SiD Muon System

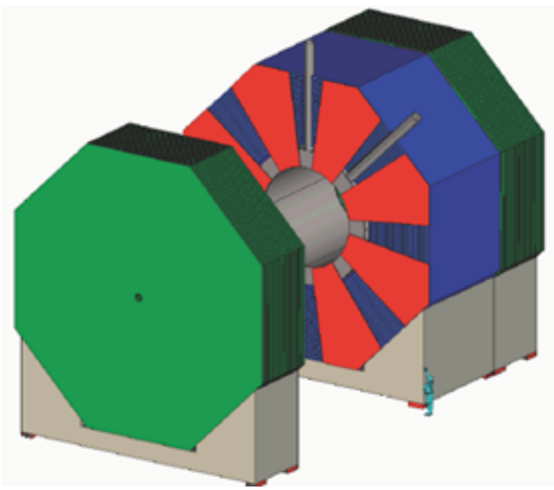
Henry Band
U. Of Wisconsin
H.E. Fisk
Fermilab

Outline

- Benchmarks
- Performance studies
- Engineering design
- Technology options
  - Scintillator
  - RPC
- Schedule
  - Technology choices
  - LOI – Oct. 08
  - EDR – fall 10
- Open projects – All of the above!

SiD Muon DOD

- SiD
  - 2.3 m flux return ~14 λ + 6 λ(Cal+Sol.)
  - 15 layers
  - Tail-catcher ?



- Barrel
  - Size ~2.9X5.9 - 5.6X5.9 m
  - Area (15 layers) 2700 m^2
- Endcaps
  - area of 3400 m^2
- Weight ~ 6-8000 metric tons
- RPCs - 2600 chambers @ 2-3 m^2, 350k channels
- Scintillator strips - 50-100 k channels

Benchmarking processes - Muon

reduced list from Snowmass 2005 report hep-ex/0603010

- *Muons*
  - *efficiency vs purity* *(hadronic misidentification rates)*

0. Single $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, π^{0}, $K^{\pm}$, K^{0}_{S}, γ, $0 < |\cos\theta| < 1$, $0 < p < 500$ GeV

μ

1. $e^{+}e^{-} \rightarrow f\bar{f}$, $f = e, \tau, u, s, c, b$ at $\sqrt{s}$=0.091, 0.35, 0.5 and 1.0 TeV;
2. $e^{+}e^{-} \rightarrow Z^{0}h^{0} \rightarrow \ell^{+}\ell^{-}X$, $M_{h} = 120$ GeV at $\sqrt{s}$=0.35 TeV;
3. $e^{+}e^{-} \rightarrow Z^{0}h^{0}$, $h^{0} \rightarrow c\bar{c}, \tau^{+}\tau^{-}, WW^{*}$, $M_{h} = 120$ GeV at $\sqrt{s}$=0.35 TeV;

   $\rightarrow \mu^{+}\mu^{-}$

6. $e^{+}e^{-} \rightarrow \tilde{\tau}_{1}^{+}\tilde{\tau}_{1}^{-}$, at Point 3 at $\sqrt{s}$=0.5 TeV;

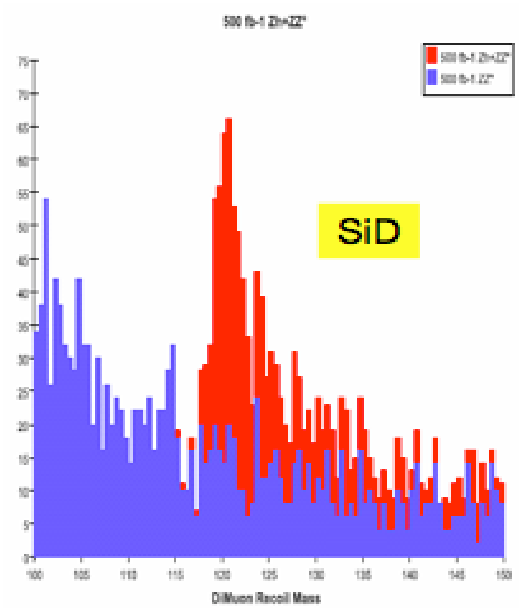
   $\rightarrow \tilde{\mu}^{+}\tilde{\mu}^{-}$

- *No serious study of how good the muon ID should be*
  - *Keep efficiency high (obvious)*
  - *Acceptable hadronic fake rate ?*
- *Need simple fast MC analyses utilizing Tim's data set of SM processes and ZH signals*

2. $e^+e^- \to Z^0h^0 \to \ell^+\ell^- X$, $M_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;

- *Most (all?) fast MC analysis assume 100% muon eff. & 0% pion fake rate*

$e^+e^- \to ZH \to \mu\mu X$

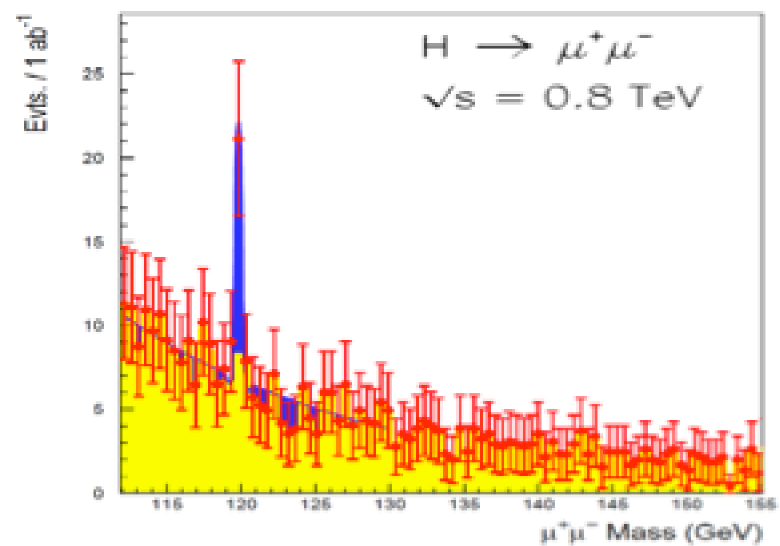


Measuring $H \to \mu\mu$

$\sqrt{s} = 1\ TeV$

$L = 1000\ fb^{-1}$

A fourfold improvement in resolution ($a = 8 \to 2$) is worth a factor 1.9 in $\mathcal{L}$

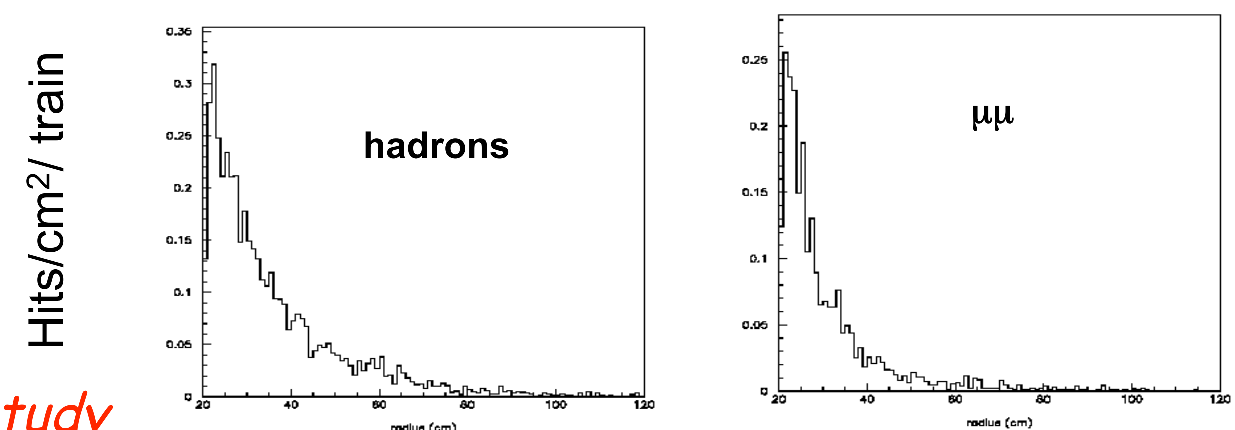


Design

- *What's needed to achieve a specific hadronic mis-id level ?*
- *Study by C. Milstene (2006) showed that an external muon system would increase the purity of a muon sample in 500 GeV bb jets from 69% to 94%.*
- *Design parameters*
  - *Number of layers*
  - *Segmentation/resolution*
  - *Steel thickness (flux return)*
  - *Cost*
  - *Expect modest requirements - (10 double layers, 3-4 cm?) but need to justify*

Design (2)

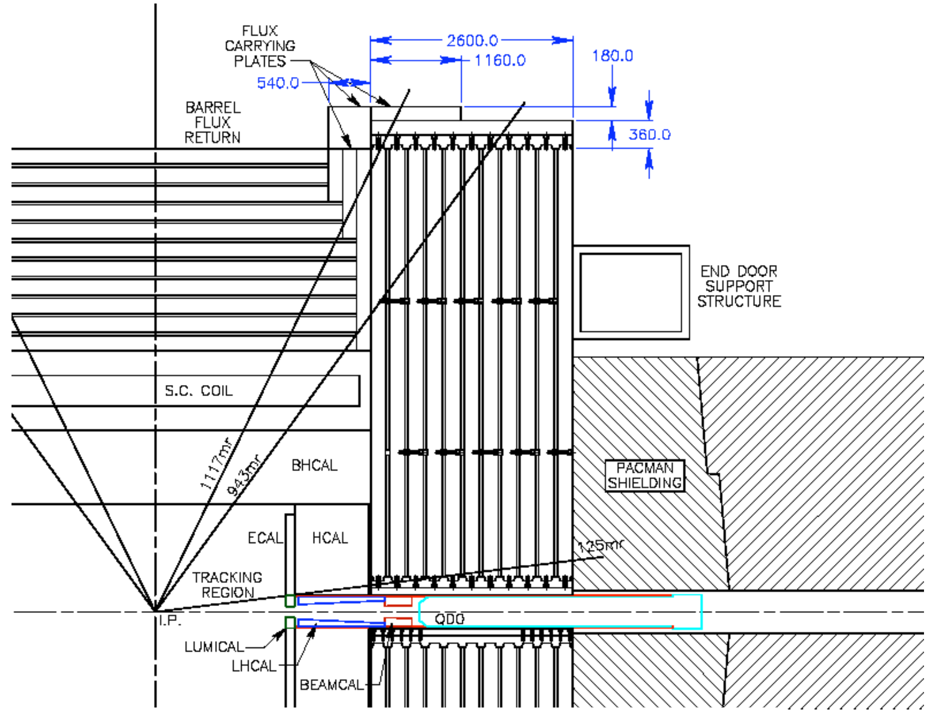
- *Design inputs*
  - *Multiple scattering in coil sets min. resolution (~1 cm @ 4 GeV/c)*
  - *Steel thickness -set by flux return requirements*
  - *Rate capability set by machine backgrounds*
    - *0.01 hit/cm² per train (change from ~2 10^{-4}) N. Mokhov*
    - *0.4 hits/cm² per train in the endcaps T. Maruyama*
      $\gamma\gamma \rightarrow$ hadrons: 0.65 events/bx, $\gamma\gamma \rightarrow$ muons: 1.3 events/bx

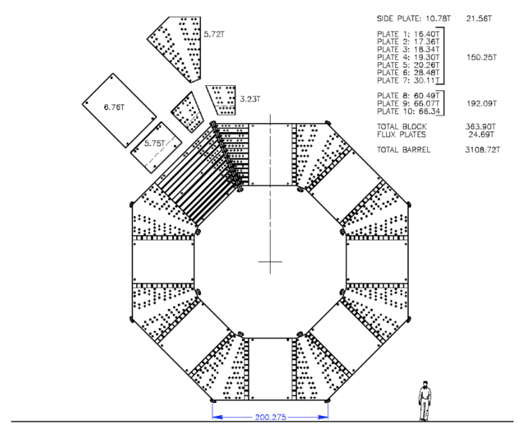


  - *Study*
    - *Efficiency and hadronic mis-id vs momentum while varying #layers, resolution*

Engineering Design

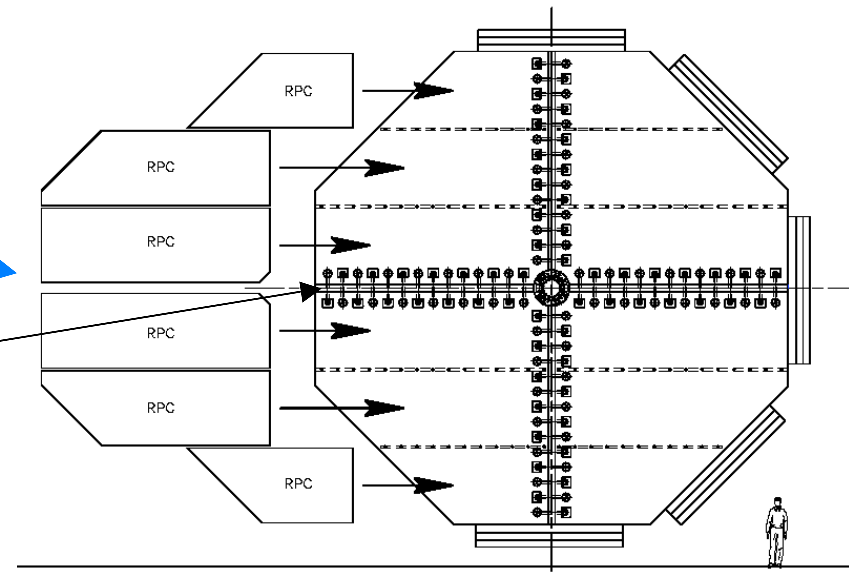
- Jim Krebs has started on steel flux return design
- Goals - minimize
  - weight & cost
  - Flux leakage
  - # of layers
- Goals – Mechanically rigid (< 0.5 cm movement)
- Goals – Ease of assembly (sub component weight)
- Goals – Good Muon id

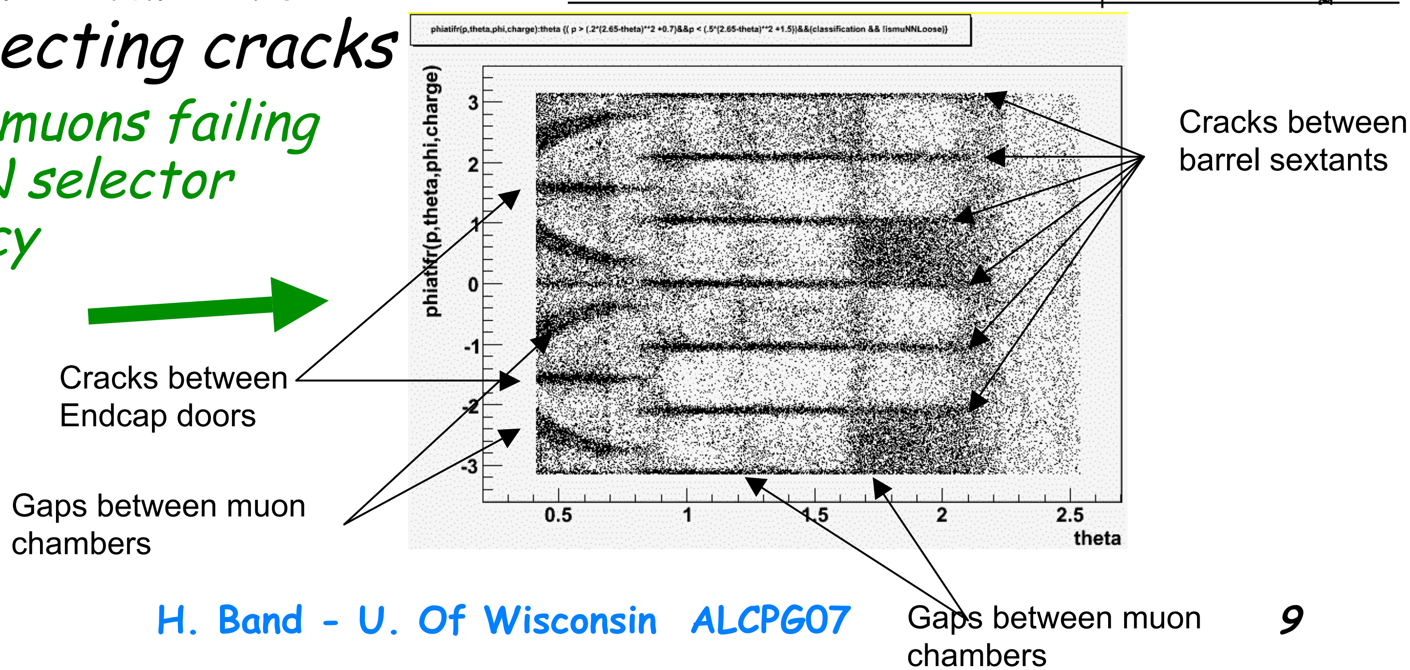




Engineering Design(2)

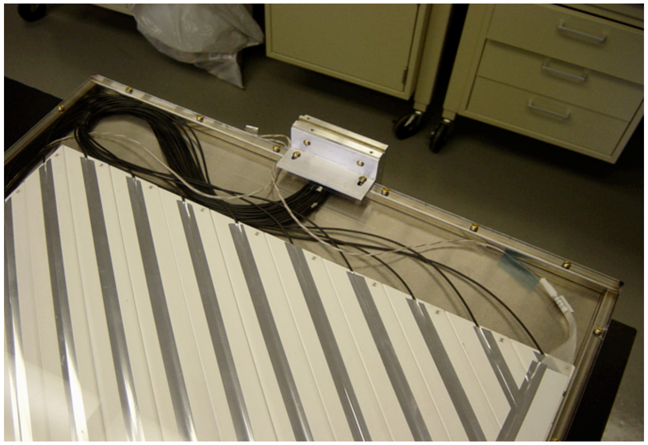
- Main concern – flux leakage
- Muon Chamber installation (RPC) in endcap
- Dead spaces not optimal
  - 28 cm of steel between quadrants
- Should work hard to avoid projecting cracks
  - BaBaR – muons failing loose NN selector efficiency

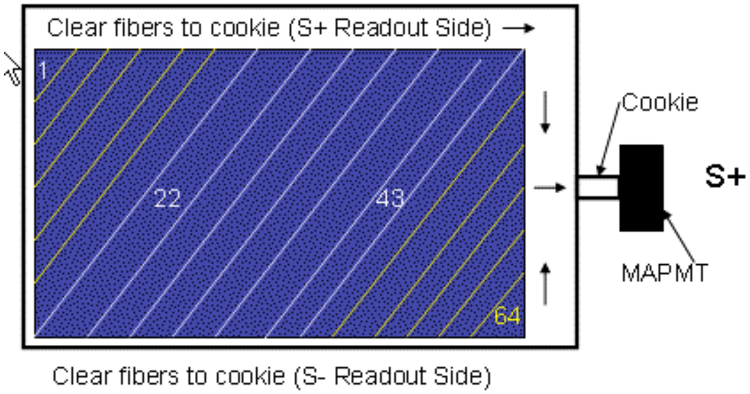




Technology - Scintillator

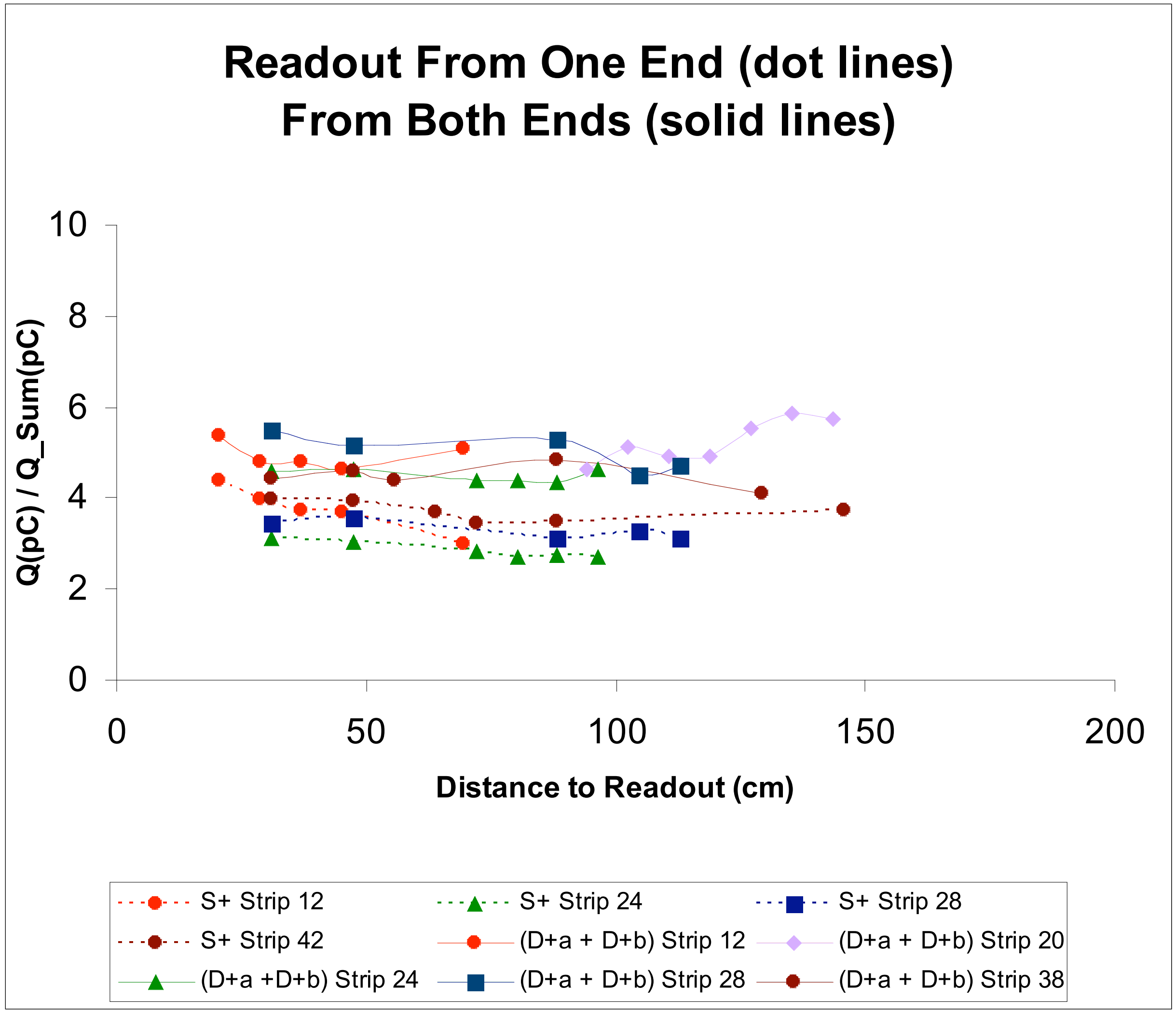
- *MINOS style extruded Scintillator strip*
- *4.1 cm wide by 1 cm thick*
- *±45° to keep lengths short*
- *Light collected by wavelength shifting fiber*
- *Coupled to clear fiber on one end*
- *Readout by MultipleAnode PhotoMultipliers (64 channels) mounted outside gap or SiPM inside gap*
- *Four (1.25m X 2.5m) prototype modules with 64 strips built in 05*
- *Test beam data in 06 & 07 reported in detail in Monday's session*





Single vs. Double Ended Readout

Beam test data



Scintillator Plans

- *Focus on SiPM readout of muon scintillator strips*
  - *Eliminates clear fibers*
  - *Compact geometry*

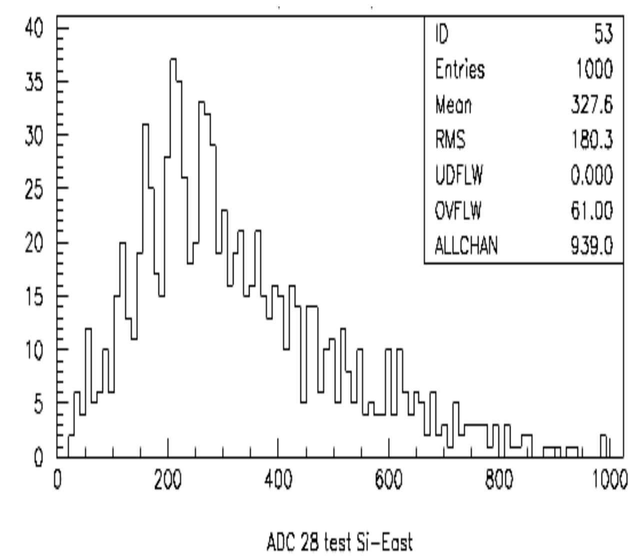
G. Pauletta

$$N_{p.e.} \approx 6.5\,p.e.$$

$$\varepsilon = 99\%$$

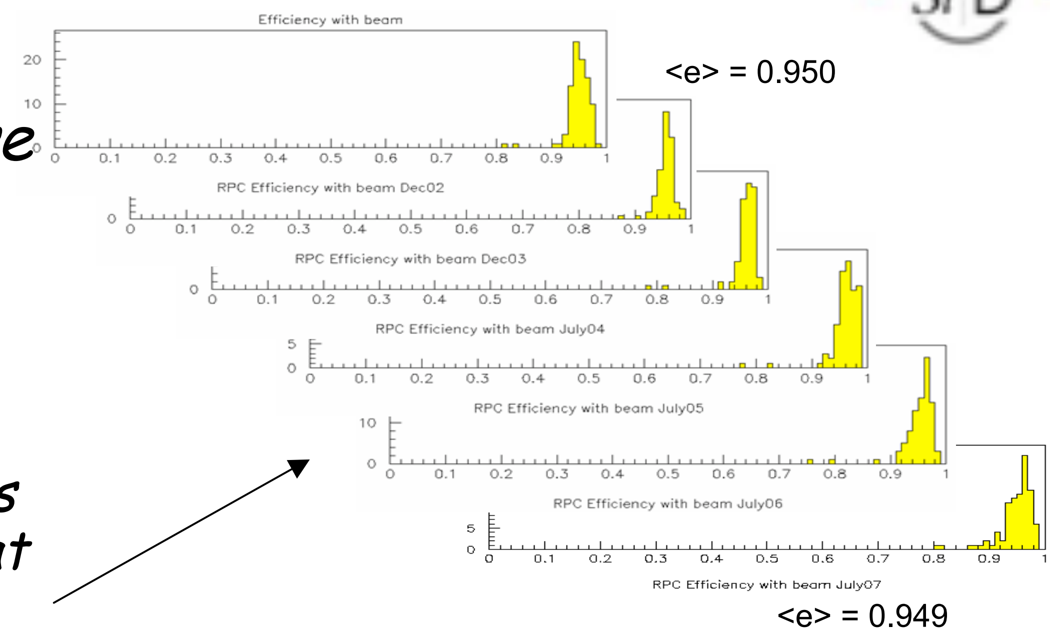
$$N_{d.c.} \approx 1.5\,MHz$$

$$G \approx 1.6 \times 10^{6}$$



Technology - RPCs

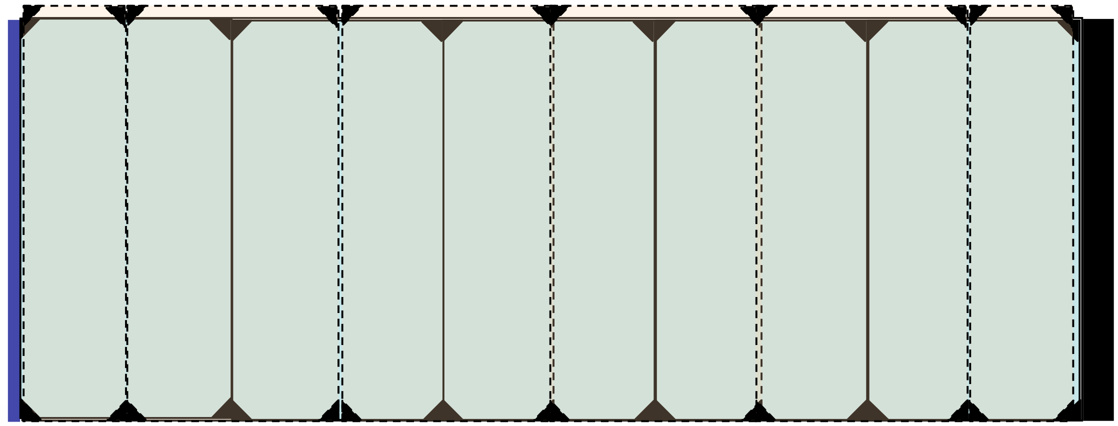
- Despite Babar experience RPCs are good match to ILC environment
  - Cost advantage
  - Flexible shapes
  - 2nd generation RPCs have been reliable at low rates
  - Will be tested in many new applications
- Avalanche mode
  - 3 styles
    - Italian Bakelite - linseed oil(Atlas, CMS) avalanche

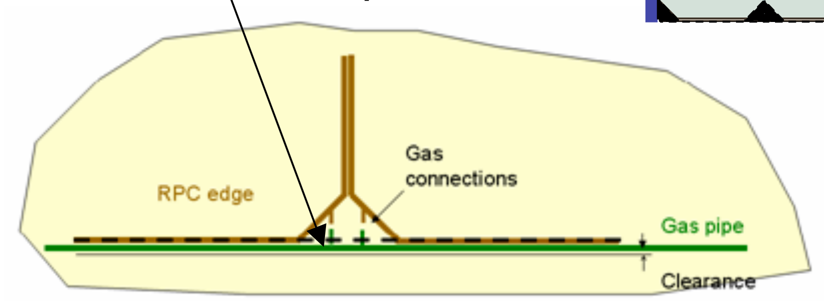


- IHEP Bakelite (streamer) (BESIII, Daya Bay
- Glass - Argonne

Effective Efficiency - RPCs

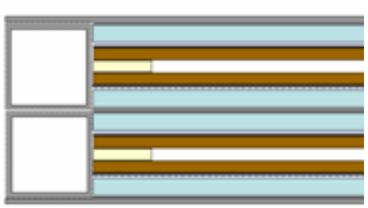
Stagger 2nd layer chambers so internal joints and buttons do not overlap



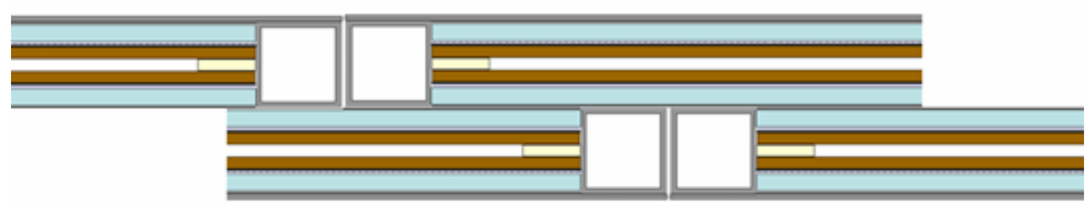


@ 90% efficiency the average single gap layer eff. is 80.2% , double gap 93.0%

Outside edge

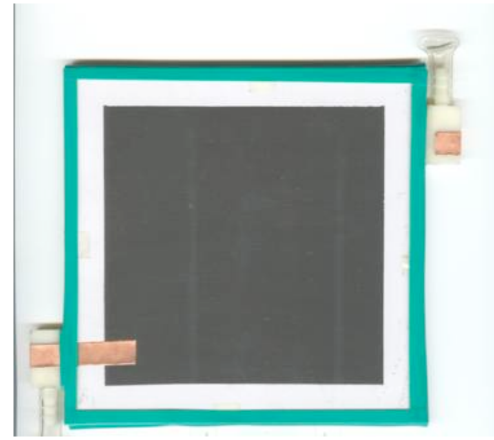


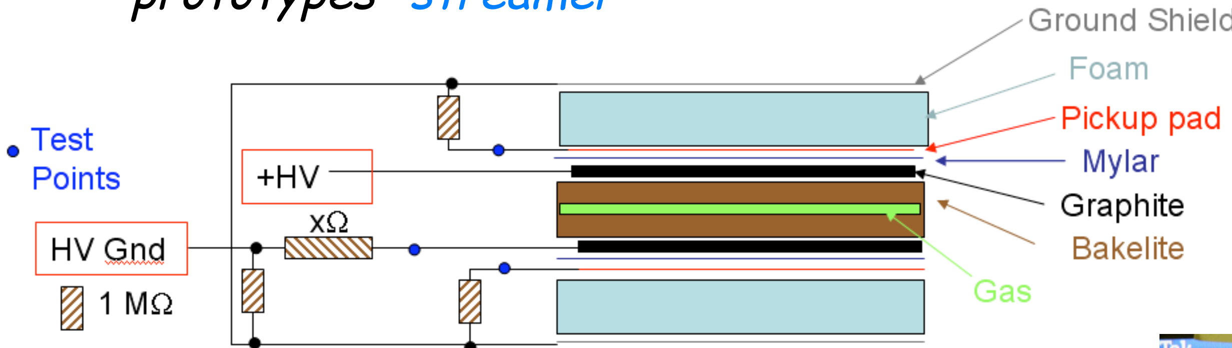
Mid-layer Overlap



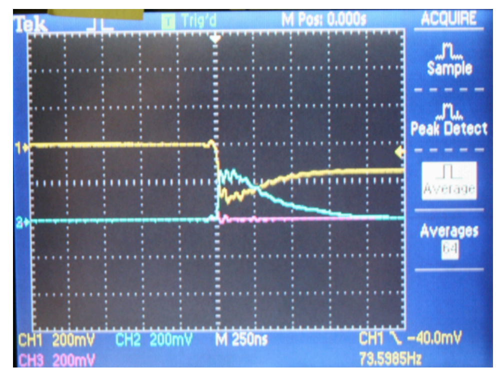
IHEP RPC & KPIX Studies

- *Cosmic test stand built with BaBar spares and gas*
- *Initial tests of small 15 *15 cm IHEP prototypes -streamer*





- *KPIX is DC coupled ~2 μsec integration time*
- *RPC strips(pads) are AC coupled and see fast signals ~300 nsec decay time depending on termination of pad and HV ground*
  - *Revise KPIX*
  - *Directly connect to Bakelite ground plane*



RPC Plans

- Obtain larger IHEP RPCs
- Design and build KPIX(64 ch) interface board
  - Test on spare BaBar and New IHEP RPCs
- More F- sensitivity tests
  - Last year of BaBar running is good source of F- (and any other pollutants)
  - Test IHEP RPCs
- Cosmic ray tests (08)
- Need beam tests (09-10), Fermilab test beams have capability for ILC like time structure

SiD Muon Technology Choice

- New baseline
  - 10 layers
  - Double layer
  - 3-5 cm segmentation
- Criteria
  - Rate capability
  - Reliability
  - Required services
  - Ease of installation
  - Cost
- Cost Estimate
  - "Now"
  - Potential future savings
  - 10 year operating costs

Summary

- *Muon System studies are severely manpower limited*
- *New people can make major contributions*
- *NEED*
  - *Fast MC study of the effect of hadronic mis-id rates in the benchmark processes*
  - *Optimization of the number of layers and segmentation*
- *Well defined, short term projects for those wishing to learn LC -SIMulation packages*
- *Contact*
  - *Gene – hefisk@fnal.gov*
  - *Henry - hrb@slac.stanford.edu*