Progress Report on GEM based TRD

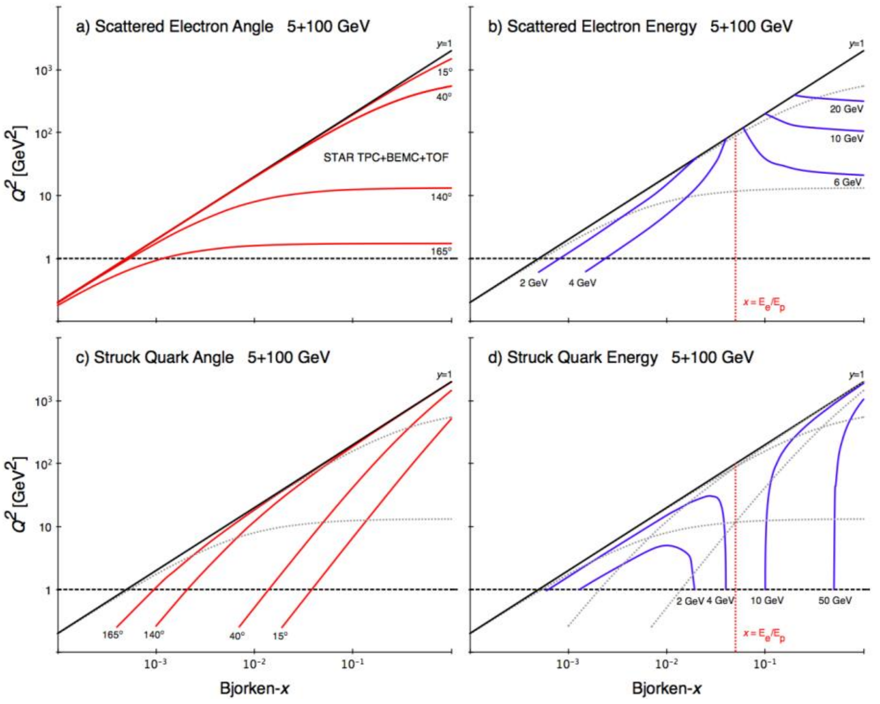
Zhangbu Xu (BNL)
Prof. Ming Shao (Co-PI, USTC)

- Brief Introduction
- Hardware setup
- Results
- Plans
- Simulations

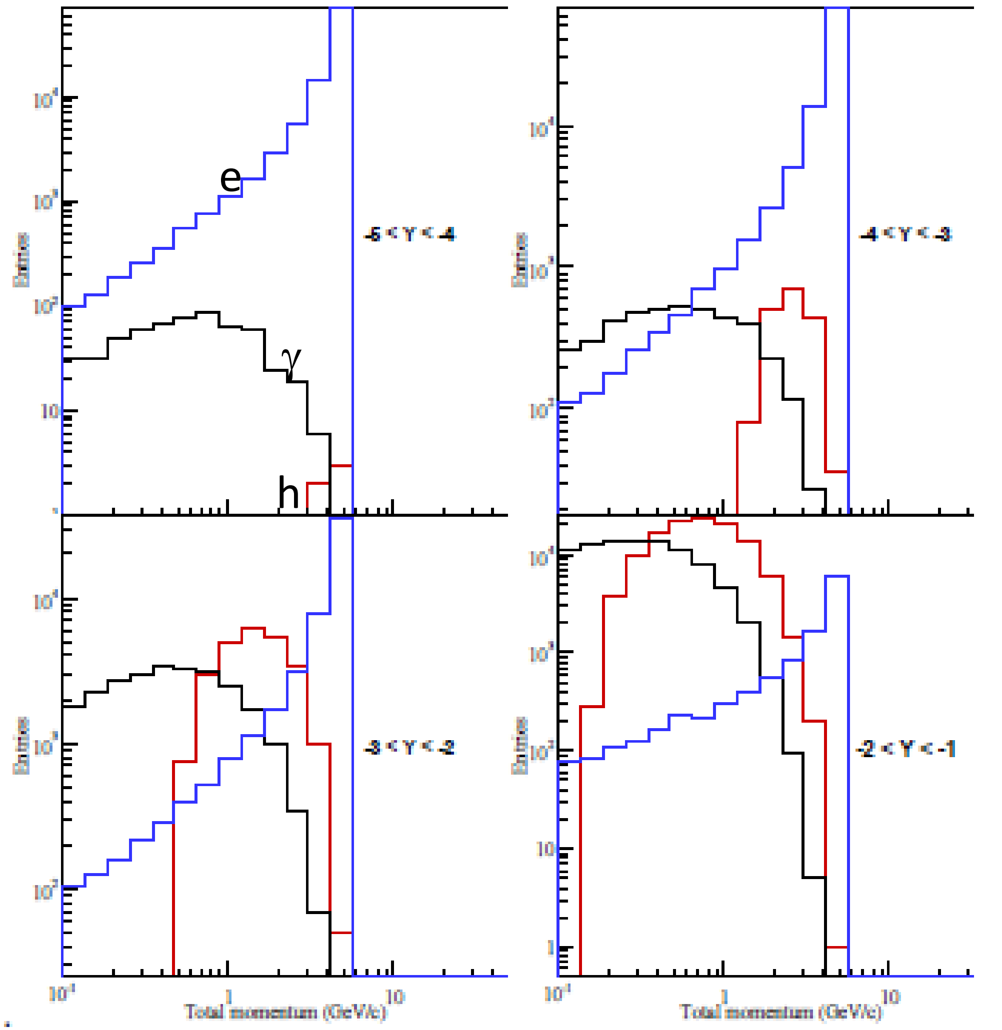
Electron ID in EIC

5x100 ep

Ernst Sichtermann (LBL)



INT report (arXiv:1108.1713) Fig.7.18.

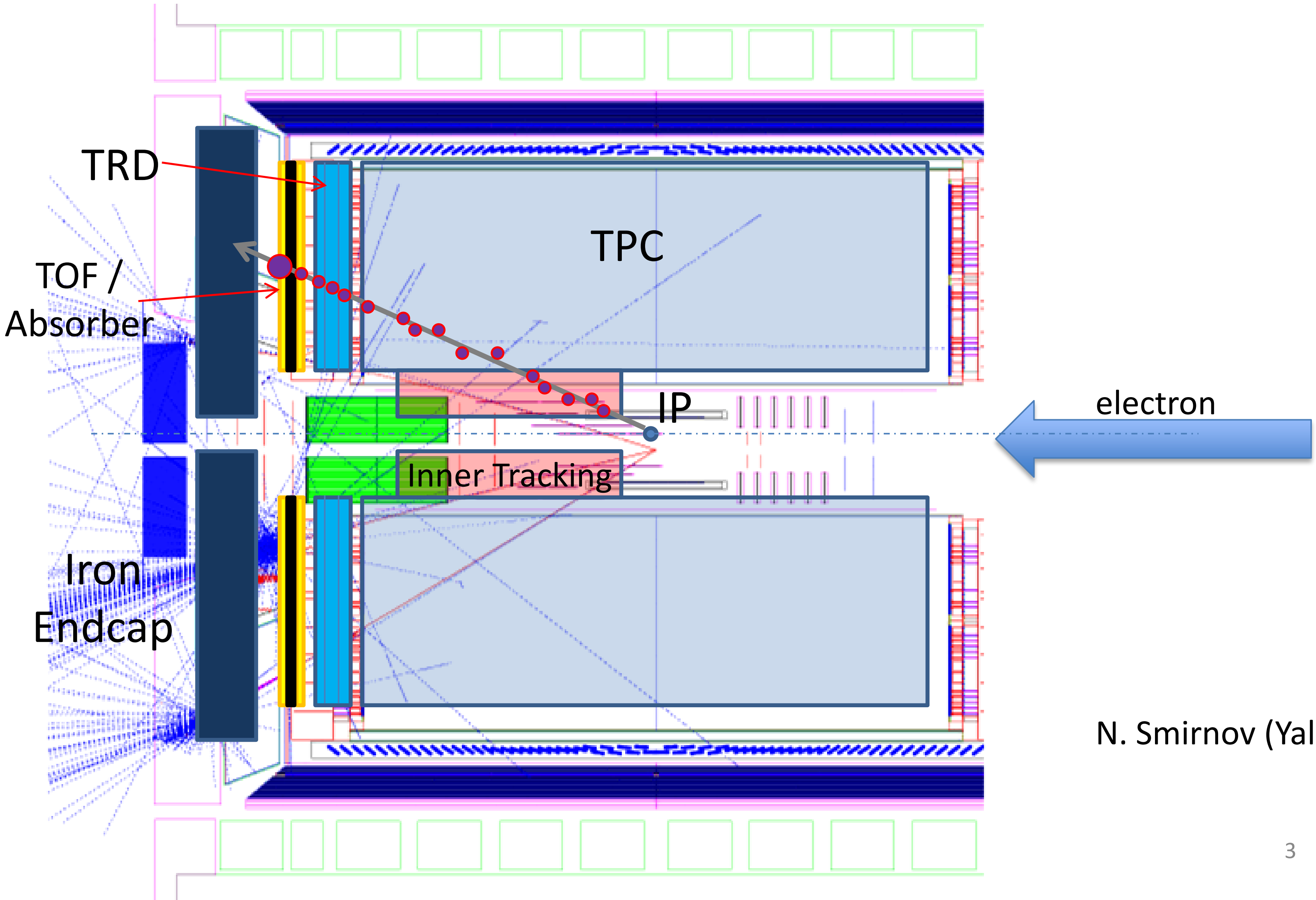


Electron coverage: 1>eta>-2.5

PID e/h: 1000

Low material: photon conversion

Conceptual Configuration



N. Smirnov (Yale)

STAR→eSTAR Concept

- Large Coverage
- Low Material
- Electron and hadron ID with gas detector and TOF, EMC

- Extend this concept to hadron direction
  - GEM tracker (FGT++)
  - Cherenkov
  - Forward Calorimeter
- Extend this concept to electron direction
  - Reinstrument inner TPC
  - MiniTPC (GEM based?)
  - TRD+TOF

Electron Identification (dE/dx+TOF)

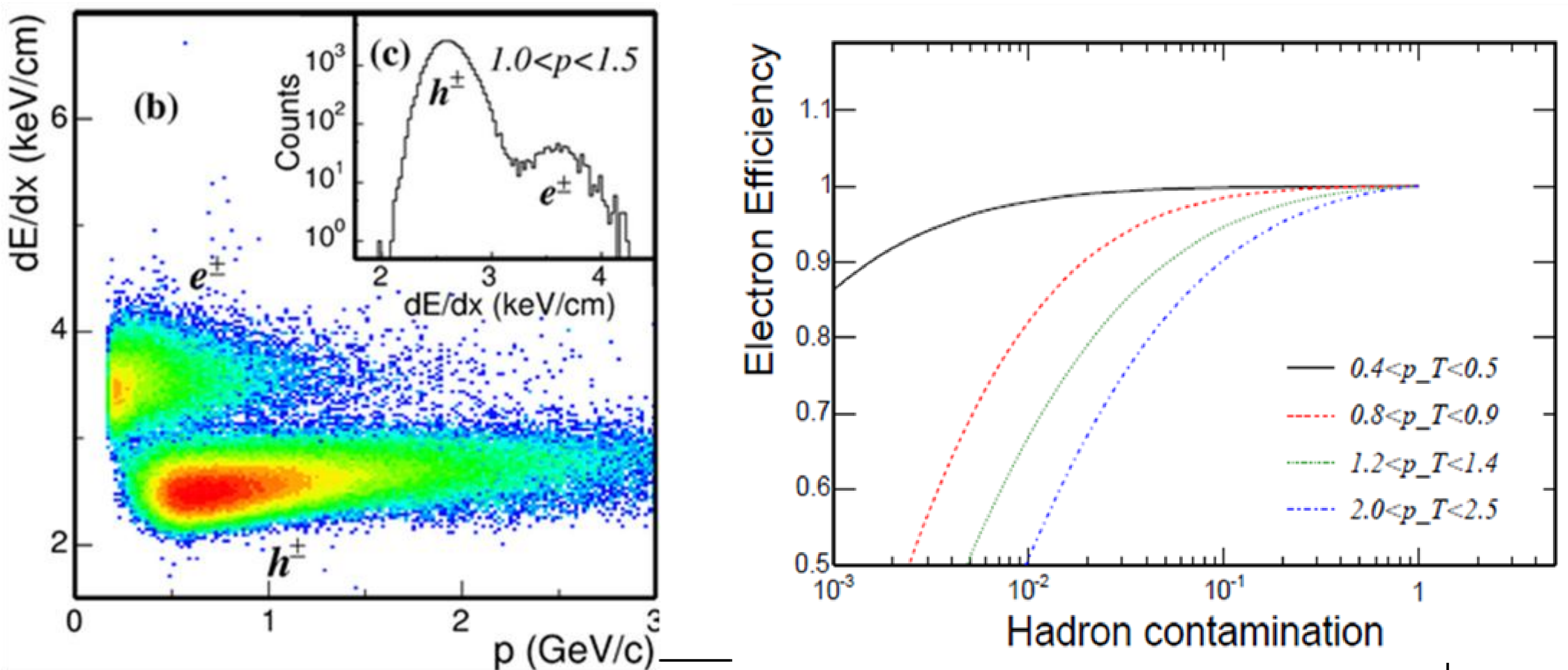
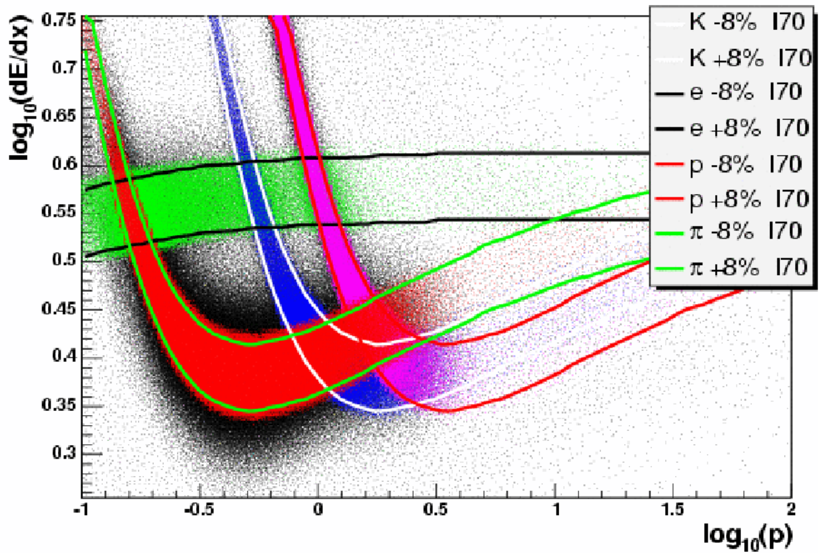
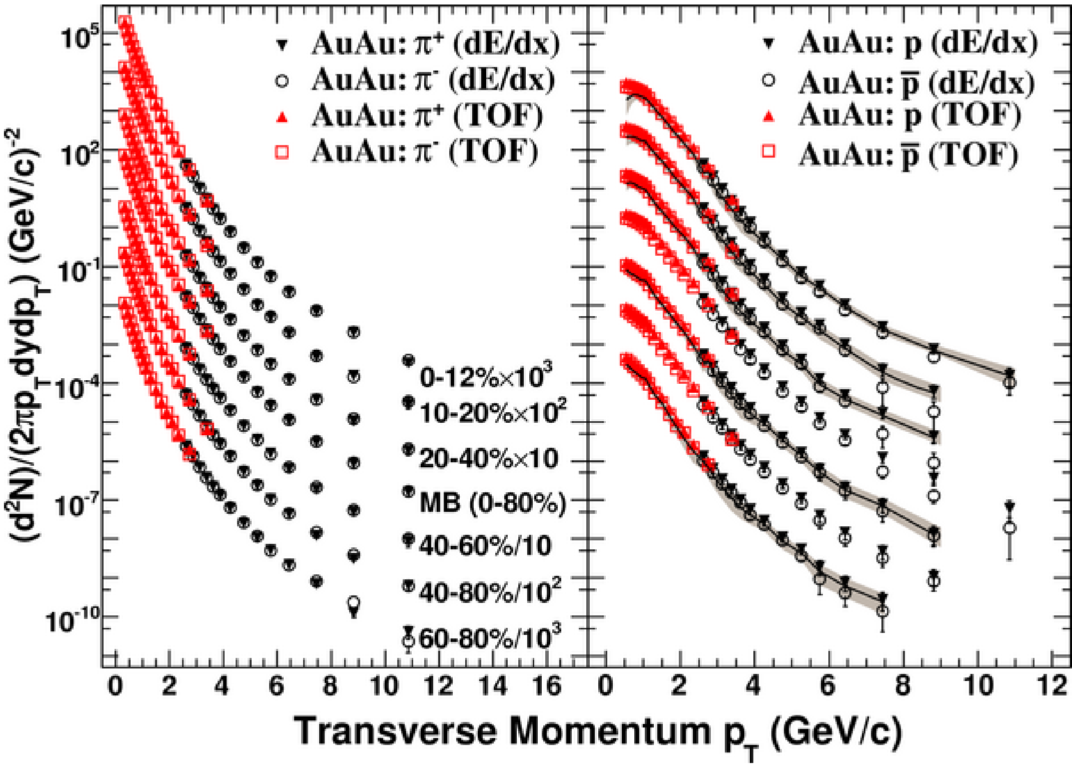


Figure 9. The dE/dx measured by STAR TPC as a function of particle momentum, with velocity cut by TOF, and (right panel) the electron efficiency after dE/dx cut as a function of hadron contamination in different pT range.

Ming Shao (USTC), Xin Dong (LBL)

Hadron PID





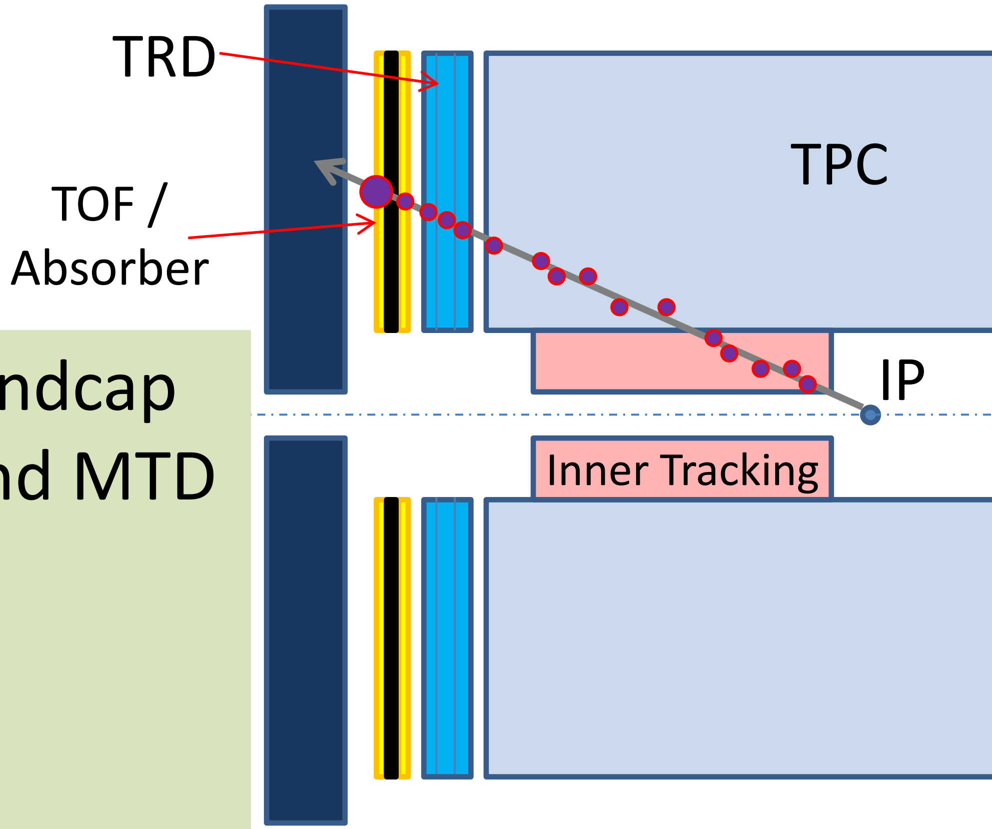
dE/dx, relativistic rise, TOF

dE/dx resolution: ~7% at L=70cm

Lijuan Ruan (BNL)

TRD+TOF at Endcap ($-2<\eta<-1$)

- Inner tracking
- TPC (endcap region):
  TRD +
  TOF/Absorber sandwich



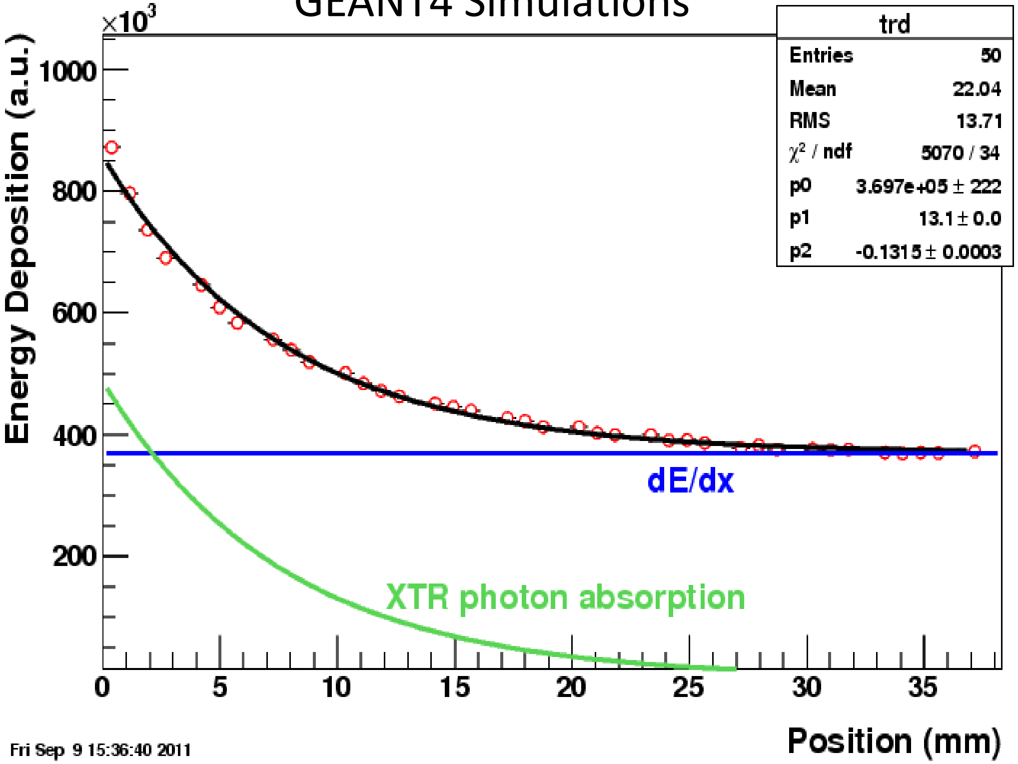
Ming Shao (USTC)

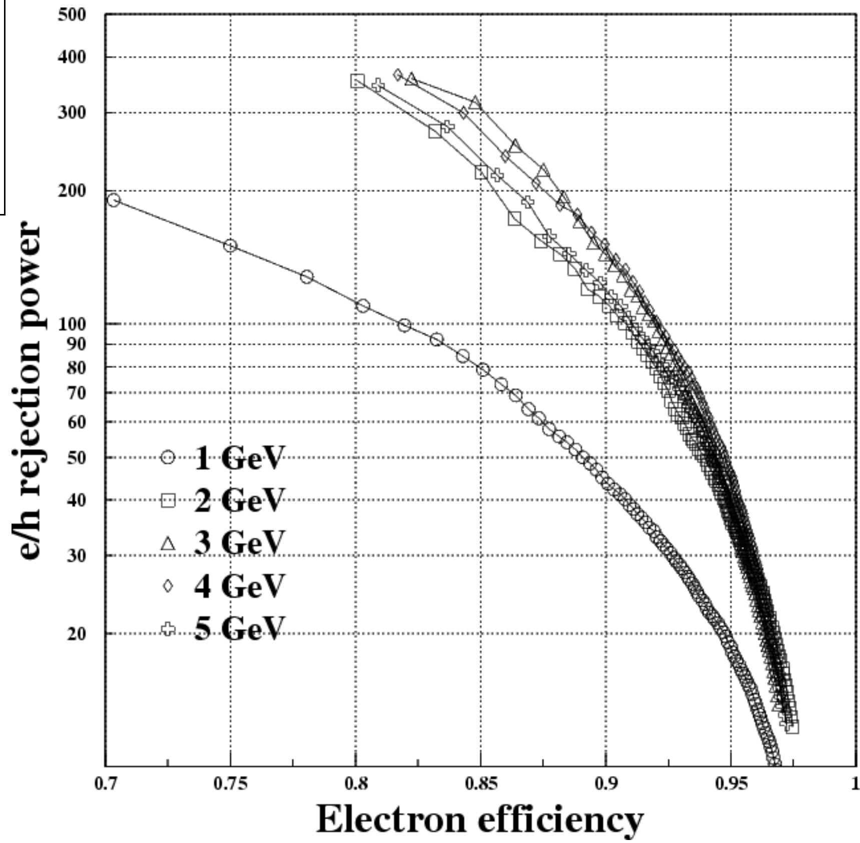
- Within <70cm space inside endcap
- TOF as start-time for BTOF and MTD
- TOF + dE/dx for electron ID
- TOF for hadron PID
- Extend track pathlength with precise points
- High-precision dE/dx (Xe+CO_2) TRD

Similar concept can apply to other detector configuration
The R&D explores the generic features of this concept

Additional dE/dx and tracklet

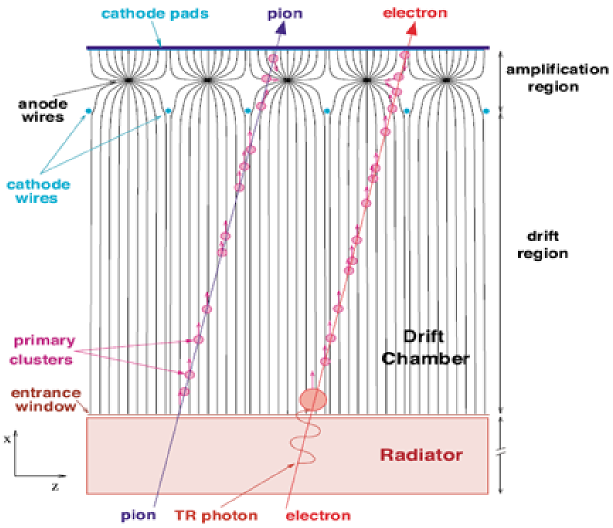
GEANT4 Simulations



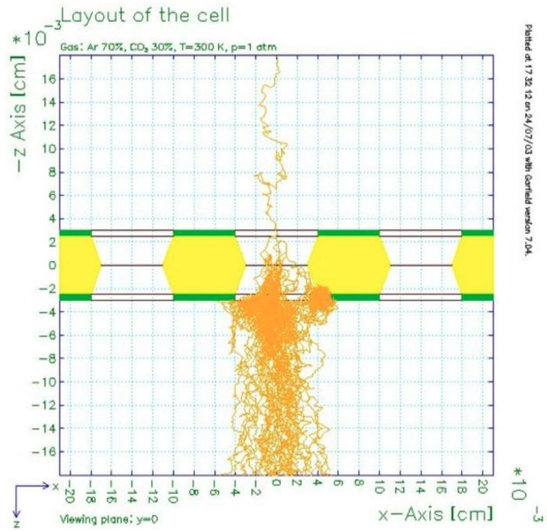


dE/dx and TR signals for electron and hadron discrimination
High-position tracklet for hadron momentum reconstruction

GEM based TRD – R&D



ALICE TRD



Readout: MWPC -> GEM

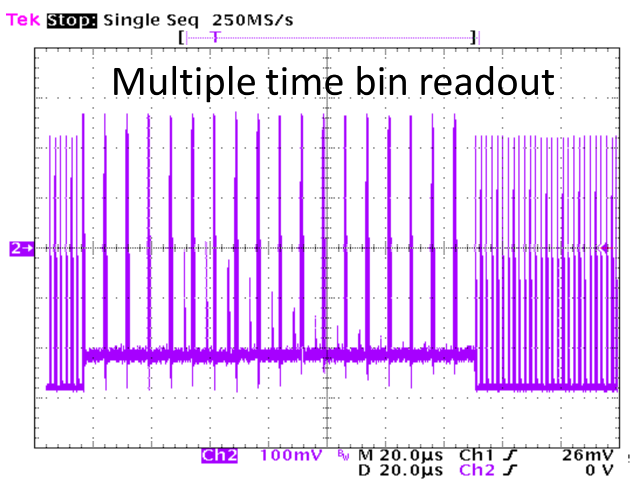
work with $Xe+CO_2$

better position resolution by GEM

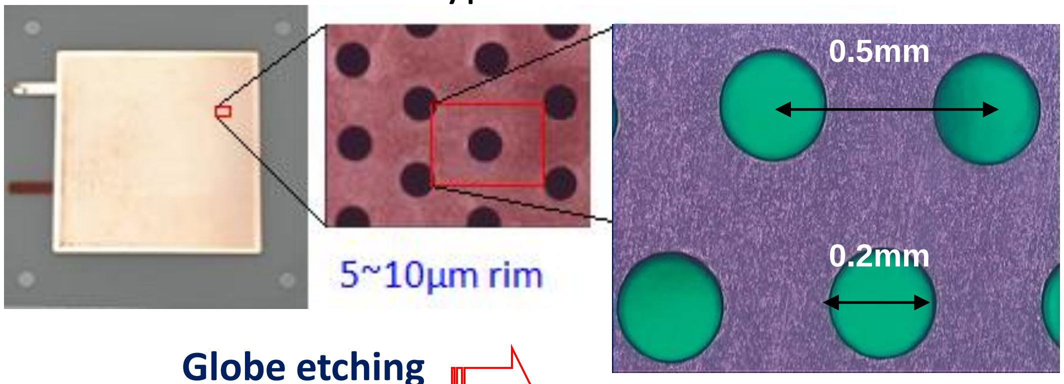
better rate capacity / space charge

Need R&D

- TRD readout structure – thin/thick GEM?
- Multiple time bin readout
- TRD gain in Xe/CO_2 and uniformity
- GEM long time stability



New type thick GEM



Globe etching

(micro etching)

EIC R&D Committee Recommendations

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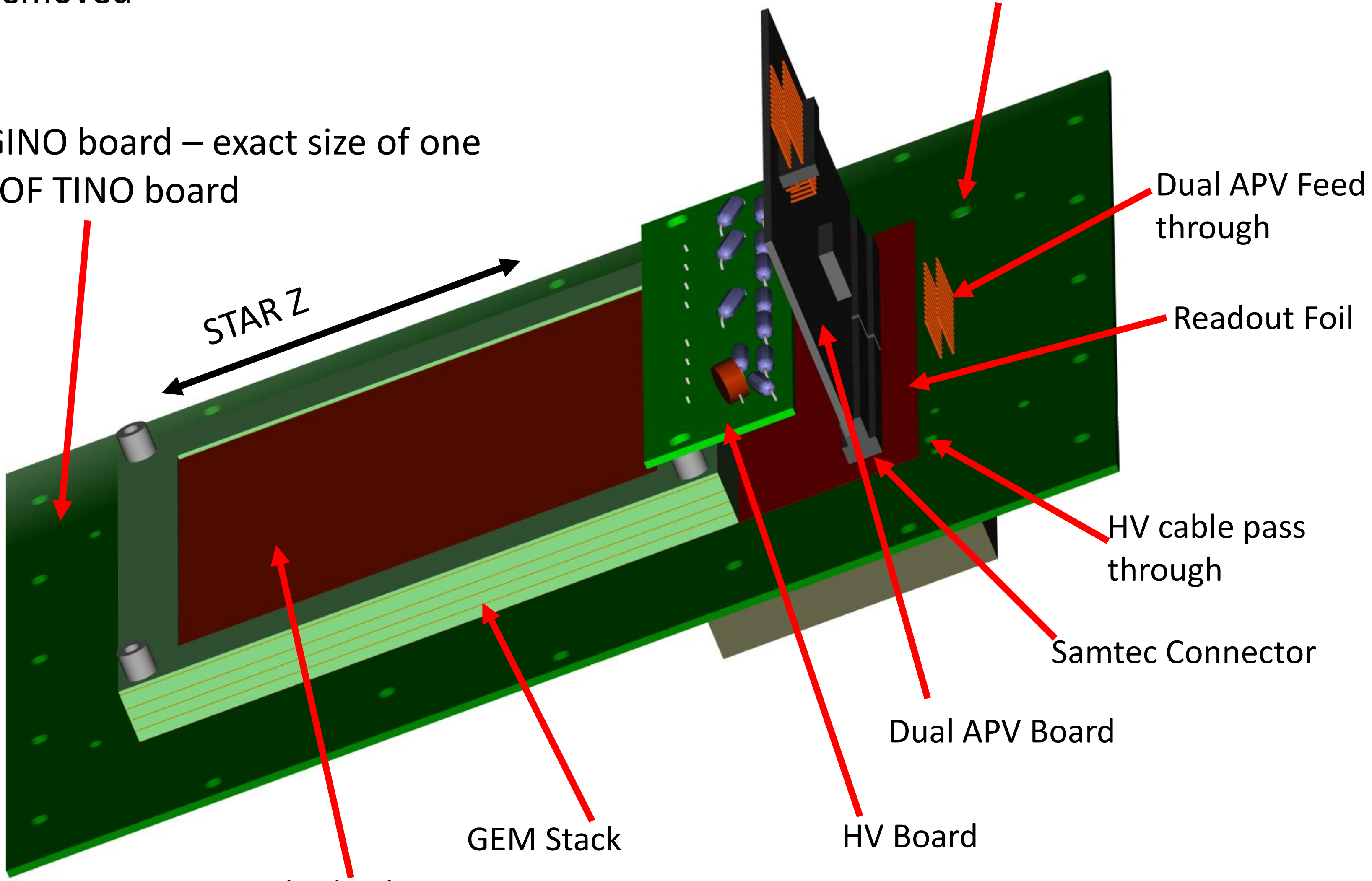
- A TRD clearly helps TPC tracking resolution in the forward direction. However, there is presently a discussion whether a thick GEM is suitable for the dE/dx measurements because of (a) gain non-uniformities, (b) long-term stability (charging and drying). In addition, there are questions whether the TRD concept can work successfully behind thick TPC endplates. **The Committee supports R&D activity to address the GEM questions (should one use "classical thin GEM" vs. "various types of thick GEM"), and background simulation effort addressing TRD and dE/dx performance in the forward direction.**

- *The Committee recommends the first year be funded with* ***a concentration on resolving whether various GEM structures can work in the proposed environment (behind a TPC endcap) and whether GEMs have acceptable gain uniformity and resolution.*** *Background simulation should be part of this effort. Later in the year once chamber performance is understood, a fill with Xe + CO2 and study of TR emission should be done. The Committee would like to learn the progress before proceeding to the second year's funding.*

GEM Monitor of TPC Tracking (GMT)

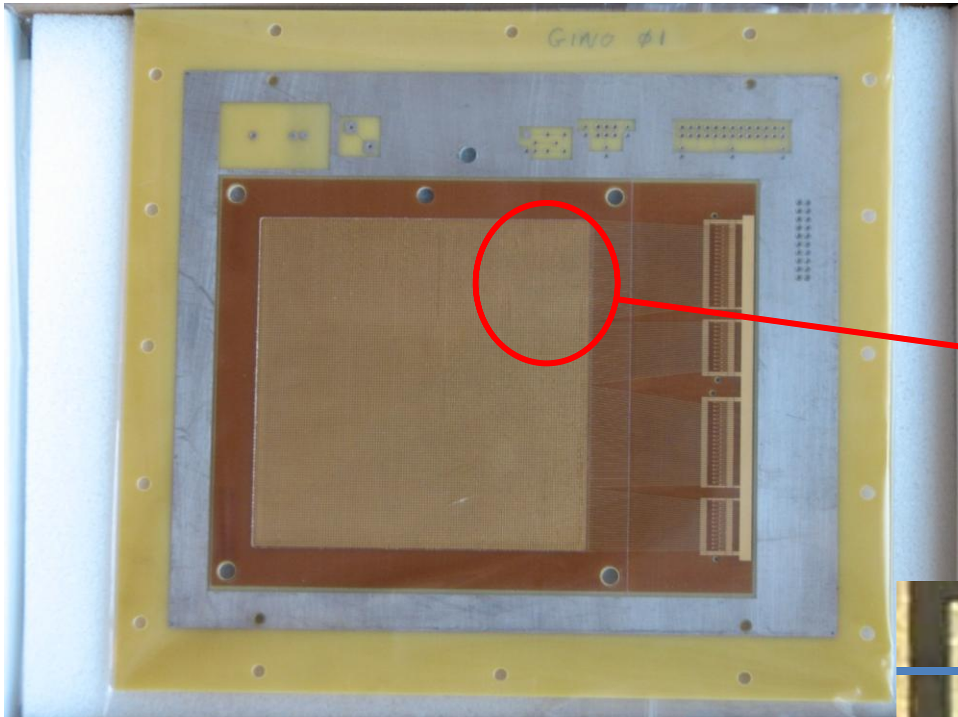
GMT Chamber – Gas enclosure removed

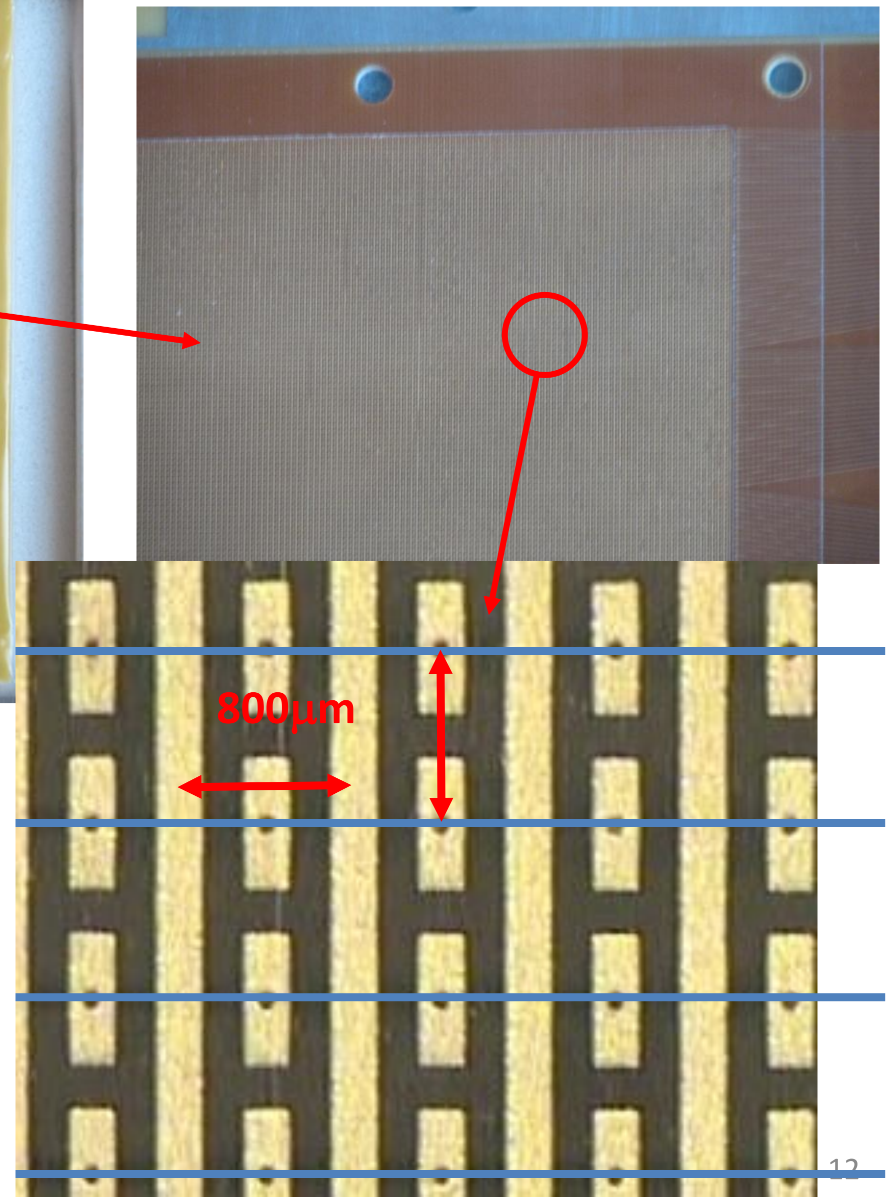
GINO board – exact size of one TOF TINO board



Project led by Dick Majka
Most of TRD components from GMT

Readout Board (Foil) Mounted on GINO Board, strip/pad style, 800μm pitch





Pads connected by vias and traces on back side to form the orthogonal coordinate

Richard Majka (STAR Upgrade 12/01/2012)

A GMT Chamber

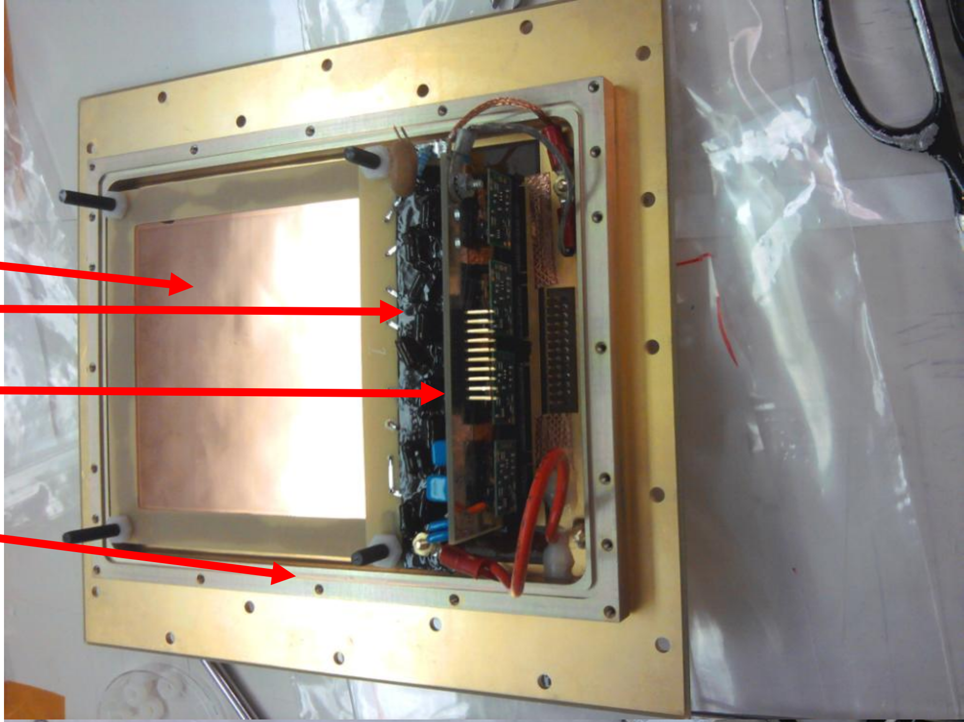
GEM Stack and cathode

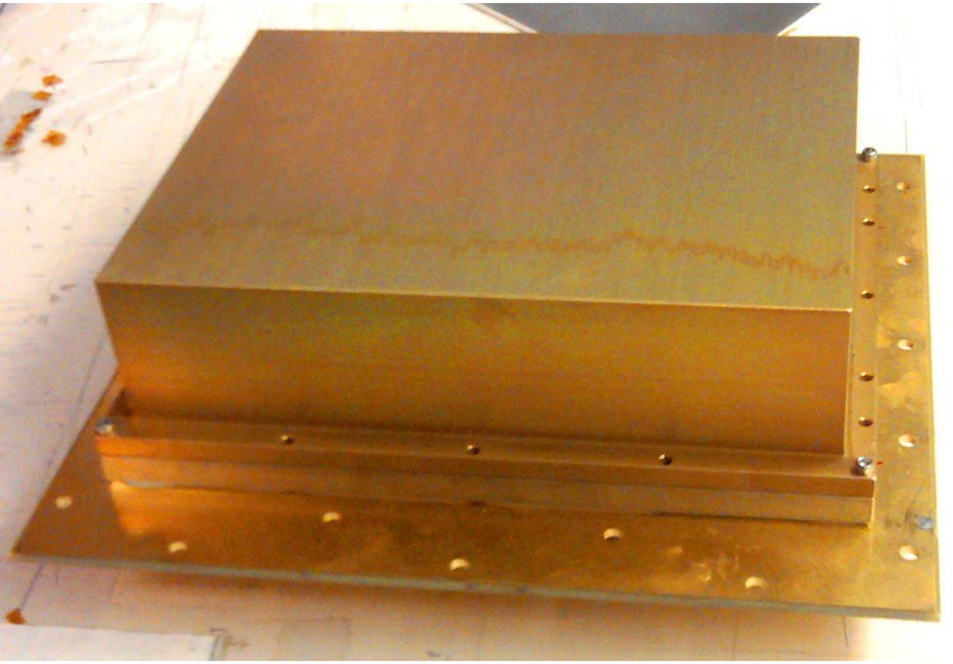
HV Divider board

FEE

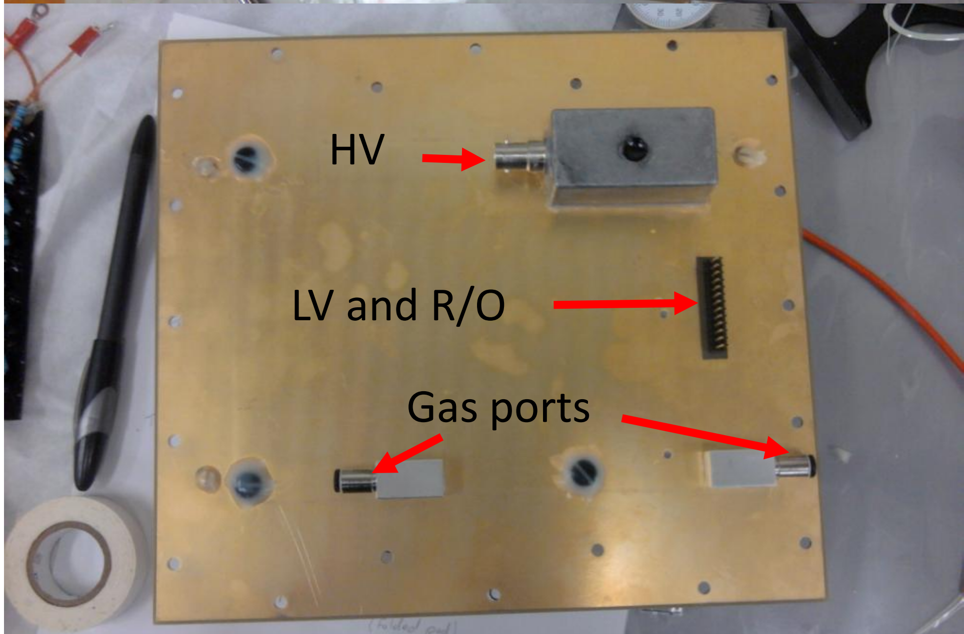
Flange for gas seal

Richard Majka (STAR Upgrade 12/01/2012)





Gas enclosure sealed – everything on this side is inside TOF gas volume

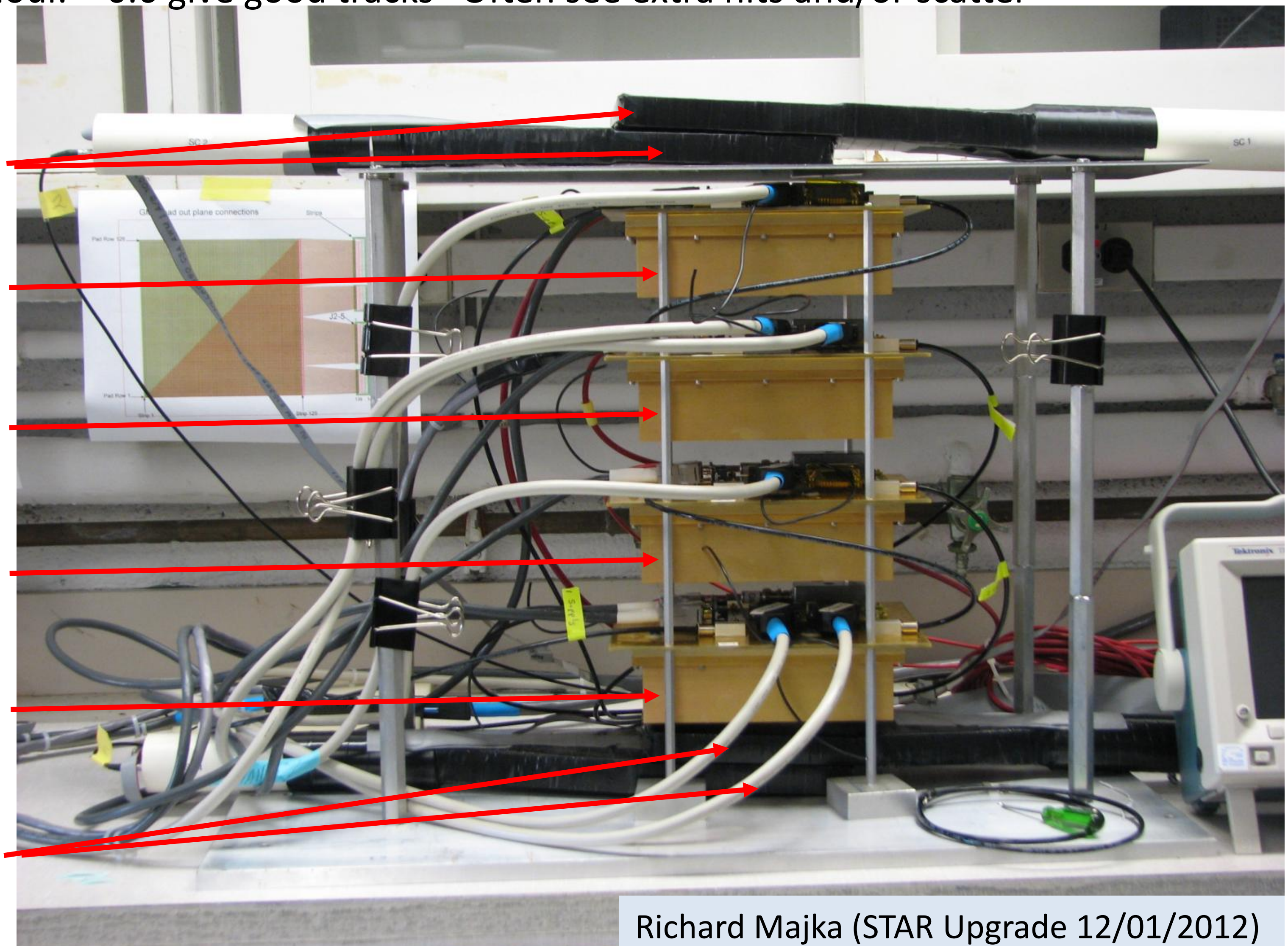


Back side – this is in air

4. Integrate with final readout, measure efficiency, estimate (upper limit) for resolution in cosmic ray test stand at BNL (Zhangbu's lab)

Trigger = Scintillator 4-fold   Scintillators ~12 x 12 cm^2 GMT = 10 x 10 cm^2

Rate ~350/hour. ~0.6 give good tracks   Often see extra hits and/or scatter



Richard Majka (STAR Upgrade 12/01/2012)

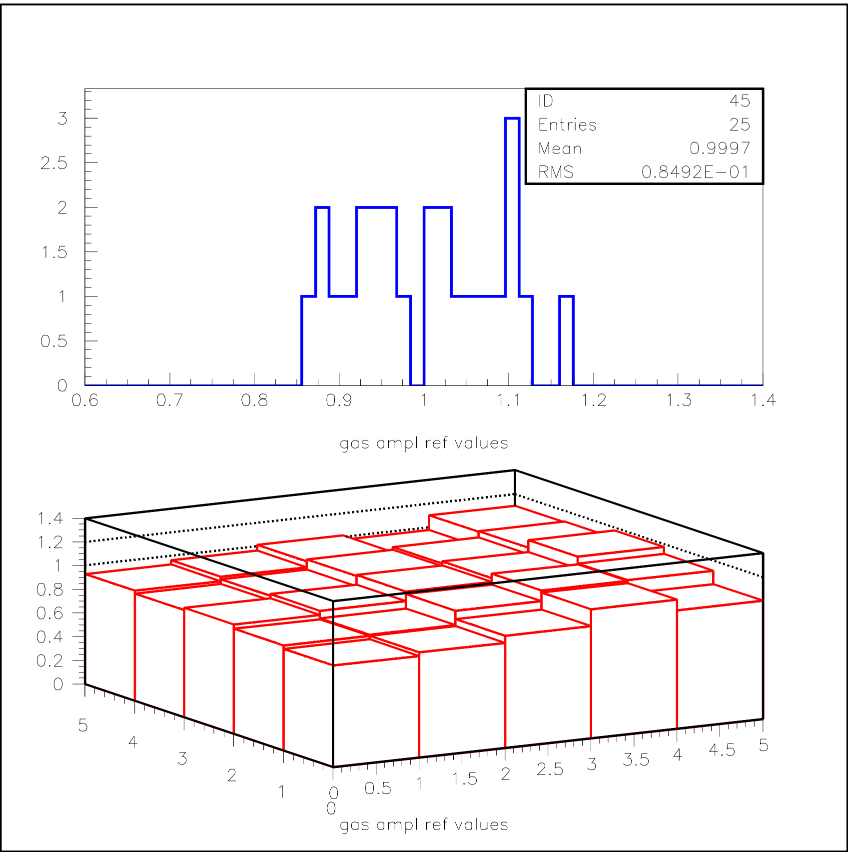
Lots more photos at: http://rhig.physics.yale.edu/~rmajka/GMT/BNL-photos/photos.html

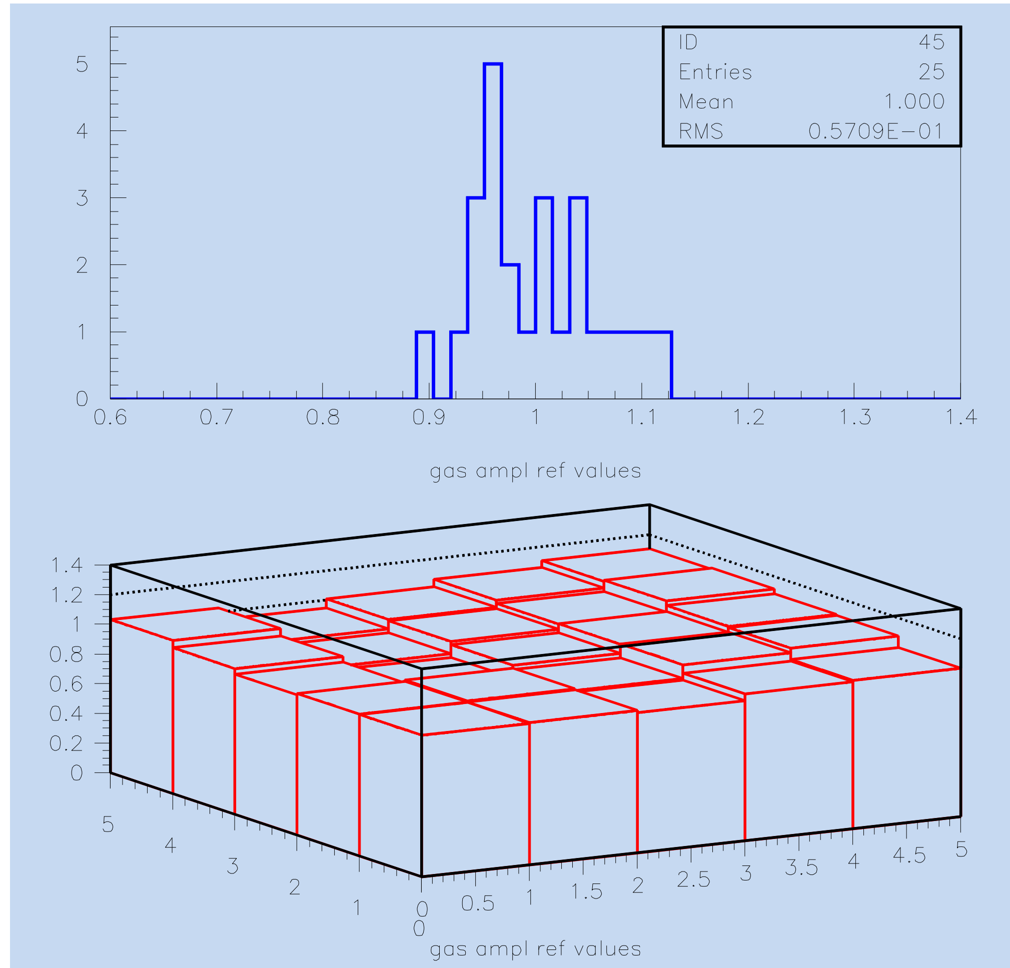
QA and Testing

1. Measure gain and gain uniformity for all foils – ^{55}Fe source, readout 5 x 5 array of pads

Thick GEM foil

Gain normalize to average is plotted.



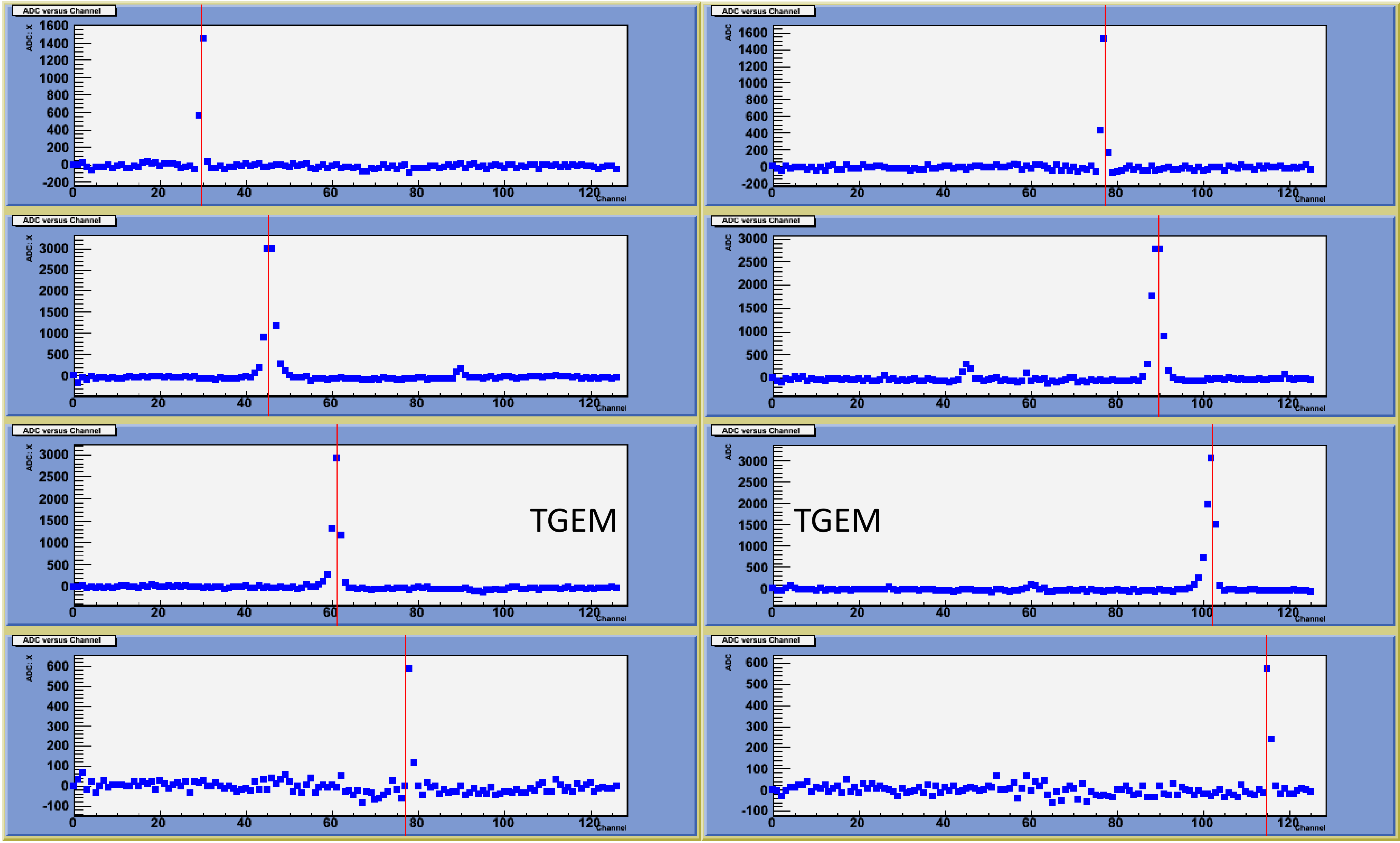


Regular GEM foil

Measured at Yale (Dick and Nikolai)

Cosmic ray tracking

X-axis: strip **Y-axis: pad**

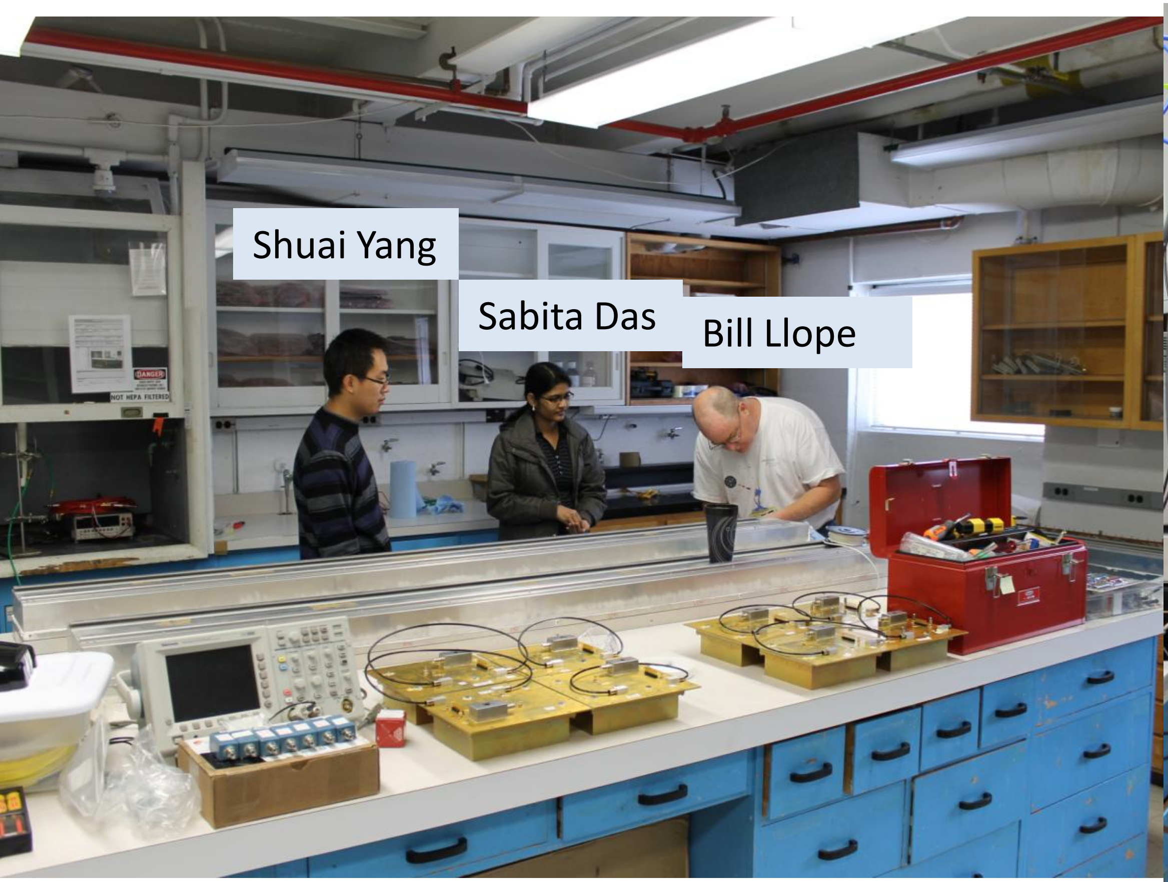


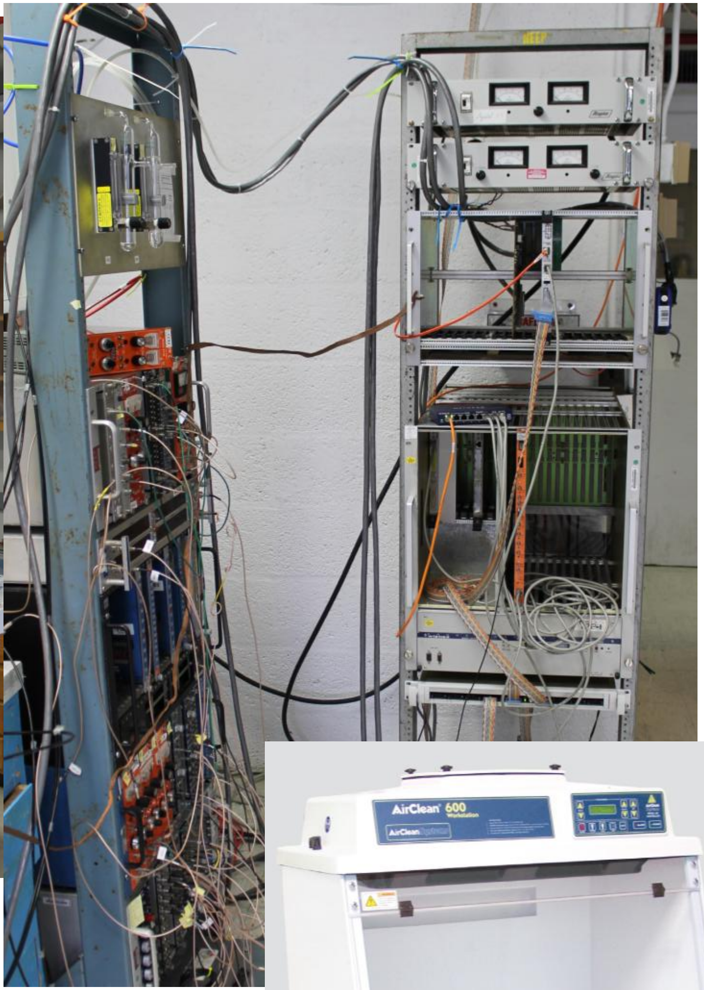
Some CR events – Red Line shows fit (Note: CR go up in the display)

Sigma of residual (regular GEM: 200µm, Thick GEM: 300µm)

Sabita Das (IOP/India)

GMT installation

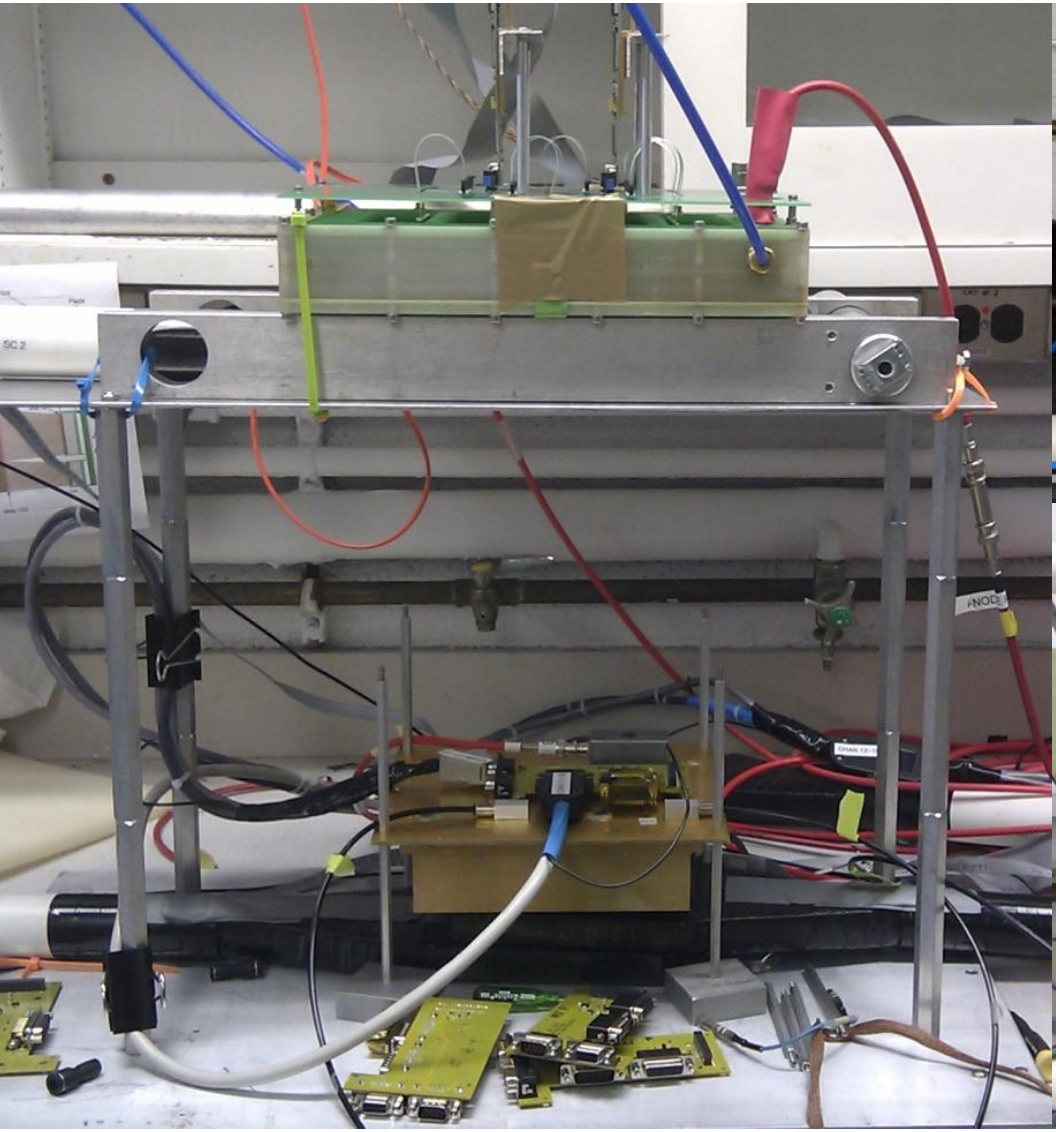


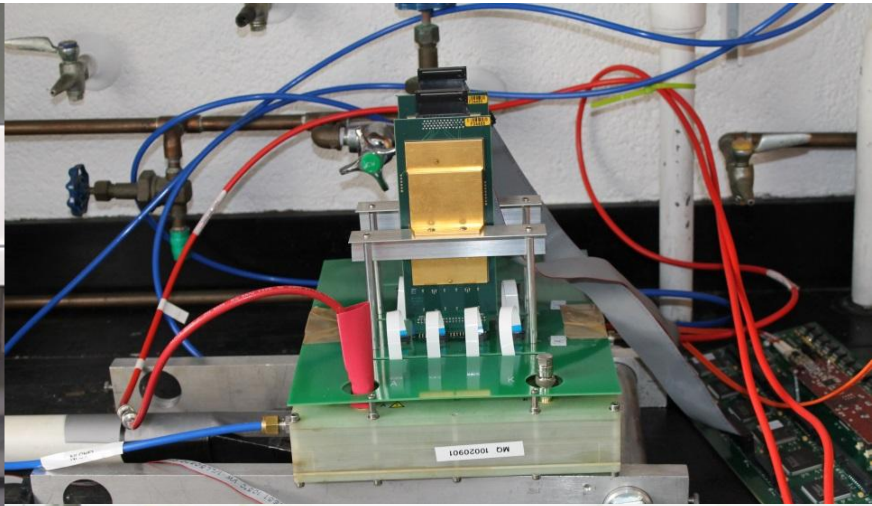


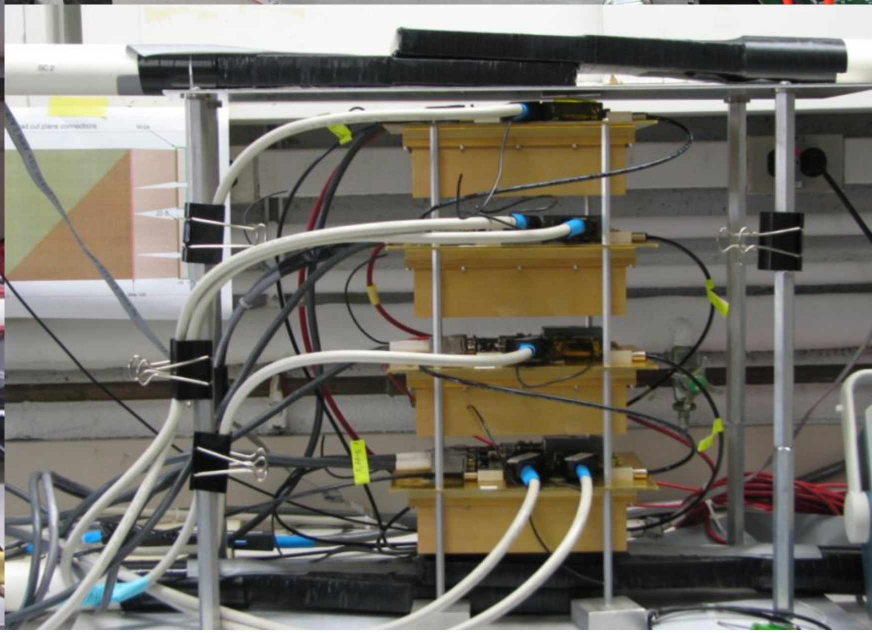
TPC Readout Electronics (TPX)
APV Readout Controller (ARC)
Trigger & Clock Distributor (TCD)
Data Acquisition and Linux (DAQ)
Cosmic Ray NIM Crate
Bertan HV for Wire, GEM Chambers
AriClean Hood, CAMAC

Biology building, RM167

MTRD and GTRD





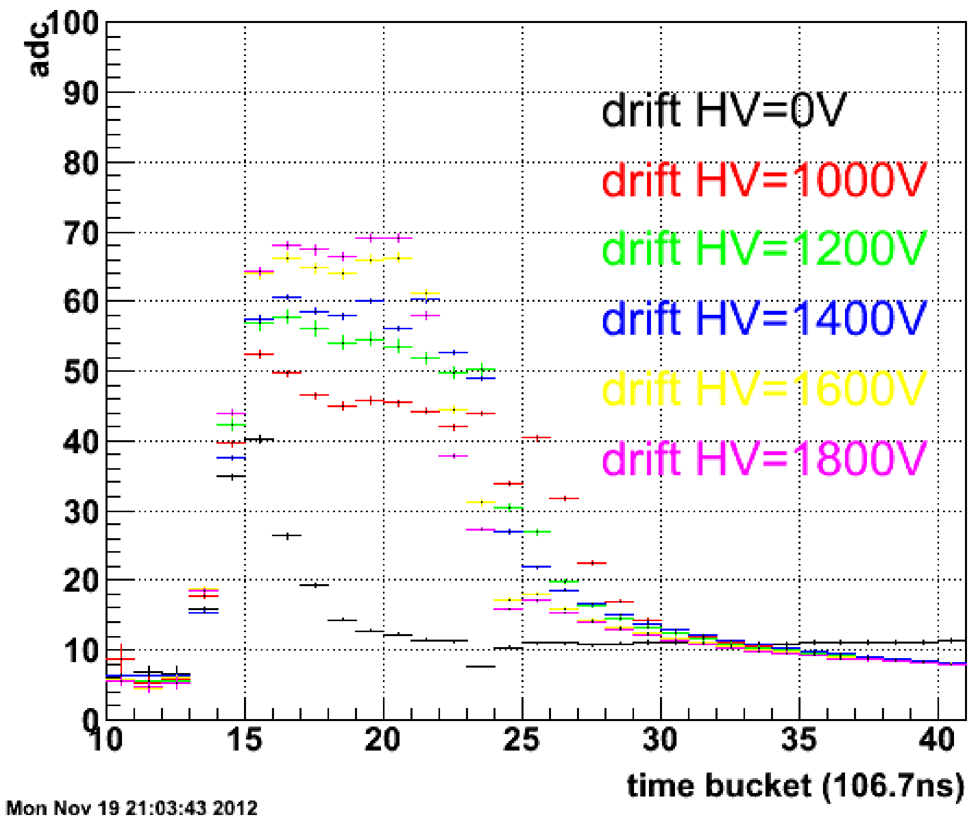


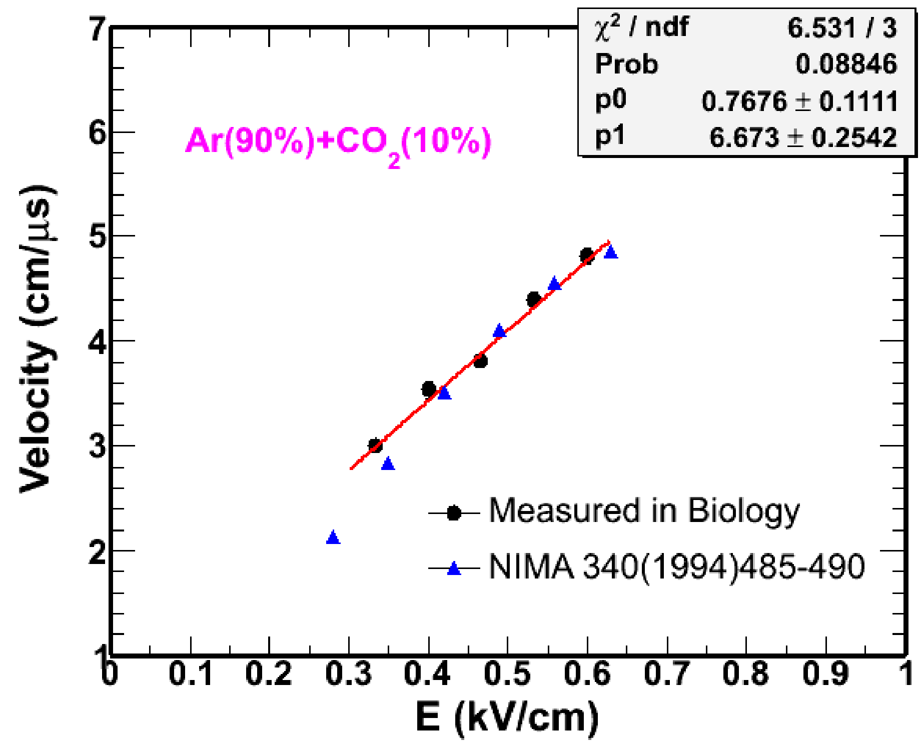
Checking the data match of wire chamber and TGEM

Wire Chamber: STAR TPC readout (107ns per time bin)

GEM: STAR FGT/GMT APV readout (26.7ns per time bin)

Drift velocity measured in WTRD





Average over many events

Shuai Yang (USTC)

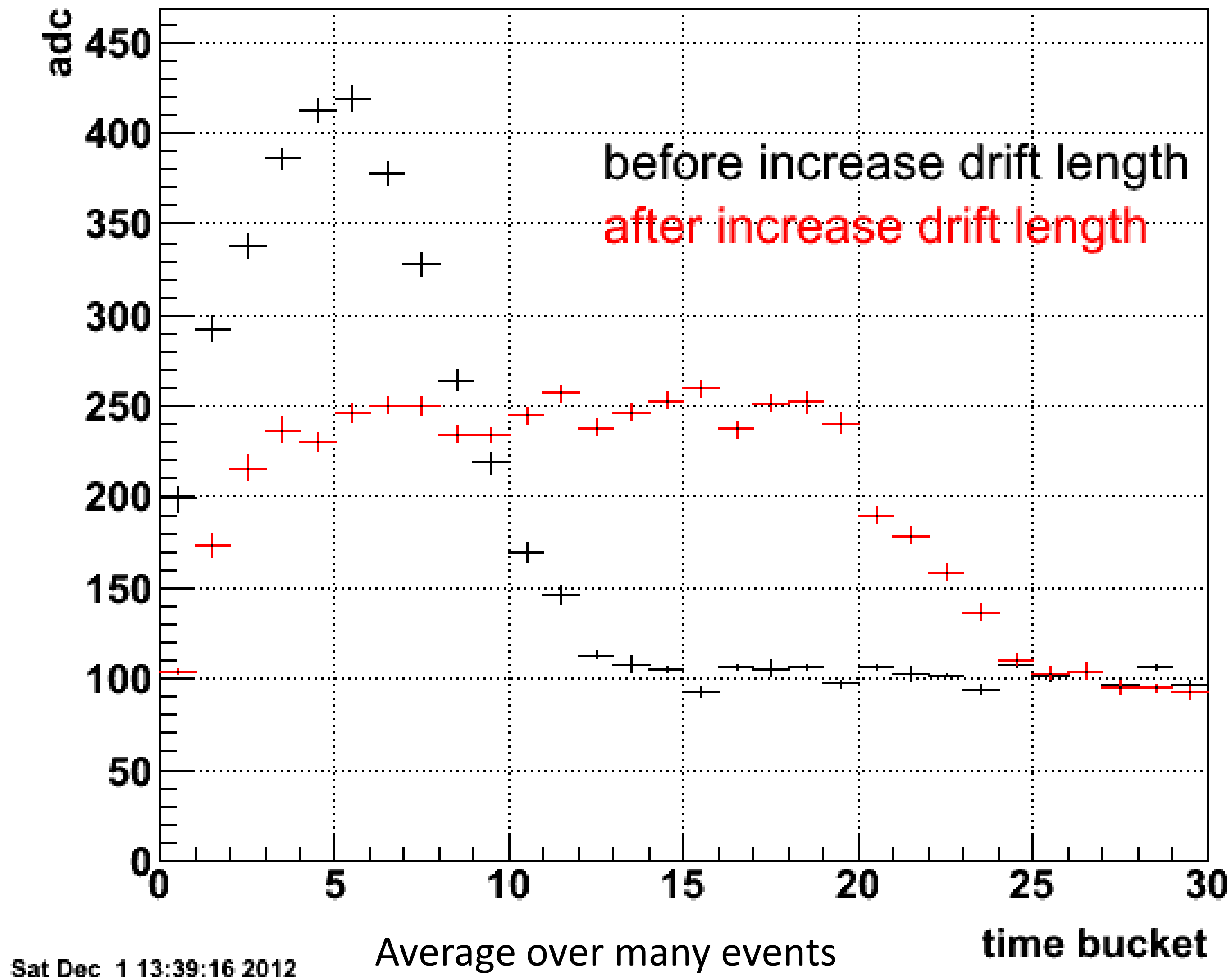
Wire Chamber from GSI (ALICE prototype)

GEM multiple Timebin Readout

From ~1mm to **1cm**
TRD signals should be at late time

Cosmic ray trigger jitter 100ns (4timebins)

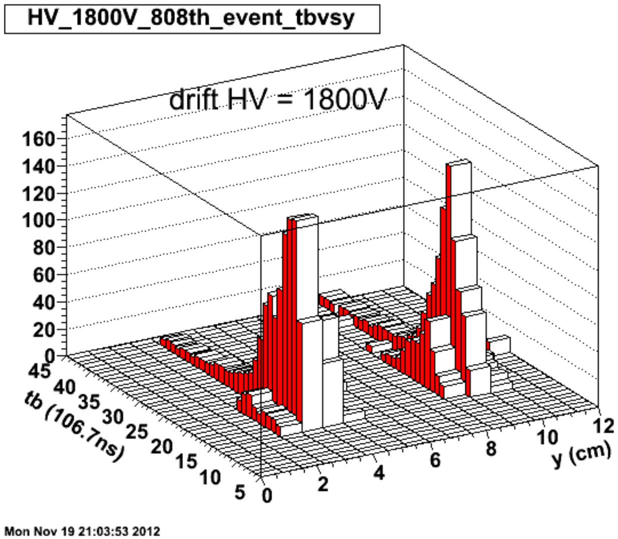
Increase the APV timebins from 7 to 30
Gerard Visser (IU)

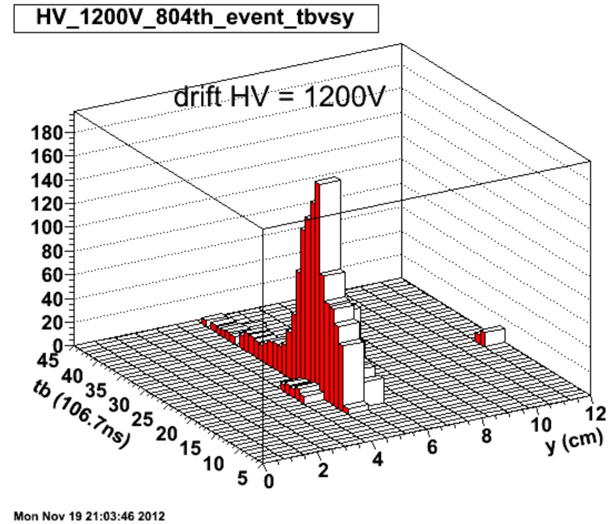


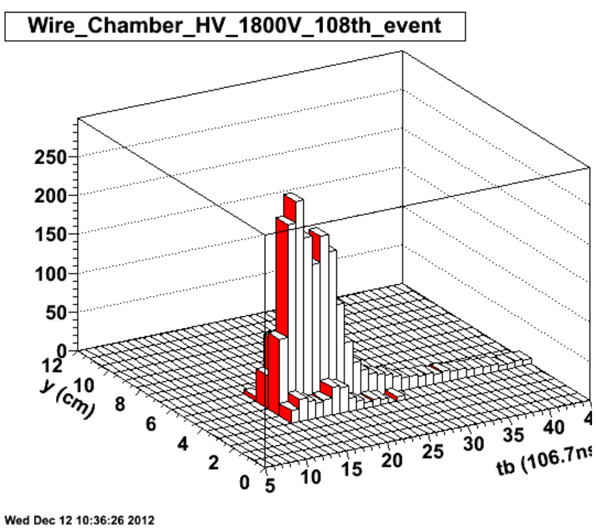
Average over many events

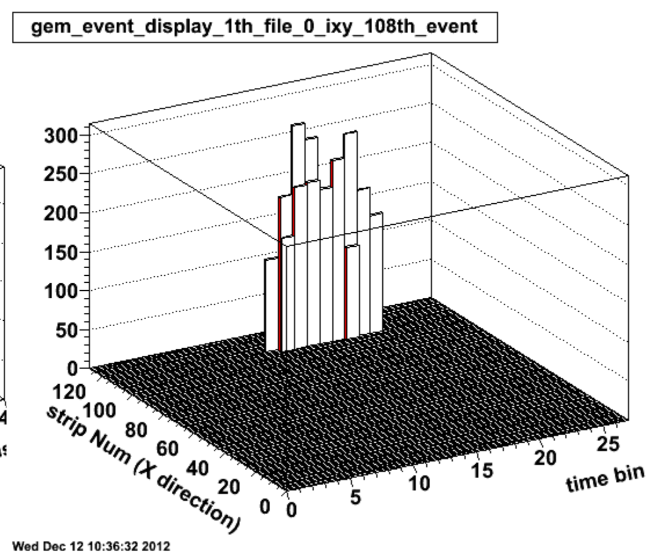
Position and Time Projection

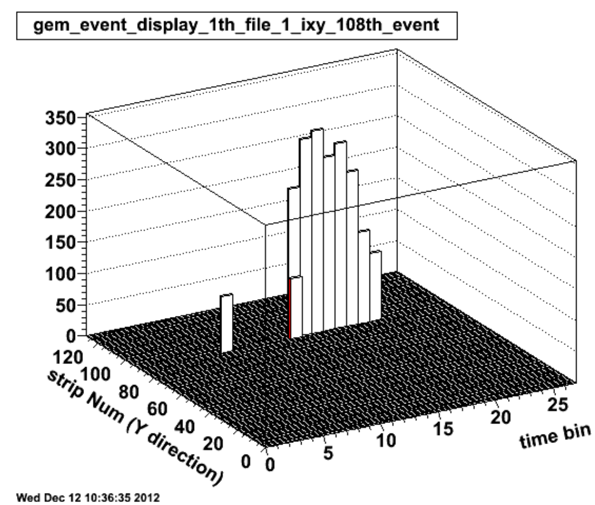
Event Display











Electronics Technical Driven Schedule iTPC

- Assume CERN Super-ALTRO chips will be available.
- A combination of 2 ASICS.
- Could be used for other detectors in the future.
- The ADC is not licensed and proprietary (unlike the original ALTRO) so the chip production could be easier and its lifetime might be longer.
- Possible cheaper than DAQ1000, but our estimate based on DAQ1000.
- Its production schedule is unknown, but due to CERN and other interests, we are optimistic and we expect to have a clear picture within 6 months.

Tonko:
R&D Proposal submitted to STAR and favorable support
Readout for both wire and GEM chambers

	Manpower (in FTEs)*	Funding for
FY13	0.5 FTE Physicist (architecture, design, firmware, test, software, project) 0.5 FTE EE[2] (FEE prototype, RDO&FEE board design, planning) 0.1 FTE Tech (PCB design, other)	- small prototypes - travel to CERN etc.
FY14	0.5 FTE Physicist (same as above) 0.6 FTE EE (FEE &RDO design & test, planning, other) 0.2 FTE Tech (PCB design, parts procurement, other)	- S-ALTRO - some electronics parts
FY15	0.5 FTE Physicist (same as above) 0.4 FTE EE (integration, oversight) 0.8 FTE Tech (parts procurement, boards Q&A, installation)	- other electronics parts - PCBs - PCB stuffing

EIC R&D Committee Recommendations

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Summary (from May 2012)

We propose to build a prototype of Transition Radiation Detector based on 10x10cm^2 triple GEM detector. We will take advantage of the design of the GMT readout pad and its available GEM foils for building this prototype. ☑ The goals are:

1. dE/dx resolution with Xe+CO_2 gas in 2-4cm ionization chamber;
   both wire chamber and GEM setup successfully ☑ ;
   timebin readouts (30+) from both detectors in one system; ☑
   Measure drift velocity and uniformity; ionization gap increases to 1cm ☑
2. hit position resolution for tracklets;
   hit resolution for single hit performed ☑
3. investigating readout electronics options (Stage I) ☑ .
4. Test beam at SLAC (10 GeV electrons) with Dick Majka, Craig Woody in May 2013

Part of the R&D support (not requested by this proposal) on large-area GEM readout are conducted in India and China.

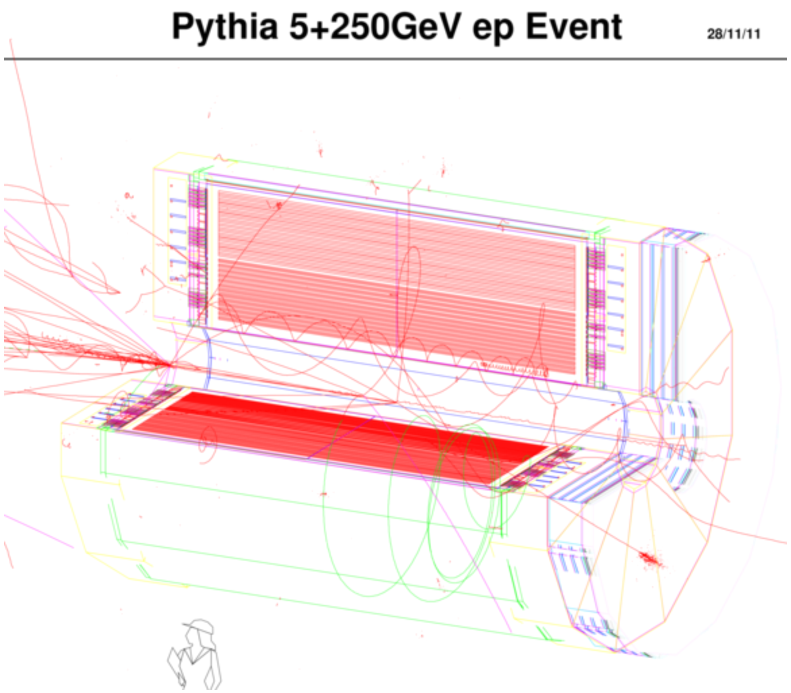
Possible R&D on endcap-type TOF design and electronics may be proposed to NNSFC/China in early next year.

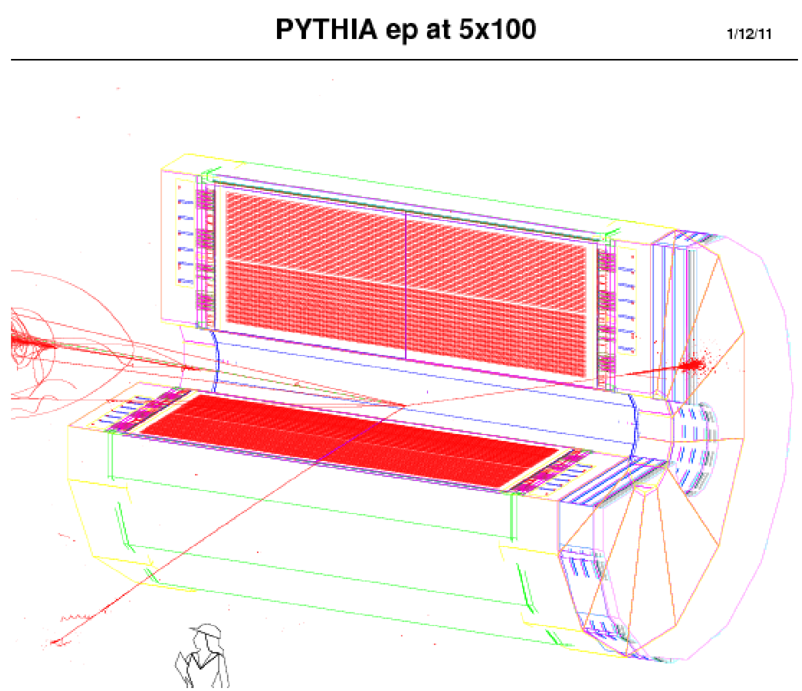
In addition, we plan to carry out simulations including a realistic simulation for a combination of TPC and TRD tracking, TOF with converter for identifying scattering electrons at the level of better than 1000 hadron rejection and for detecting large background photons in a possible first-stage EIC detector.

We envision a Stage II R&D proposal at the end phase of Stage I R&D (this proposal) to continue the following possible investigations:

1. complete TRD prototype with radiator and tracking capability;
2. TOF prototype detector with the necessary radiation and rate capabilities;
3. Stage II TRD electronics design and new TOF electronics options.
4. install the prototype in realistic magnetic field and radiation environment.

Detector Optimization





Optimization with realistic simulation of detector material in Stage I R&D proposal:

a) Material reduction before TRD for best electron ID

b) TRD position resolution necessary for improving hadron momentum resolution

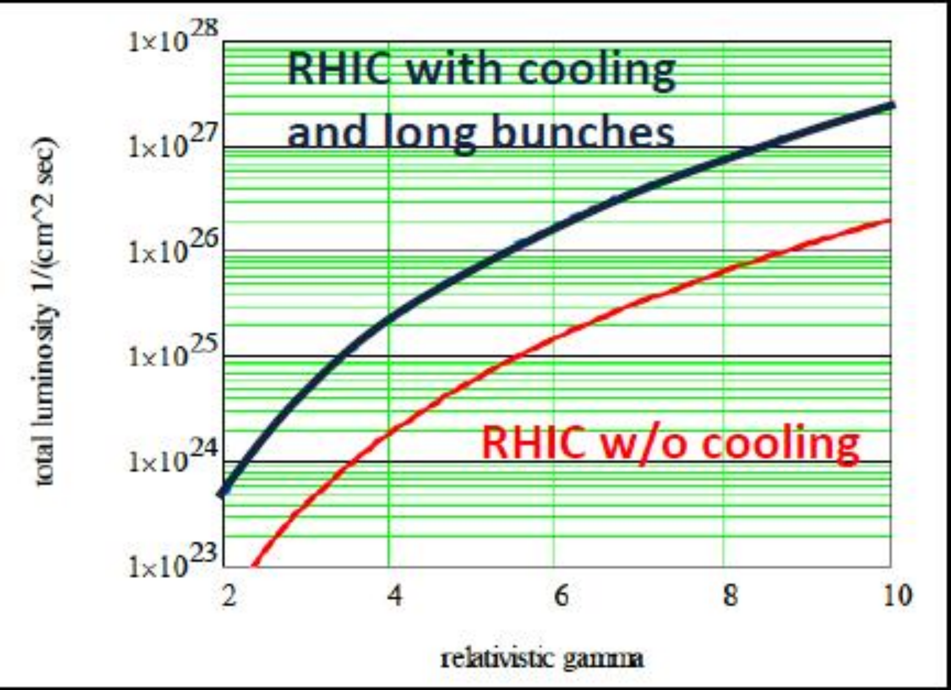
c) TOF pad/strip size optimization

d) Converter size/thickness

Must move from "Hints" → "Definitive Answers"

Beam Energy Scan (BES) Phase II

e-cooling for low energy RHIC operation

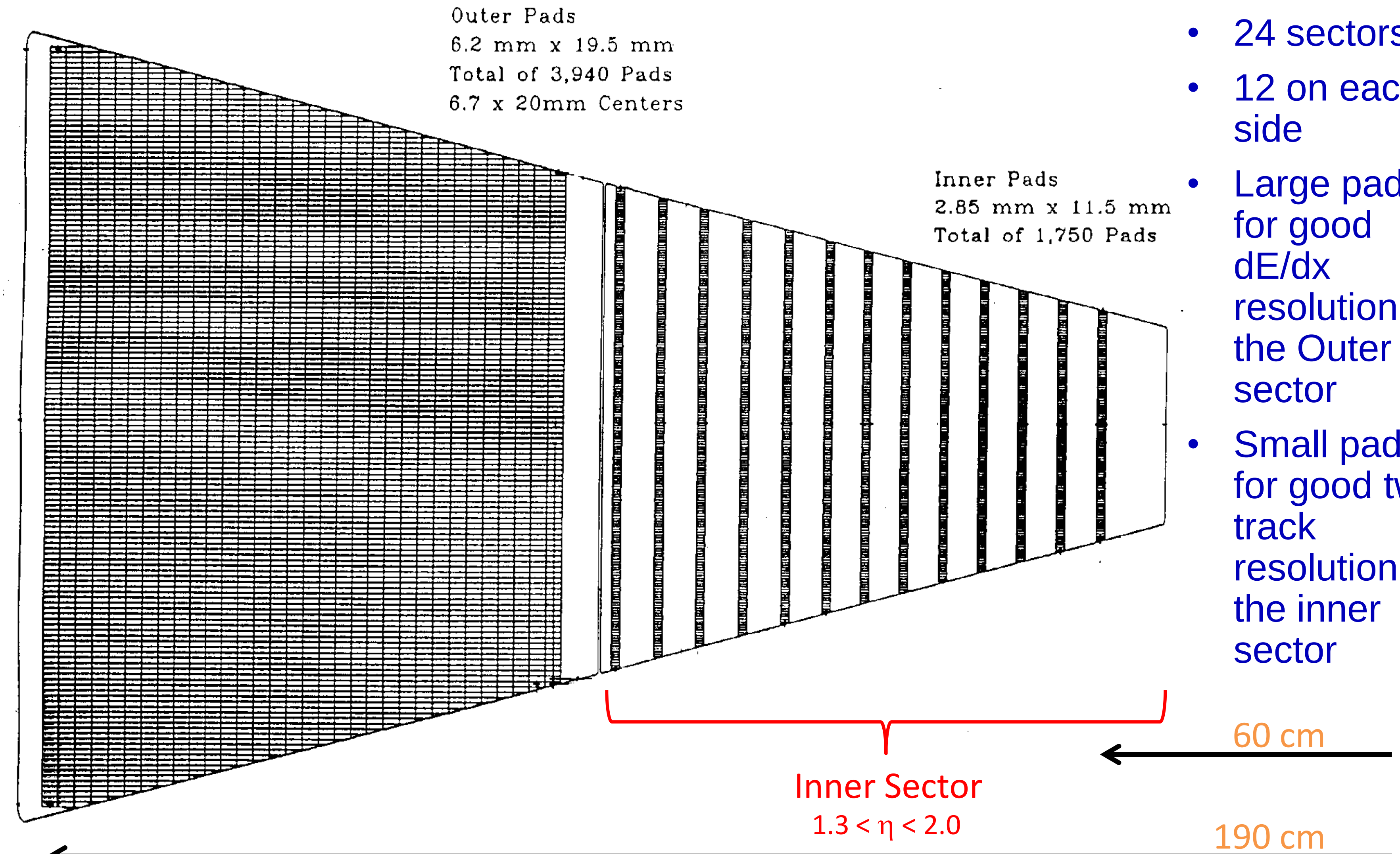


High brightness SRF electron gun or Fermilab Pelletron for 10x L

Increased acceptance for STAR and PHENIX

STAR Inner TPC Readout
Improved tracking and dE/dx PID
Extend η coverage 1.0-1.7

What is the upgrade?



- 24 sectors
- 12 on each side
- Large pads for good dE/dx resolution in the Outer sector
- Small pads for good two track resolution in the inner sector

More pad rows and larger pads in the inner sector

Simulation Framework

Hui Wang/Yuri

Padrow Options

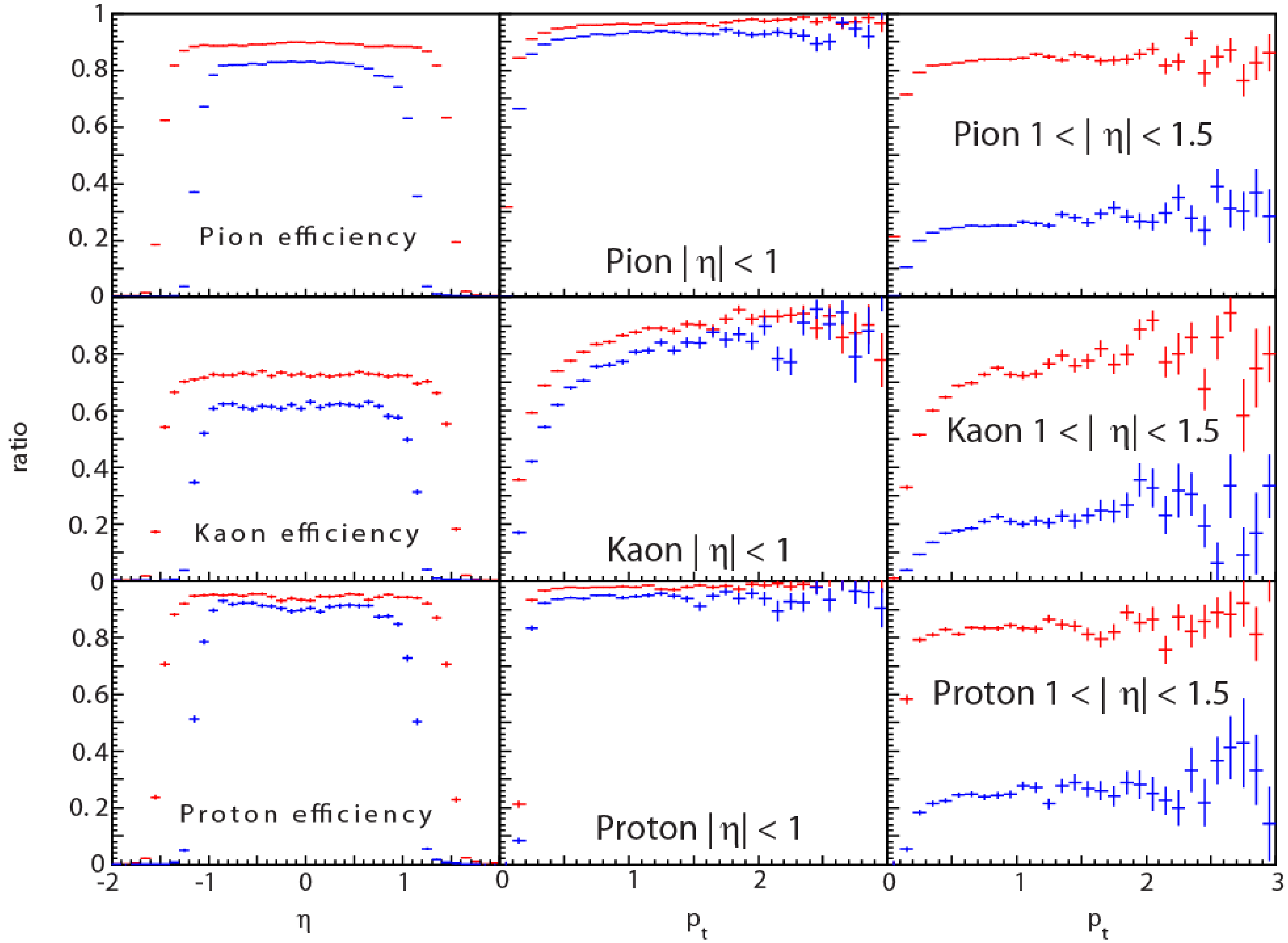
Geometry Tag	devTA	devTB	devTC	devTD	devTE	devTF	y2011	y2011 Sti
Pad size (cm*cm)	0.670*2.0	0.670*1.6	0.5*1.6	0.5*2.0	0.335*1.28	0.4*2.0	0.335*1.15	0.335*1.15
Number of rows	32	40	40	32	50	32	13	13
Number of pads	2162	2572	3496	2762	6494	3456	1750	1750
Tracker	StiCA	StiCA	StiCA	StiCA	StiCA	StiCA	StiCA	Sti

- Optimizing forward tracking algorithm for iTPC
  For tracks at large eta, currently all time bins are lumped together as one hit
- Physics "money plots" with the new simulation framework
  - Quantify the improvement for BES correlation, PID
  - Hyperon efficiency improvements

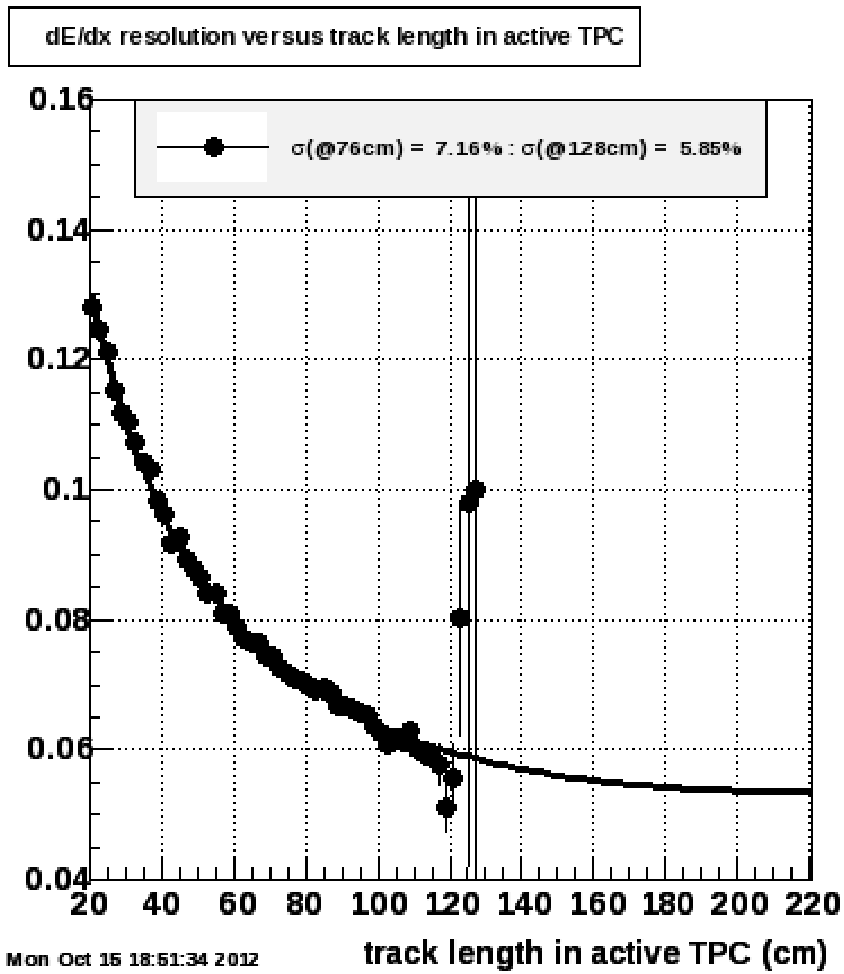
Basic Concept of improvements

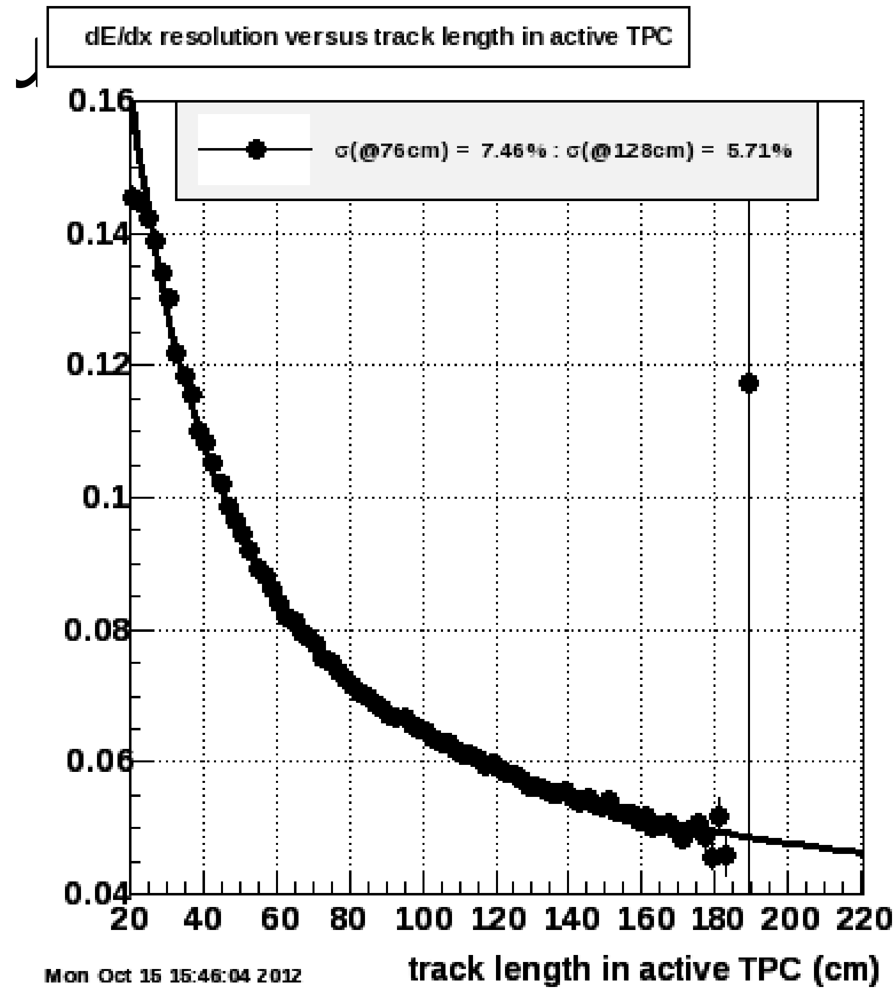
ACCEPTANCE: high eta and low pt

Hui/Yuri



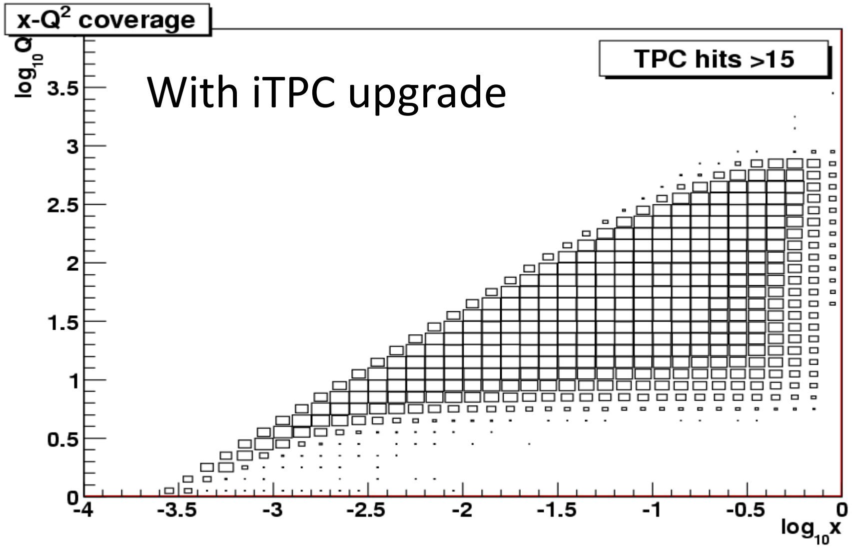
Simulation of improved dE/dx

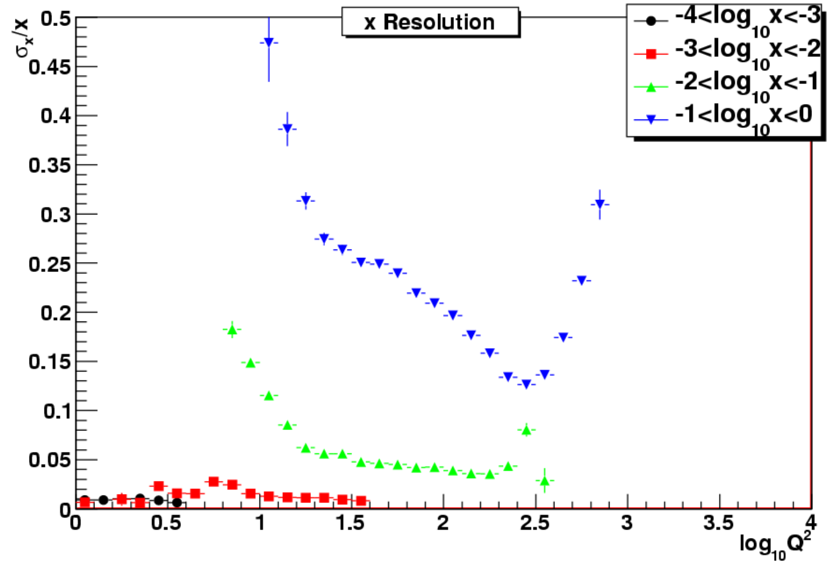


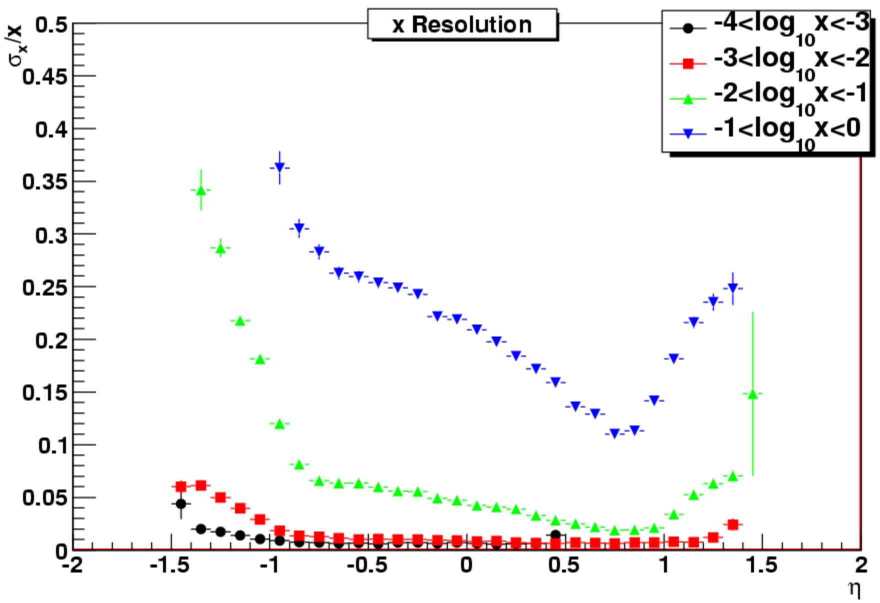


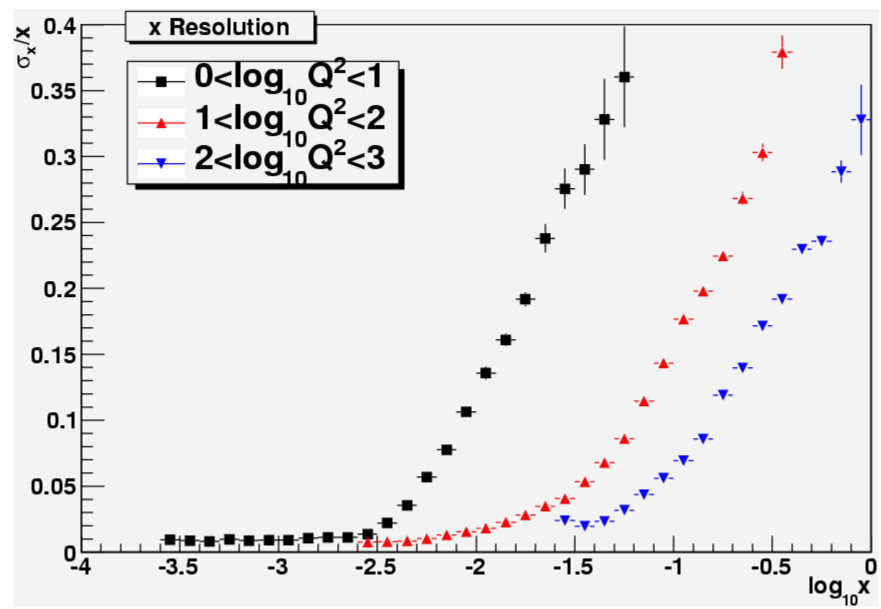
Simulation from HIJING Au+Au 200GeV
Should be better at lower energies
Improving: 7.2% to 5.7%

iTPC acceptance (5x250 eRHIC)

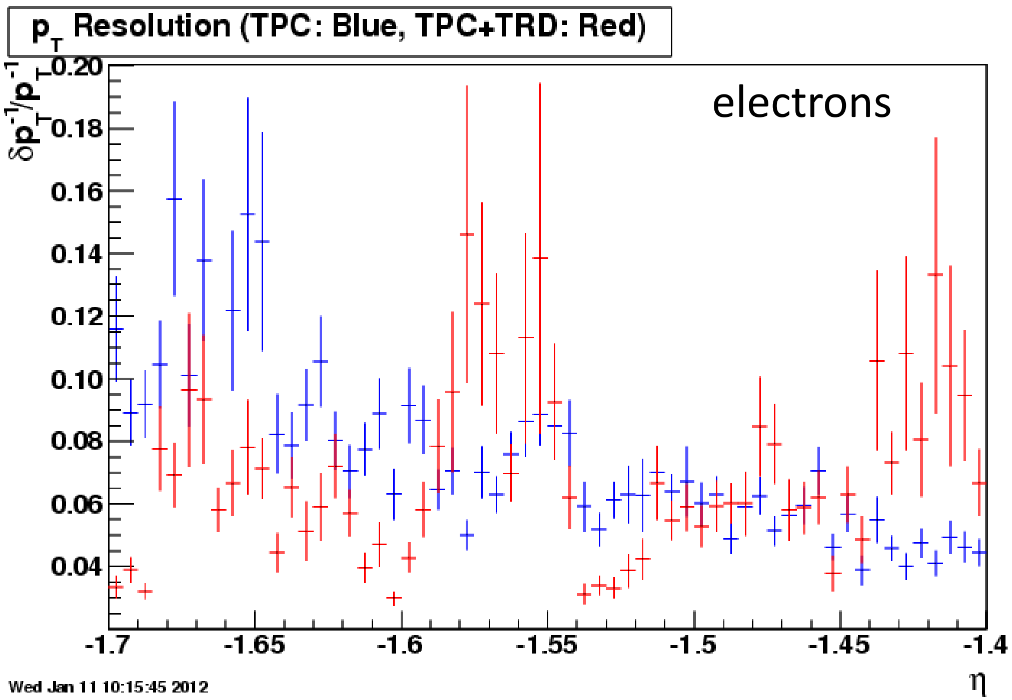


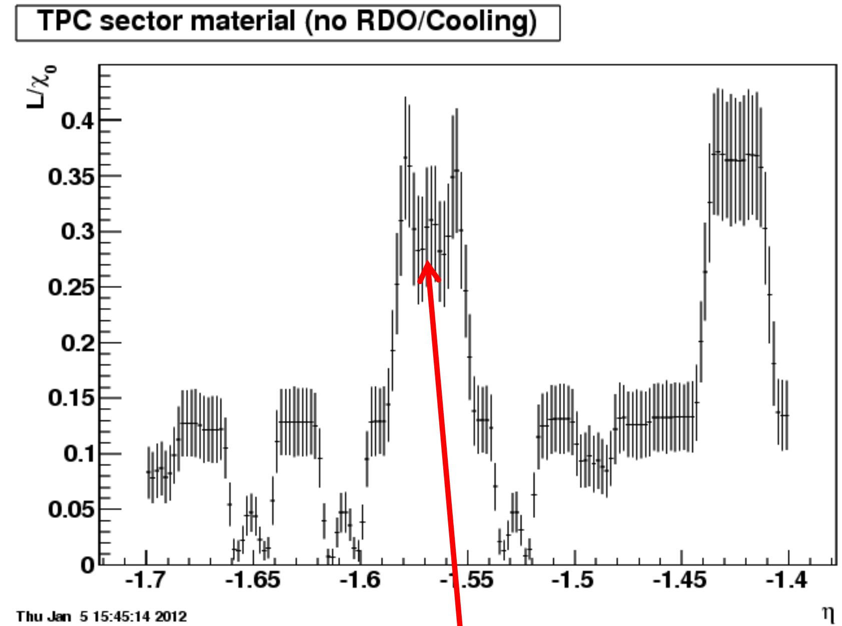


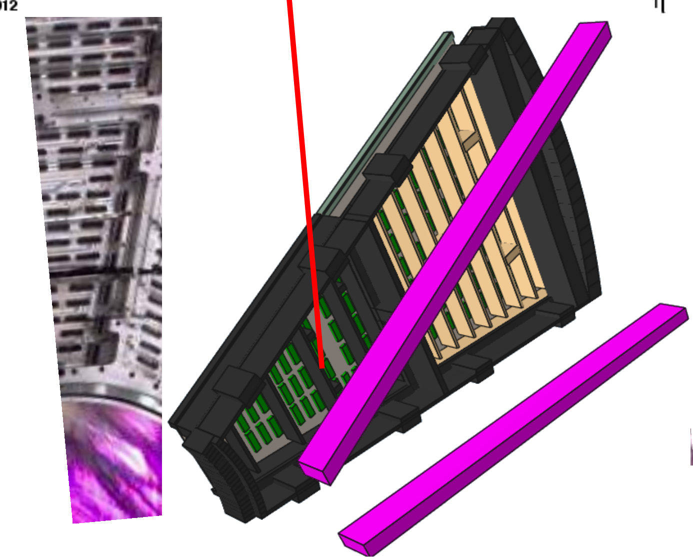




Track reconstruction with ETTIE







Need material suppression to improve electron momentum resolution

iTPC will help

For -1>η>-1.4, pT resolution by TPC alone is good enough -> TRD can be coarse readout?

Long-term Strategy Option

Agenda for Users' Workshop on RHIC Future Strategy (June 21-24, 2011)

Session I: Long-Term Options and Near-Term Plans

Session II: Decadal Planning for RHIC Heavy-Ion Program

Session III: Decadal Planning, continued

Session IV: eRHIC

Session V: Panel and Community Discussion Toward Developing a RHIC Strategy to Present at Next Long Range Plan

Among the critical questions to be discussed:

1) Since LHC HI results very similar to RHIC's, are both facilities needed? Which critical QCD matter questions are best answered at RHIC?

2) Will 2-3 year cessation of RHIC ops. be essential to fund eRHIC? If so, what is optimal timing?

3) Is it crucial to maintain AA & pp capability into eRHIC era? If so, can we reconfigure IR's annually, or do we separate HI from eA in different IR's?

4) What eRHIC science is realizable within $500M total project cost limit?

5) What is optimal path for detectors and collaborations to evolve from RHIC to eRHIC?

Steve Vigdor

Long-term Strategy Options

Two Possible Strategy Options as Discussion Guideposts

1) ***"Natural Evolution"***
   - *STAR & PHENIX each evolves toward an eRHIC (stage 1) detector, with some upgrades justified in the shorter term by enhancing the AA, p/d+A and pp programs at RHIC*
   - *AA, p/d+A and pp operations continue through ~2020, followed by few-year suspension while eRHIC constructed & installed*
   - *eRHIC construction cost would cover STAR & PHENIX upgrades beyond ~2020*

2) ***"Collaboration Reconfiguration"***
   - *Use one of STAR and PHENIX halls (infrastructure + some sub-systems) to mount substantially new, dedicated ep/eA detector*
   - *Use other hall to substantially upgrade an AA/dA/pp detector that would have a productive program past ~2020*
   - *Aim to run eA (ep) at one IP in parallel with AA/dA (pp) at the other in eRHIC era*
   - *"Reshuffle" the collaborations according to user interests*

Each option has its own significant challenges. Either must be justified by compelling science and make sense technically and financially. Detector or machine upgrades (e.g., coherent e-cooling) desired before eRHIC project must be justified by the AA/dA/pp science enhancements.

Electronics R&D Stage I

- For the baseline stage we plan to use the currently existing electronics readout used for the “Forward Gem Tracker” (FGT) at STAR with modifications already made for the “GEM Monitor for the TPC” (GMT) detector also at STAR. This electronics system was designed for FGT’s and GMT’s GEM chambers and is based upon the APV frontend ASIC, custom STAR-specific electronics and the STAR-standard DDL optical link. Such a system is already in use for the QA phase of the FGT detector and will be used in the physics production during the RHIC FY12 run.

  Apart from installing the electronics on the prototype detector the 2 necessary modifications and thus milestones of Stage I would be:

- **Milestone 1**: Modifications of the FGT/GMT readout system to enable at least 100 time samples readout.

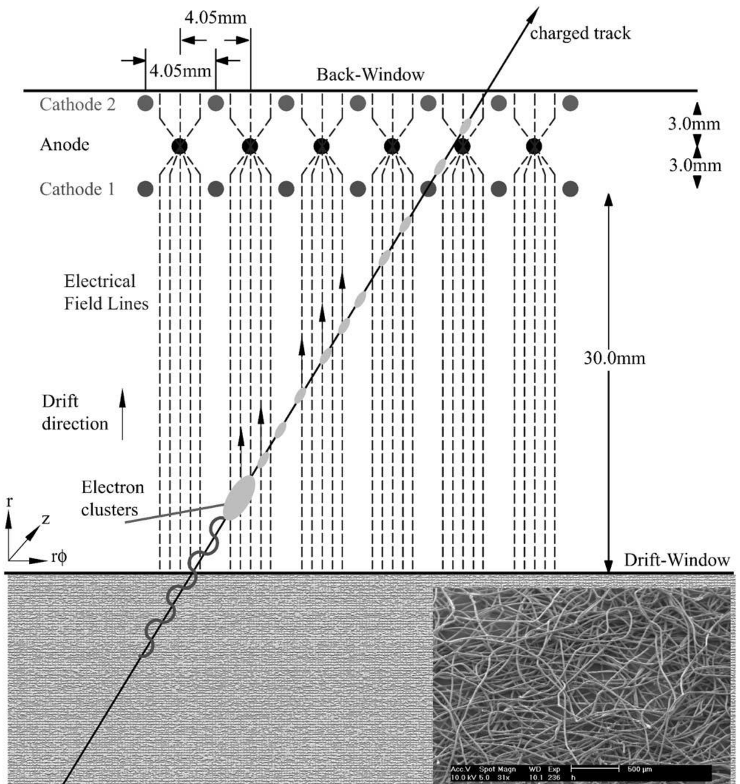
- **Milestone 2**: Modifications necessary to enable operation at collision frequencies of up to 15 MHz, as required by eRHIC.

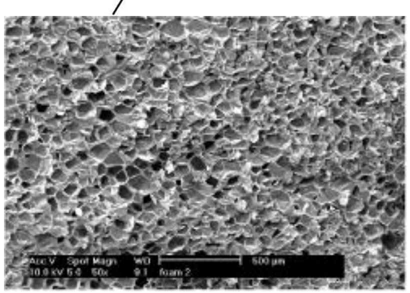
Electronics Stage II

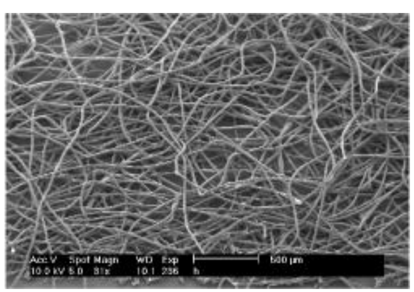
The currently known requirements for final electronics are:

- Synchronous time sampling suitable for a drift TRD with good energy resolution.
- Low mass.
- Efficient cooling.
- Some level of radiation tolerance.
- Magnetic field tolerance.

ALICE/PHENIX Radiator







A radiator sandwich is composed of 10 sheets of 17 mm polypropylene fibers (LRP 375 BK 600) on top of a Rohacell (IG 51) shell and a fiber cushion. Each fiber sheet is 0:5 cm thick with a density of 60 mg=cm2: The shell, with a thickness of 0:636 cm and the density of 52 mg=cm2; provides mechanical stability. All except the cushion are wrapped in mylar foil. A sandwich is 151–174 cm in length, 25 cm in width and has 0.94% X0 of material.

The final radiator consists of polypropylene fibre mats of 3.2 cm total thickness, sandwiched between two Rohacell foam sheets of 0.8 cm thickness each. The foam is reinforced by carbon fibre sheets with a thickness of 0.1 mm laminated onto the outer surface.

(Stage I) Responsibilities of R&D

Name	Institute	responsibilities
Zhangbu Xu (Co-PI)	BNL	Organizing the collaboration (phone meeting, tasks); construct prototype
Ming Shao (Co-PI)	USTC, Sabbatical leave at BNL (07/11—07/12)	Initial GEANT4 detector simulation; construct prototype; TOF prototype at USTC in the future (Stage II)
Tonko Ljubicic	BNL	DAQ and integrating electronics readout
Gerard Visser	Indiana University	FGT electronics upgrade for TRD R&D
Bob Scheetz	BNL	GEM Pad plane design and interface
Richard Majka	Yale	GEM Pad plane design and interface
Nikolai Smirnov	Yale	Generic simulations
Postdoc (1/2)	BNL	Simulation optimization, taking cosmic ray data and analyzing prototype results
Student	One from USTC or VECC stations at BNL	Carry out simulation and participate in prototype construction
	VECC and USTC	Independent funds on large-area GEM (not part of this proposal); request some supports for travel and material for EIC related activities

(Stage II) Responsibilities of R&D

Name	Institute	Responsibilities
Frank Geurts	Rice	Software; TOF expert
Bill Llope	Rice	TOF and TRD mechanics design
Geary Eppley	Rice	TOF module design and optimization
Jo Schambach	UT	TOF electronics and readout
Jerry Hoffmann	UT	Prototype TOF mechanics construction and testing
Cheng Li	USTC group	Independent funds on TOF and TRD R&D; may require some support depending on their funding requests
Subhasis Chattopadhyay	VECC group	Large-area GEM; may request travel support for EIC related activities
Lijuan Ruan	BNL	TOF expert on construction, operation and analyses