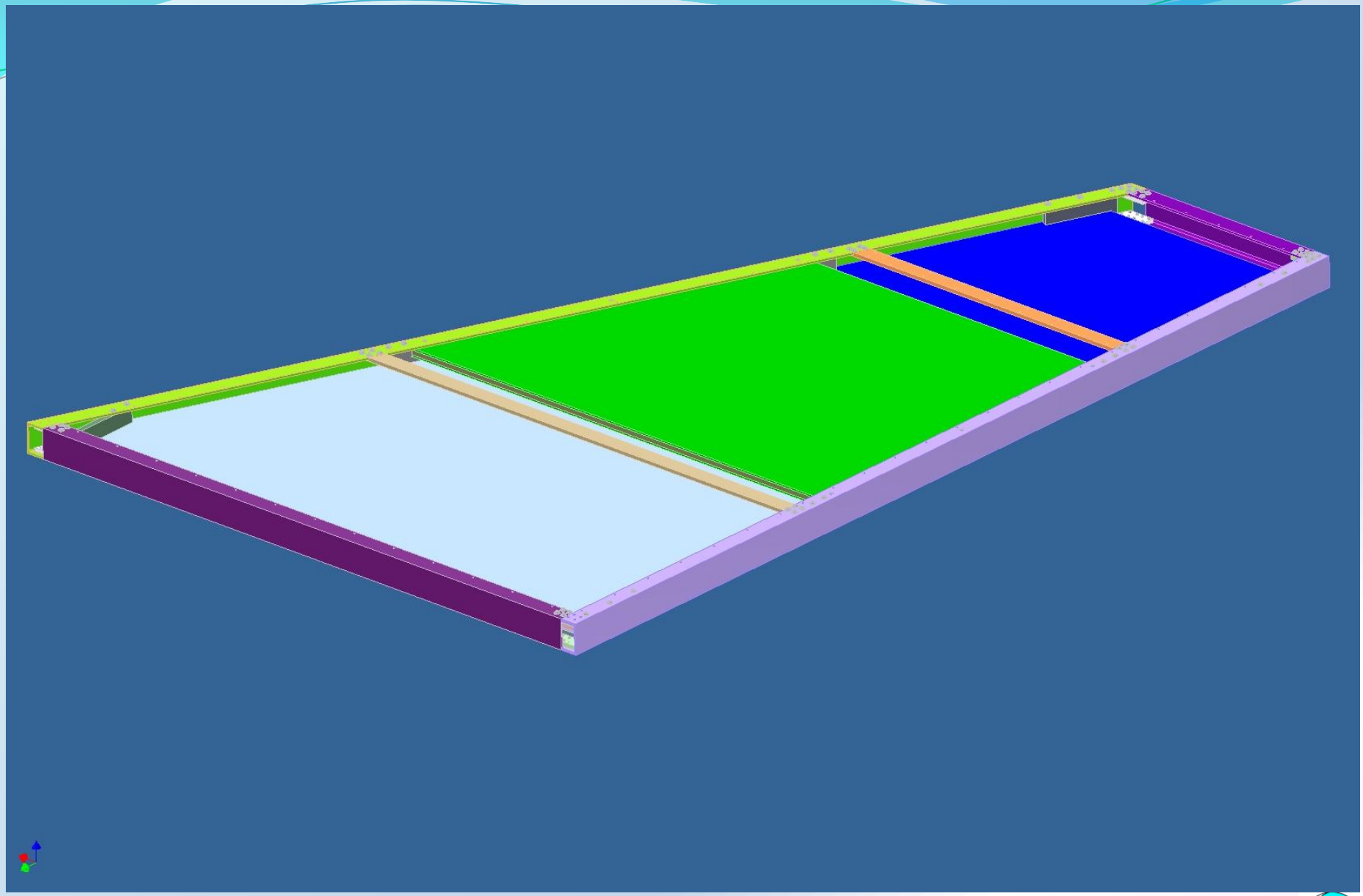
First efficiencies ~95% at 9.5 kV.



Prototype D: Exploded View



Detector Modules Assembled, upper skin removed



Schedules for PHENIX Muon trigger upgrade

Muon Tracker FEE upgrade

- Final review passed in March
- Boards in production
- Full North installation (Stations 1-3) this summer
- South installation summer 2009

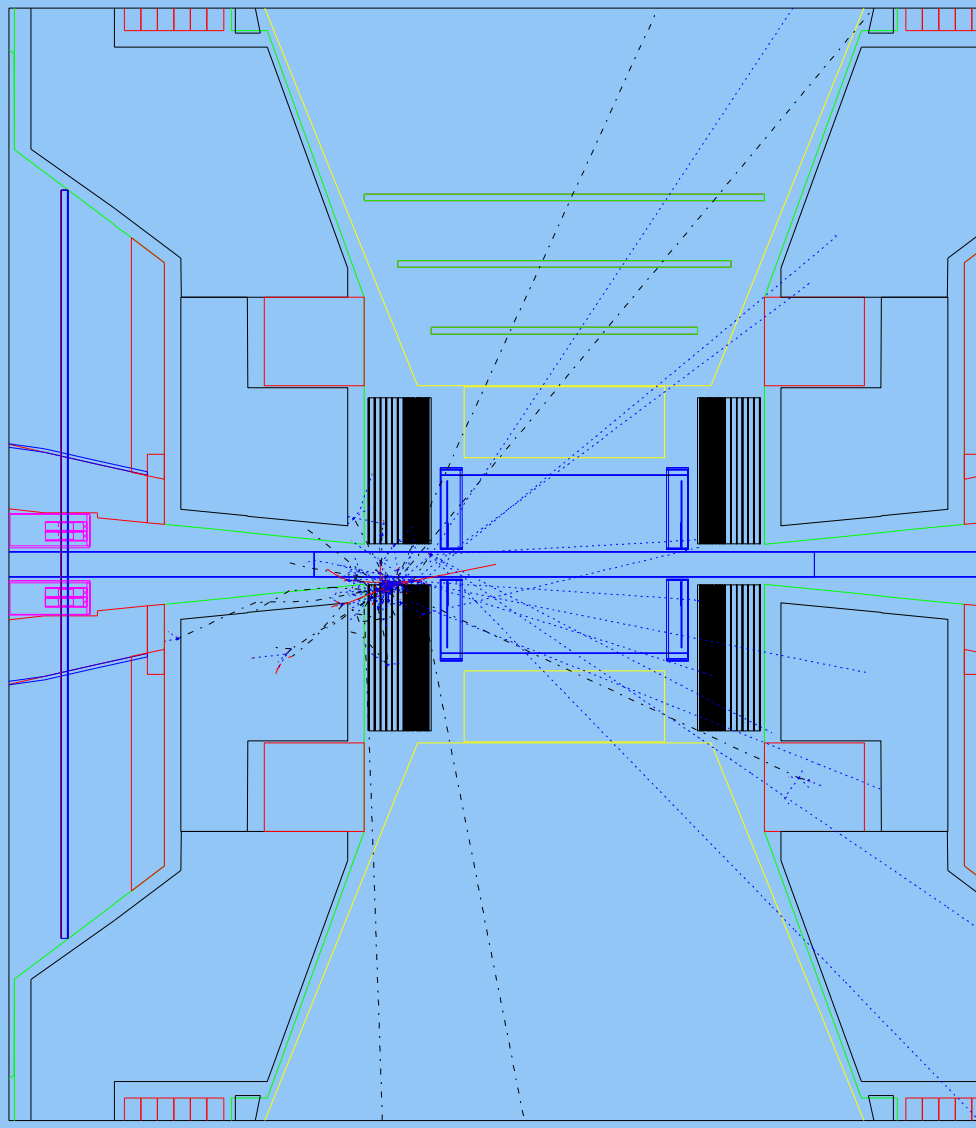
RPC upgrade

- Protoype C (2 modules running in 912)
- Prototype D (2 half octants) in production + 1Octant of Absorber , to be installed this summer
- RPCs 2 and 3 North + Absorber North to be installed 2009
- RPCs 2 and 3 South to be installed 2010

First Full Trigger FEE+RPCs in run 10

Backgrounds in the
Fake high-P_T hadron

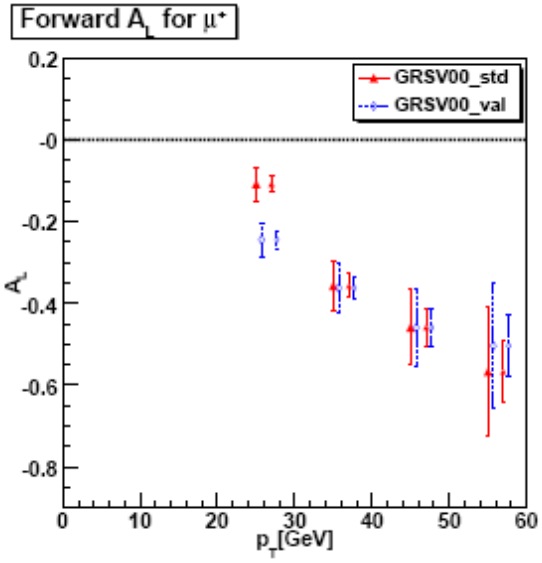
- Main offline background: Low P_T hadrons decaying within muon tracker volume mimicking a high P_T track
- Tight cuts reduce S/B ratio to 1/3
- Hadron absorber after Central magnet yoke to obtain 3/1 ratio

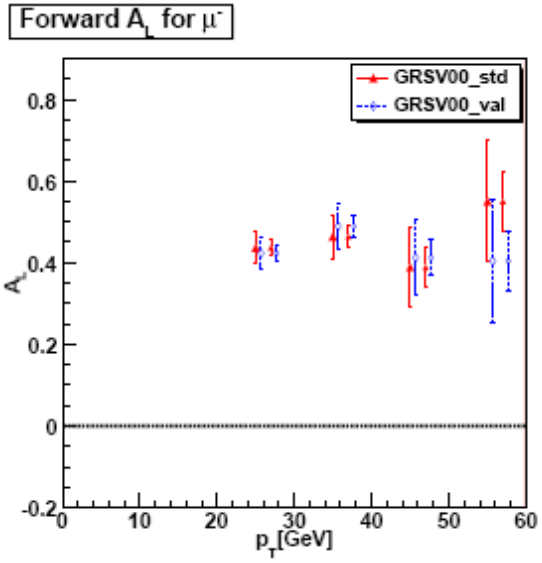


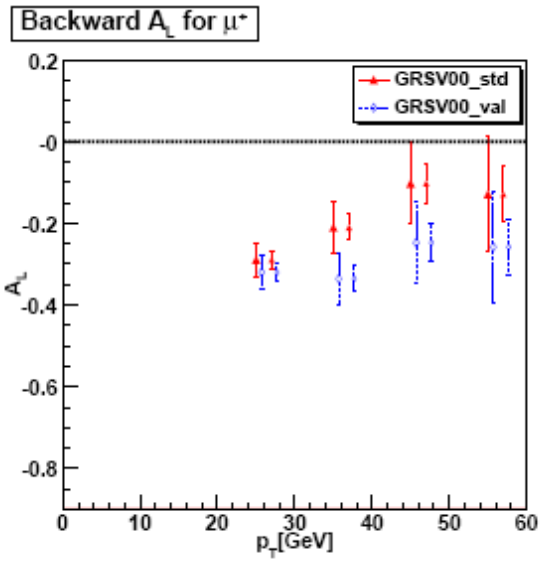
Expected asymmetries

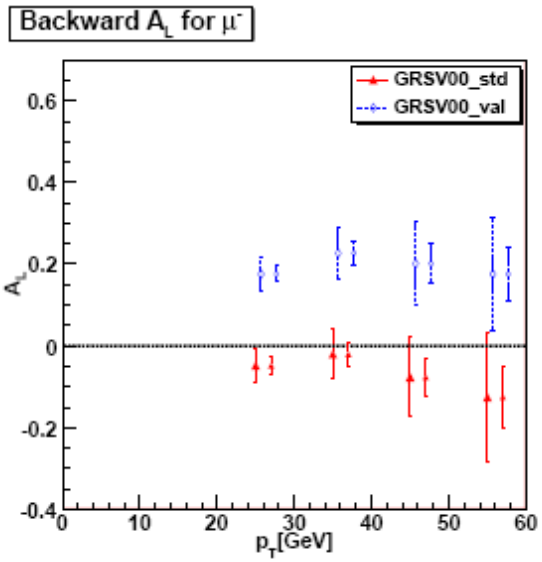
Assumed luminosity:
319 pb^{-1} and 1320 pb^{-1}

- Full detector simulation
- Inclusion of S/B of 3/1
- Huge asymmetries to be seen
- Even with RUNI statistics GRSV std and valence can be distinguised on the 7σ level









Summary

- W Single spin asymmetries as direct measurement of quark and antiquark helicities
- High scale, sensitive to distinguish sea sceanarios
- STAR:
  - Forward Gem Tracker upgrade + Endcap calorimeters to detect forward/backward decay electrons
  - Anticipated installation: summer 2010
- PHENIX:
  - FEE upgrade to use Muon Tracker in Trigger
  - RPC upgrade
  - First arm installed 2009, second arm 2010