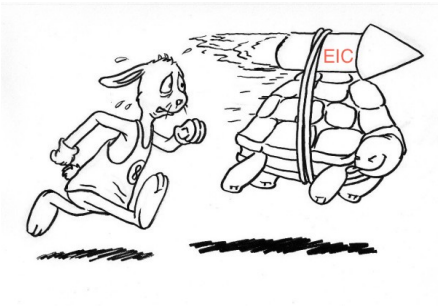
eRD10: R&D Proposal for (Sub) 10 ps Timing Detectors at the EIC
22 January Progress Report



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University of Illinois at Urbana-Champaign

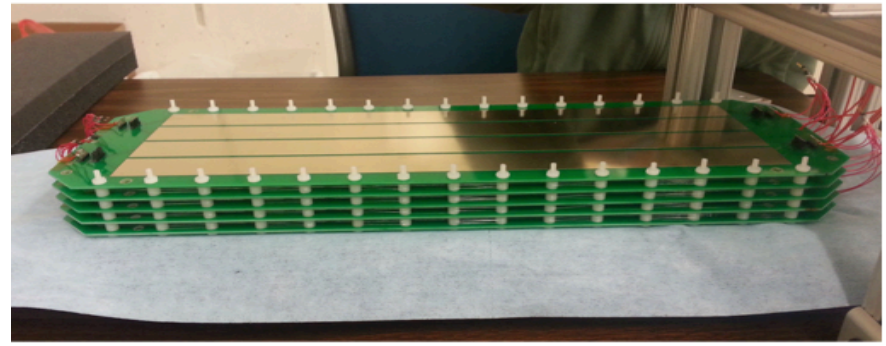
Dave Kawall
University of Massachusetts at Amherst

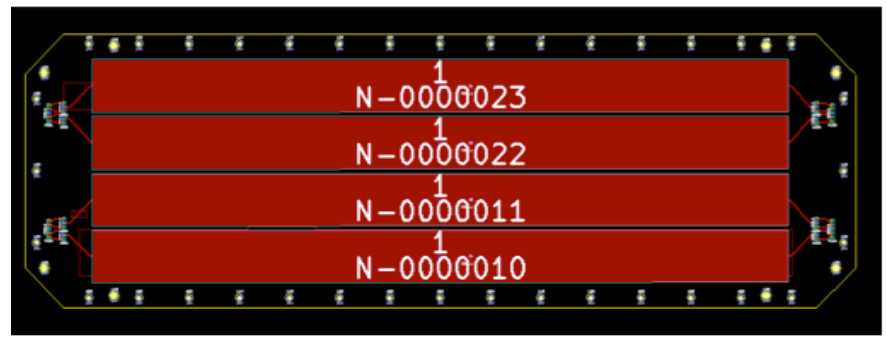
John Harris, Richard Majka, Nikolai Smirnov
Yale University

Status of psTOF R&D

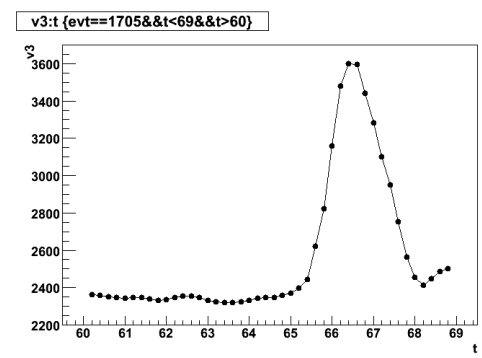
- Post-doc at UIUC (Ihnjea Choi) was hired with EIC R&D funds to work on fast mRPC development.
  - Hardware funds out of UIUC and MC PECASE grants
- Building prototype of mRPC (UIUC)
- Preparing fast electronics (UIUC, BNL)
- Setting up cosmic test-stand at UIUC (UIUC)
- Started detailed simulations of mRPC using Garfield/ Garfield++
- Studying physics capabilities using TOF in ePHENIX simulation
- Forming PID collaboration with RD11. LAPPD MCP-PMT R&D!

mRPC Prototype v0, Feb 2014

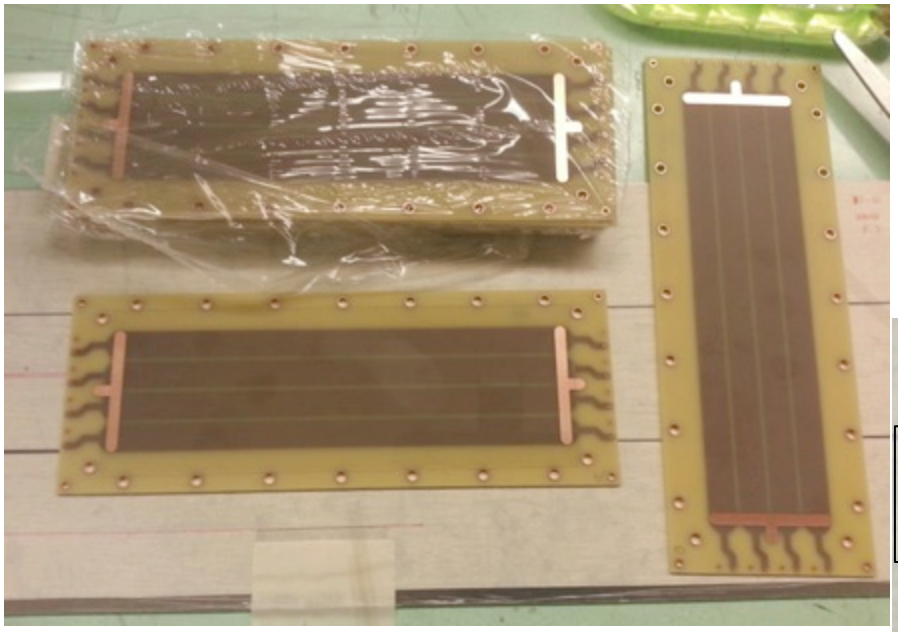


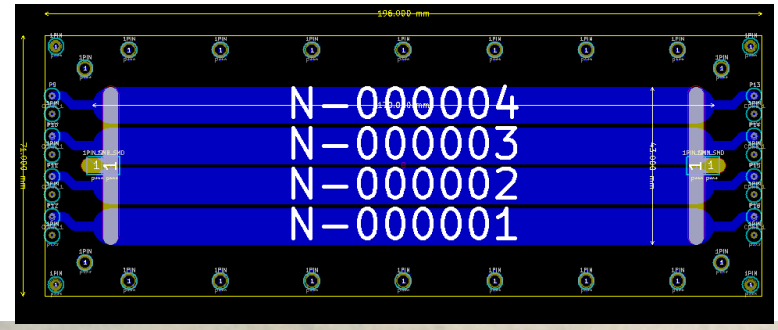


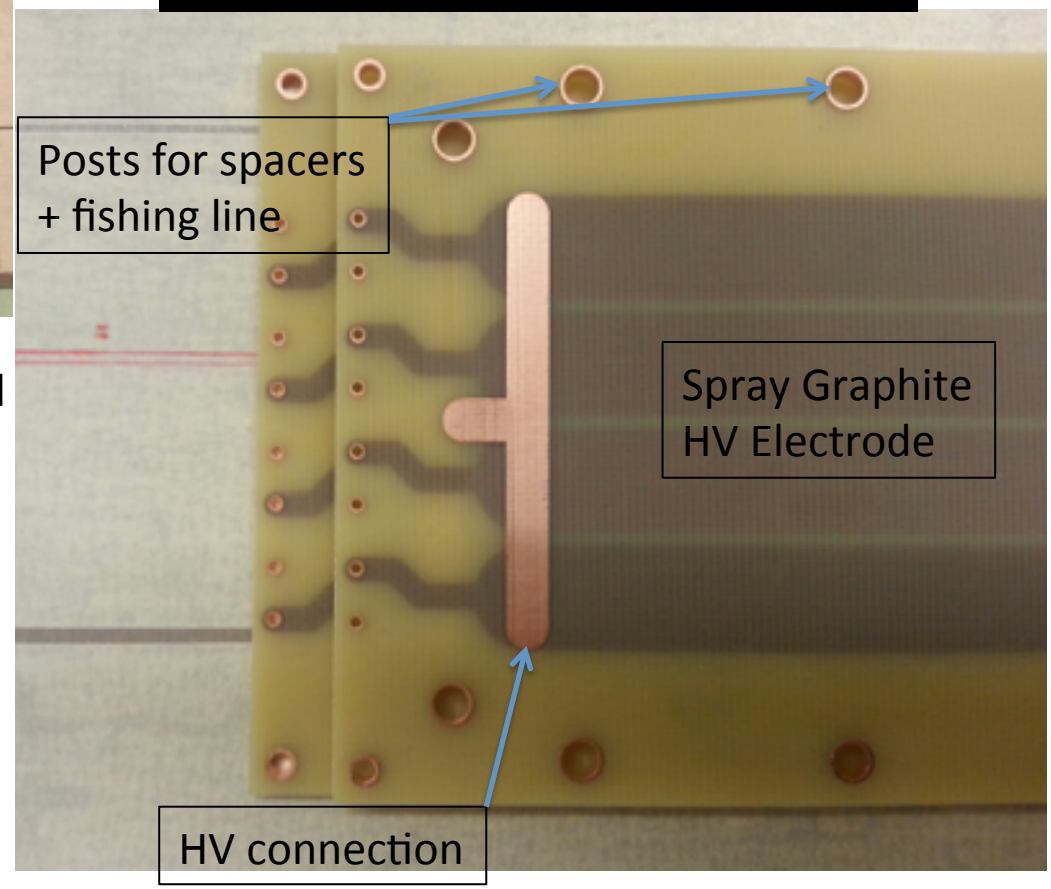
- First ever BNL/Howard/UIUC mRPC was built and tested at FNAL Test Beam Facility Feb 2014 (during same beam test as part of eRD1 and sPHENIX HCAL)
- Great learning experience. Improvements from v0 are
  - Build smaller (faster turnaround on design iterations)
  - Better PCB design, improved HV connection
  - Rigidity important (honeycomb)
  - Preamp protections needed
    - Spark events generate large pulses of both polarities
- Promising signals seen (low noise, fast rise time)



New Cathode Strip Pickup Design

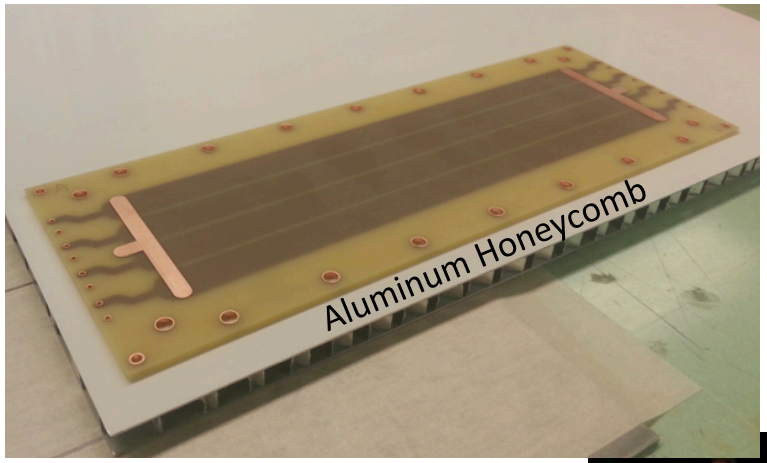






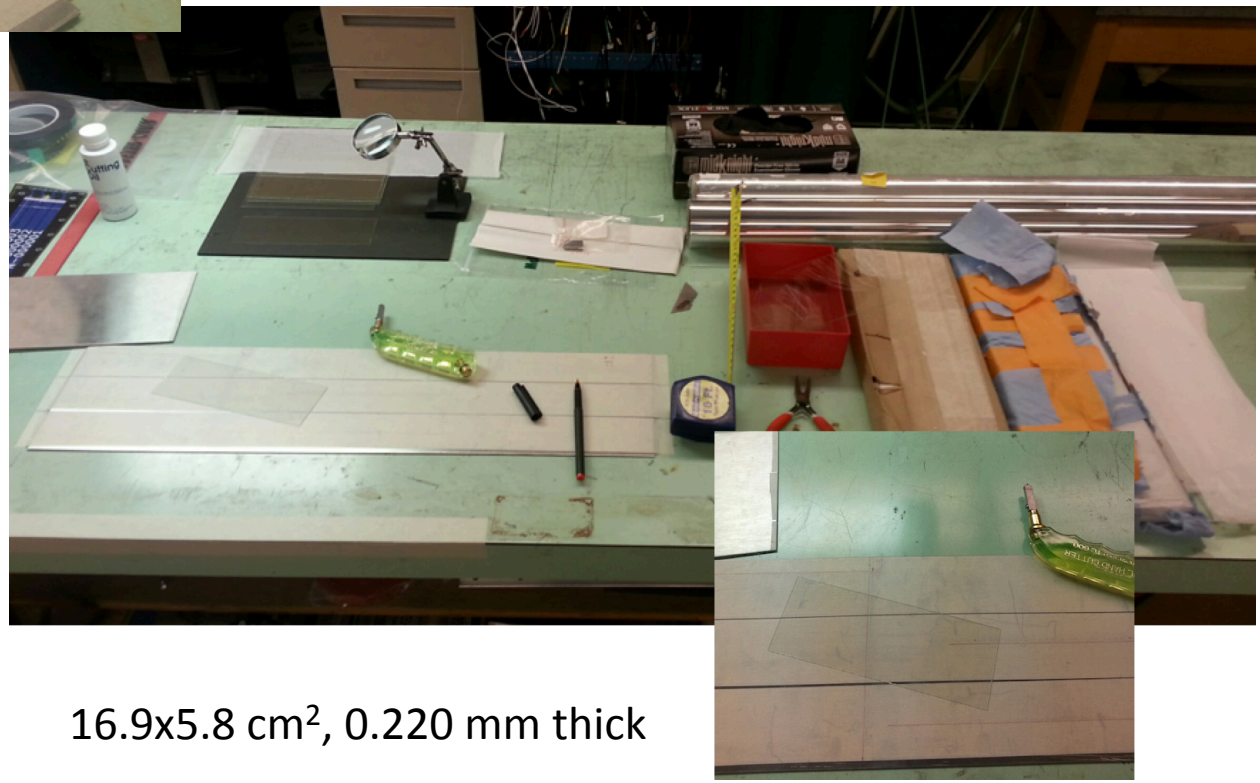
- Drawn in KICAD by Ihnjea and 12 ordered
- Improvements
  - One board flavor – interchangeable
  - HV connection integrated on board
  - Rounded cathode strips
  - Smaller (easier to take apart and rebuild)
- Starting to build two MRPCs
- Each one needs 5 PCBs

About Ready to Stack v1 Prototype



Stiffener

Glass Cutting*



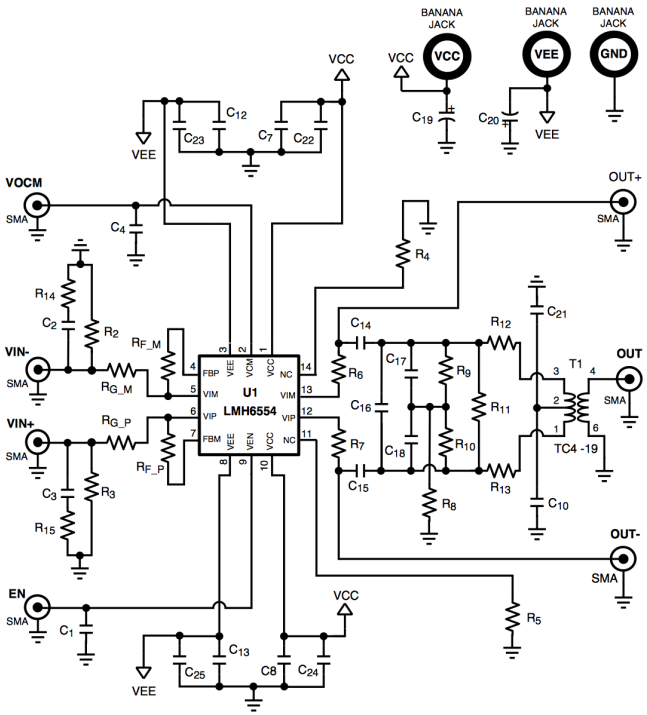
16.9x5.8 cm^2, 0.220 mm thick

*Our post-docs learn practical skills

mRPC Stack Design

	MRPC (Crispin Williams et al)	MRPC (UIUC & BNL)
Gas Gap Width	160um	105 um (and 165, 125um, 75um)
# of Gas Gaps	4 stack x 6 layers = 24	4 stack x 8 layers = 32, etc
# of thin glass layers	4 stacks x 5 layers = 20	4 stack x 7 layers = 28, etc
Gap Gap Spacer	Fishing line with 160um dia.	Fishing line 105um (or 165) Mylar strips (75 um or less)
Preamp	Differential type, NINO chip	TI Preamp (or possibly NINO)
TDC and DAQ	Oscilloscope (10Gs)	DRS4-V5(5Gs) + RPi computer
Time resolution	16 ps obtained	???

Readout



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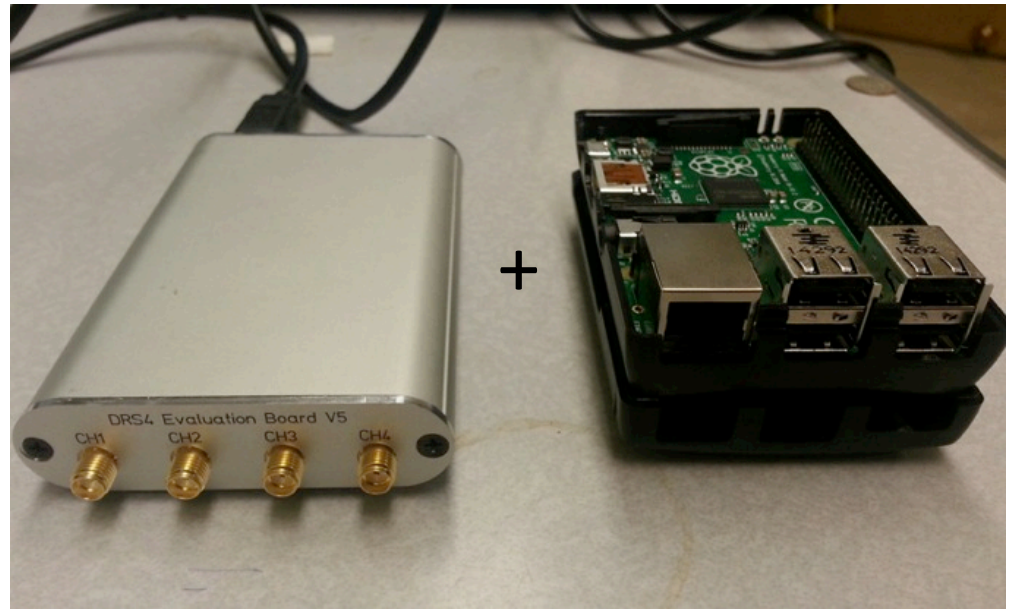


+

TI LMH6554 2.8 GHz diff amp

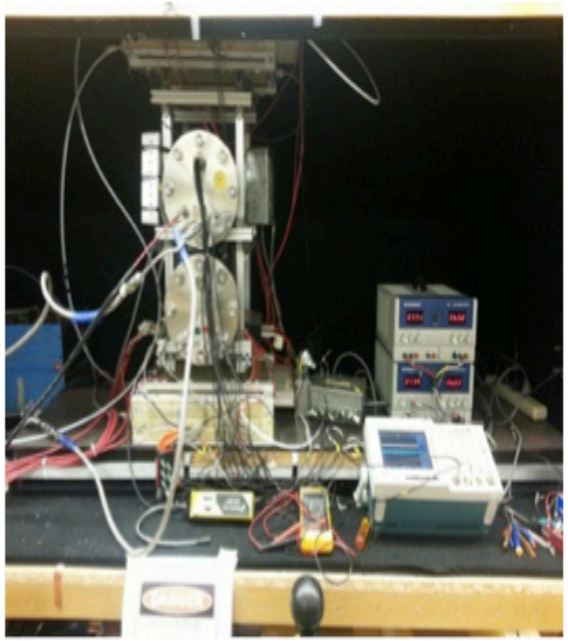
DRS4 5 GHz ADC

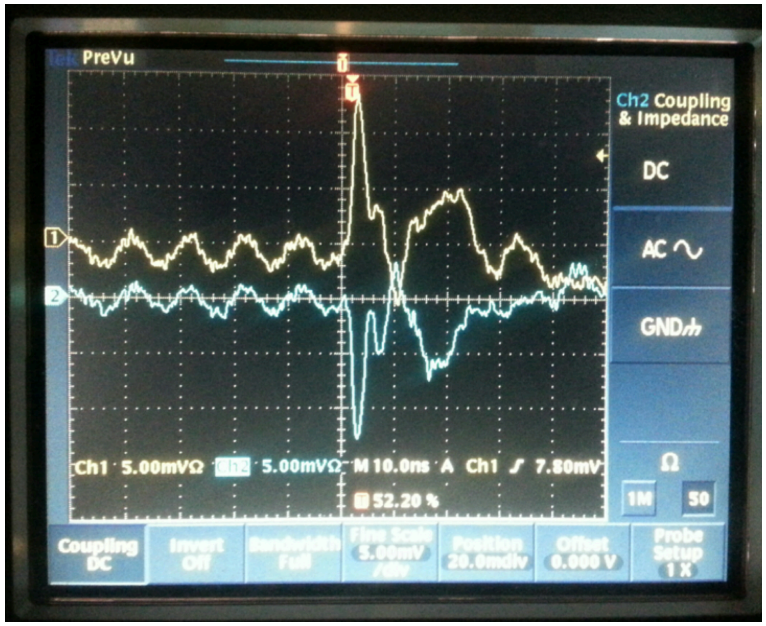
Raspberry Pi B+

- Using 1 channel TI evaluation board for now ($100)
  - Draws 1 Amp
  - Will design and fab 8 ch preamp board starting February
- Possibility to use other preamps (eg NINO ASIC)
- DRS4 was tested by us to be better than 3 ps resolution ($1200/4 ch)
  - Compare to 5 GHz digital scopes at O($20-30K)

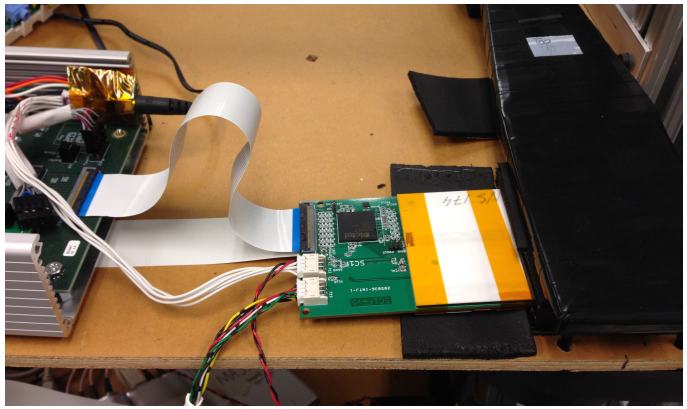
- Data recorded on Raspberry Pi running simple DAQ ($40)

Cosmic Test Stand at UIUC



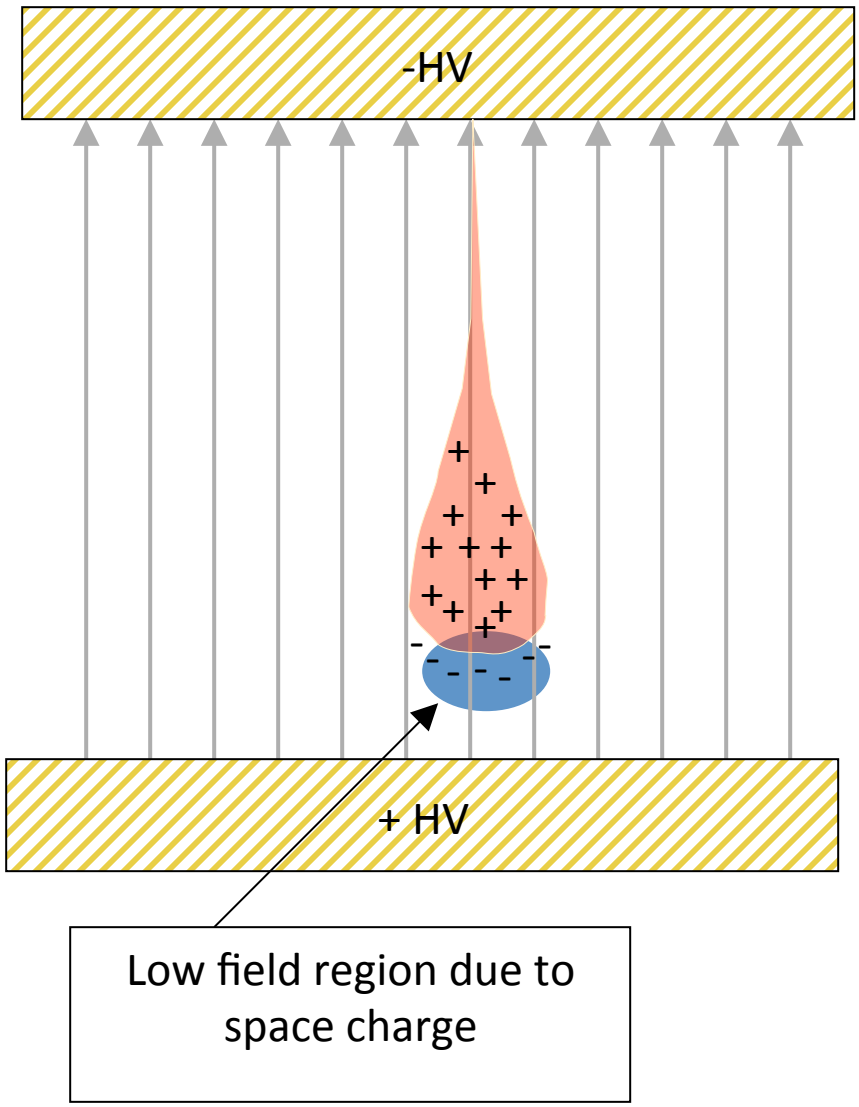


- Leverages existing test stand built for double gap bakelite RPCs (PHENIX W->Muon Trigger)
- Currently testing using Tsinghua Univ mRPC
- In February should have silicon tracker going (0.5 mm pitch hodoscope)
    - Important for studying angle and position dependence
- Also have test stand at BNL to help later with systematic studies if needed



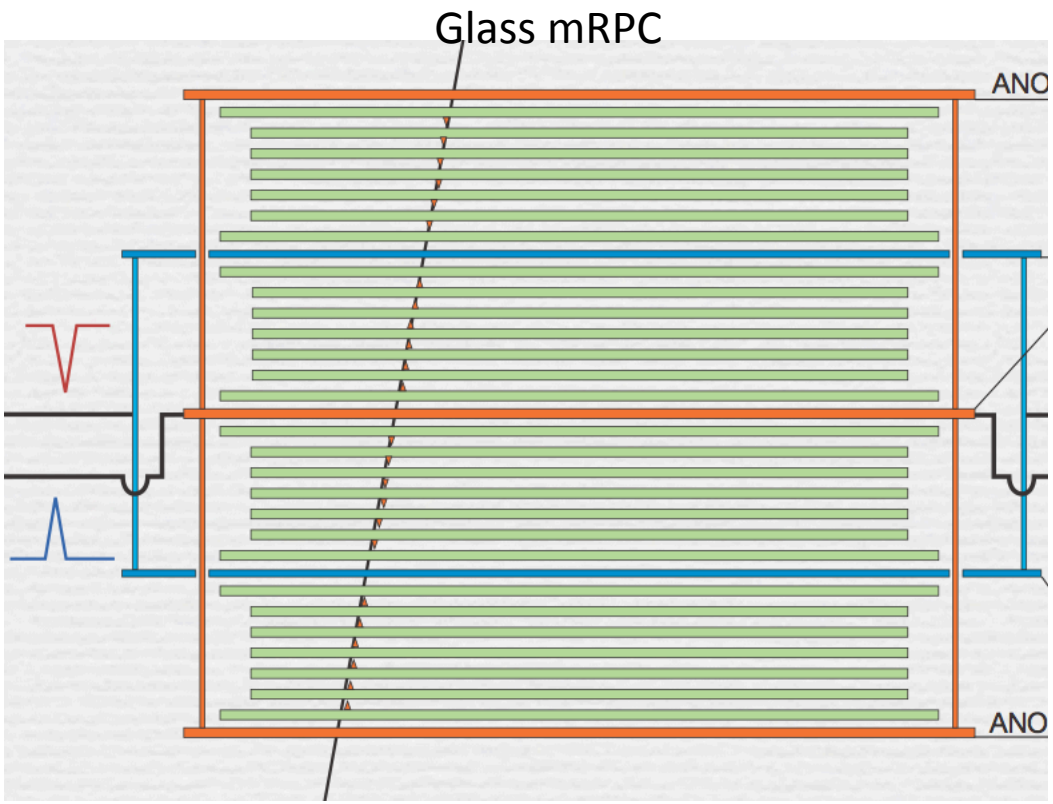
Standalone Si Tracker

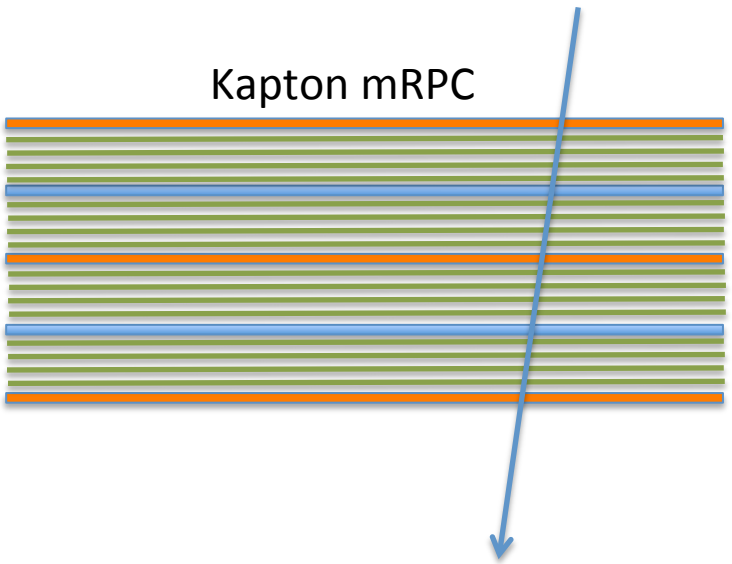
mRPC Simulations Using Garfield++



- Simulations using Garfield++ have been started and is still a work in progress (BNL, UIUC)
  - Primary electrons (HEET)
  - Avalanche Development: Townsend Coefficient, Attachment Coefficient (MAGBOLTZ) to get effective coefficient, drift velocity, diffusion coefficients
  - Signal generation (Shockley-Ramo theorem)
  - Space Charge Effects
- Have been consulting with Crispin Williams
- Code is freely available on github
- Not so clear there is much that can be optimized in the avalanche process
- It's still possible that a different gas mixture will improve timing resolution, probably by increasing number of initial electrons or drift velocity, while keeping avalanche process similar.
  - Plan to have Howard U. student learn simulation and run through various gas, gap, dielectric combinations

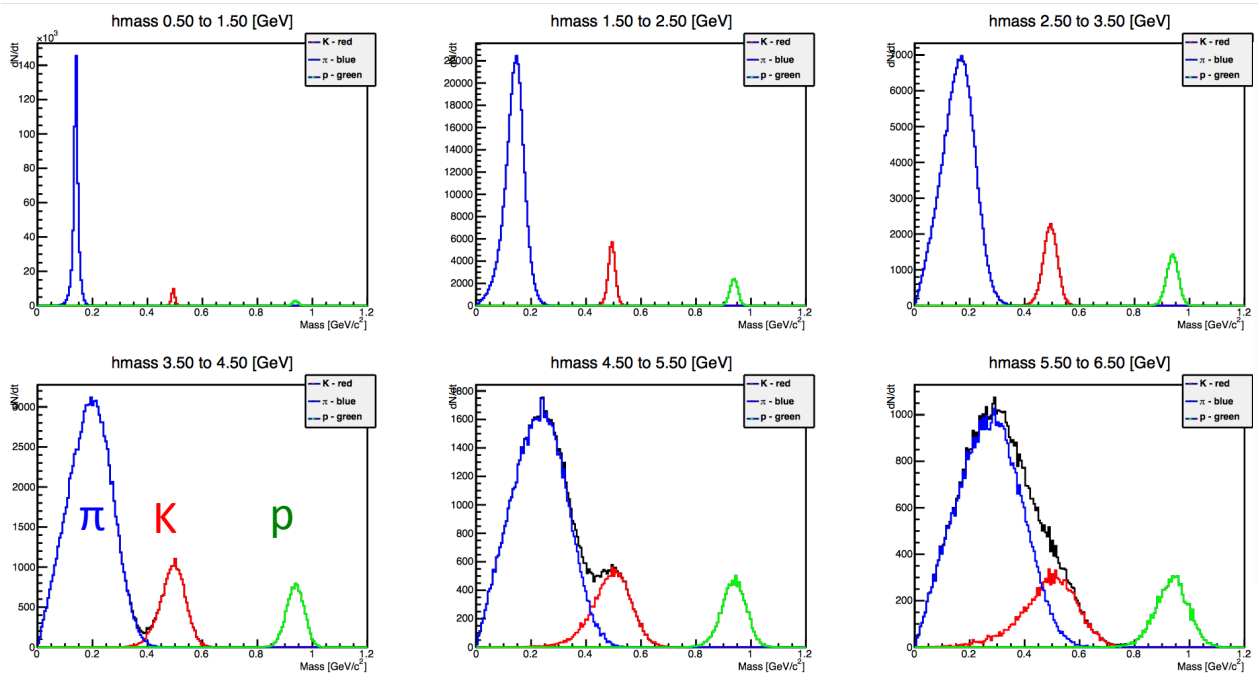
Use different material than glass?

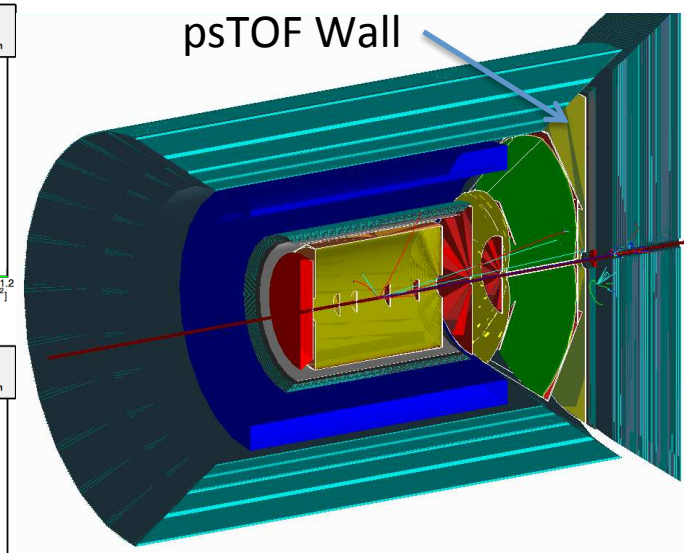




- One way to improve fast signal is to bring signal closer to pickup strips
- Thinner glass gets very expensive (and starts to become flexible)
- Somewhat fortuitously, Kapton and glass have similar volume resistivities, 10^{12} Ω-cm (Mylar is 10^{19} Ω-cm)
  - Rate capabilities should be similar?
  - How about surface resistivity
  - Will measure both (at UIUC or BNL)

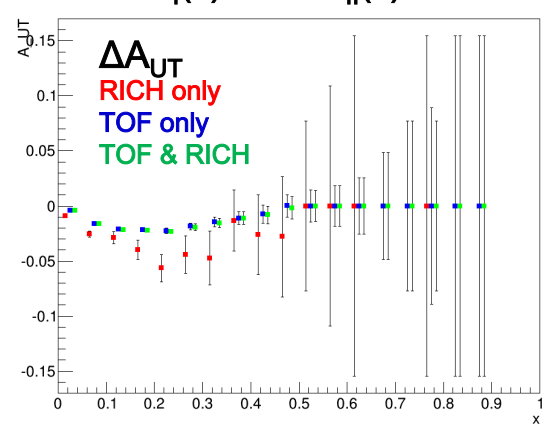
ePHENIX Simulation





- Yakov Kulinich (UIUC) has started MC studies with TOF wall implemented by Jin Huang in ePHENIX GEANT4 based MC
- Yakov and Chong Han (UIUC) will look into realistic simulations of the TOF performance requirements for various physics observables
- Initially looking into mass resolution, and will soon investigate granularity needed.

Difference ΔA_{UT} in A_{UT} for $\delta s_l(x)$ and $\delta s_{ll}(x)$



psTOF greatly increases statistical significance?

Future Timeline

- Build v1 prototype and study with cosmic rays at UIUC (Ihnjea)
  - Vary glass thicknesses, gap widths, number of gaps, etc.
- Set up silicon tracking for test stands (BNL)
- Design and fab TI based preamp boards (BNL)
- Complete mRPC simulations and compare to real data (BNL, UIUC, Howard)
  - Use simulations to guide R&D effort (Howard)
- Build and test alternative mRPC with kapton dielectric
- Test beam in the fall at FNAL?
- Study in ePHENIX MC the sensitivities to quark transversity distributions using psTOF for PID, including full detector response (UIUC)
- Expect to come back in July with results from above, and a proposal that is combined with RD11 into PID collaboration
  - Weekly meetings in specialty groups (TOF, RICH), and Monthly collaboration-wide meetings with updates and discussions
  - Merging of MCP-PMT effort, some photocathode work
  - Matthias Perdekamp as co-principal investigator

Backup

Sensitivity of 10ps TOF for Possible Strange Quark Transversity Contribution to A_{UT}

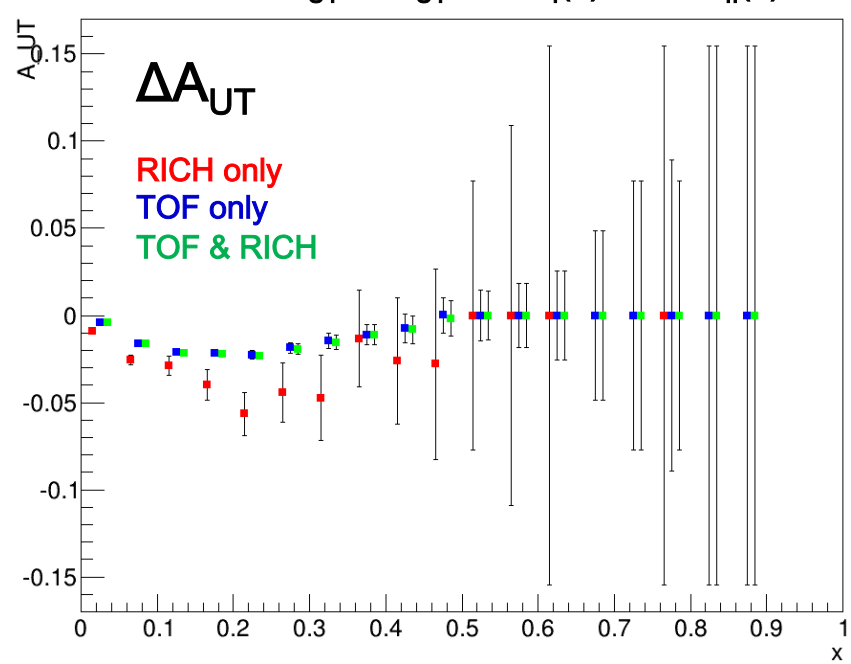
A_{UT}, Collins asymmetry
~ $\delta q(x) \times H^{\perp}_{1q}(z)$
~ transversity x Collins Fragmentation

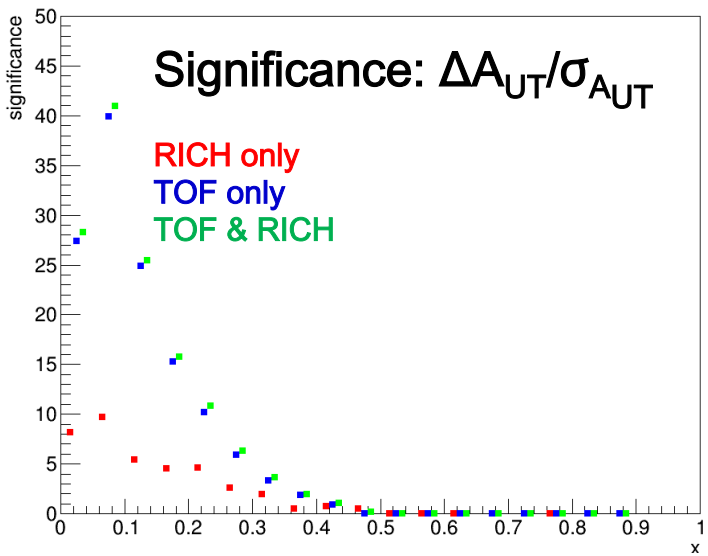
$\delta q(x)$ & $H^{\perp}_{1q}(z)$, Anselmino et al. Phys.Rev. D87 (2013) 094019

Compare two scenarios:

$\delta s_I(x) = 0$ vs $\delta s_{II}(x) = 1/2\ \delta d(x)$

Difference ΔA_{UT} in A_{UT} for $\delta s_I(x)$ and $\delta s_{II}(x)$





psTOF greatly increases statistical significance

➔added sensitivity for $\delta s(x)$ and increased sensitivity to measure p_T dependence.

Detailed GEANT based simulations will be carried out using the new Campus Cluster at UIUC or Blue Waters at NCSA.