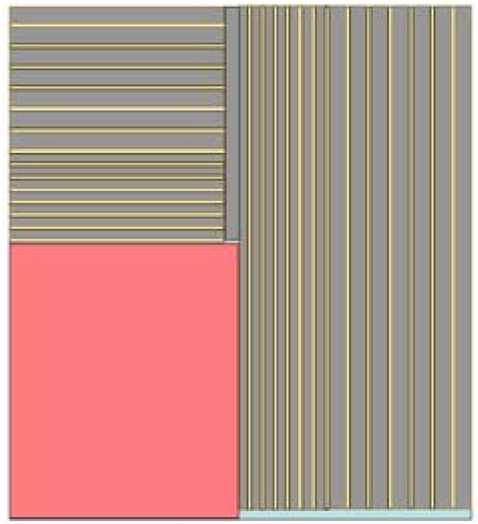


SiD Muon System

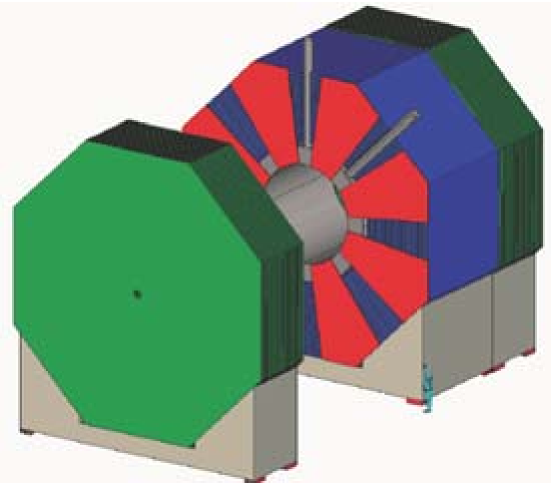
H. R. Band
University of Wisconsin
H. E. Fisk
Fermilab

Outline

- Muon DOD
- Common issues
  - Design
  - # Layers
  - Resolution
  - Simulation
- RPC specifics
  - Design
  - Cost
  - R&D
- Scintillator specifics
  - R&D Test Beam
  - Cost

SiD Muon DOD

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

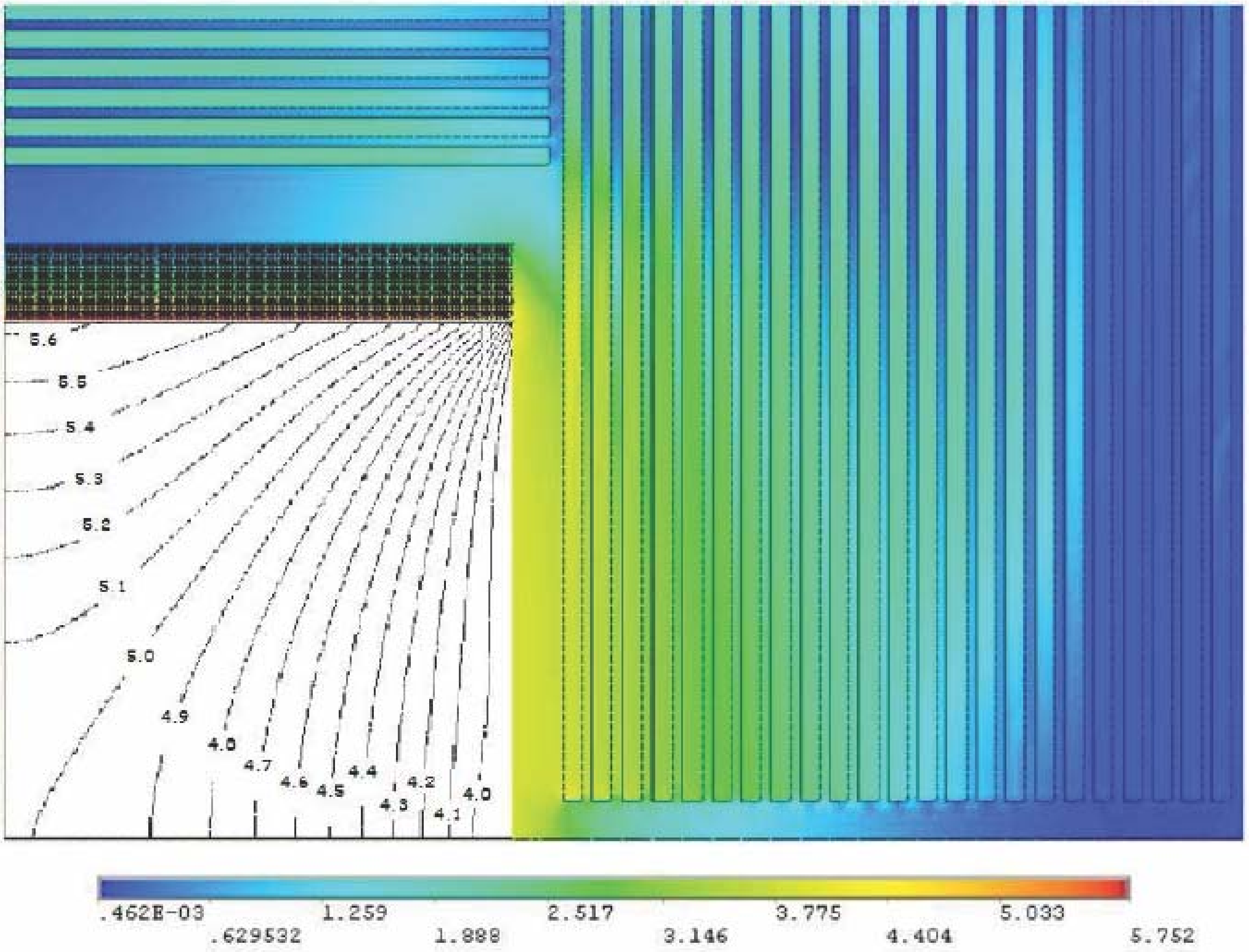


- Modest detector requirements
  - Muon bkgds with spoilers 1.2 10^{-3} Hz/cm^2 (Mokhov)
  - ~1 cm resolution
- Many technology choices
  - RPCs – 3 cm x/y strips –or–
  - Scintillators 4.1 cm x or y planes

Calculated Fields

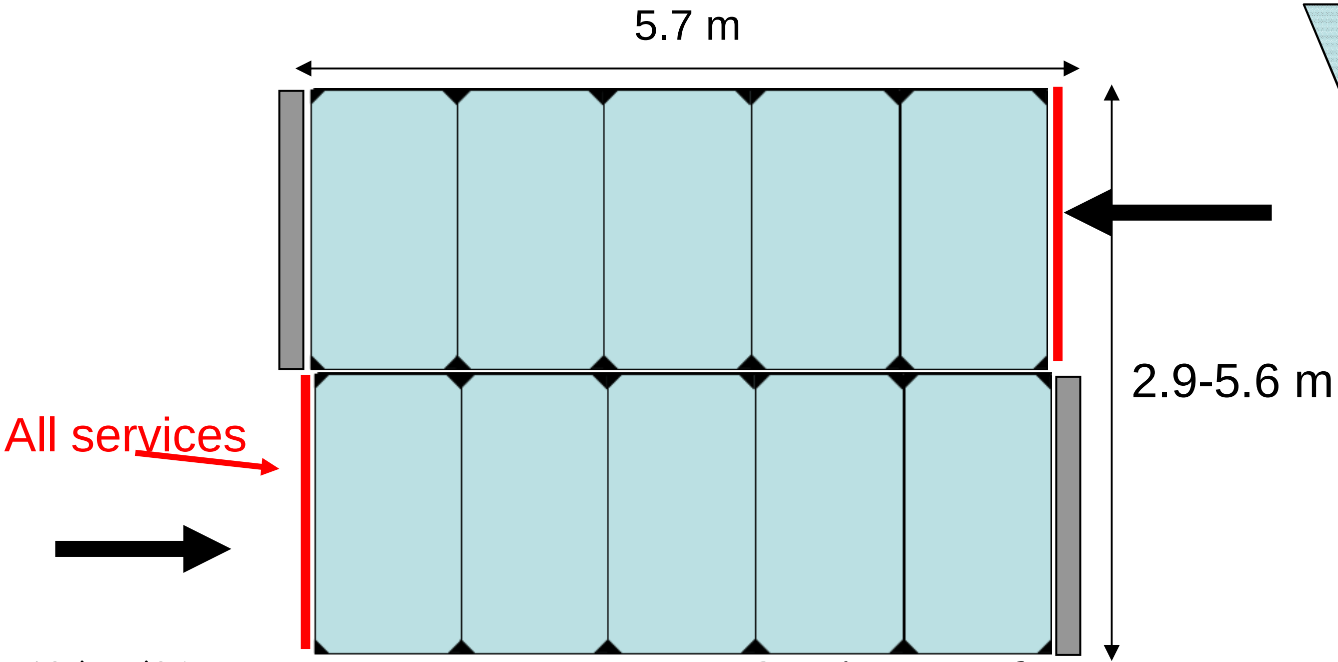
Modeled as 23 10 cm layers

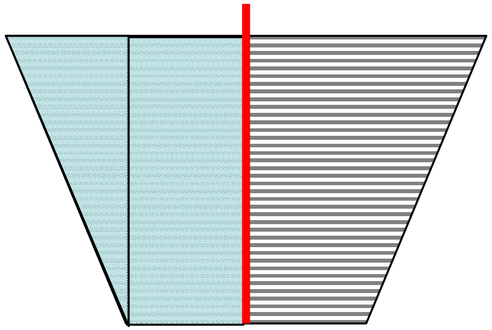
Assume that flux return needs will determine the total steel thickness needed



Barrel Layout

- *Assume Octant geometry*
  - *½ width covered by staggered gusset plates on each end*
  - *2 ½ width chambers inserted from opposite ends*
- *# of layers and gap thickness drive outside radius and amount of steel needed*

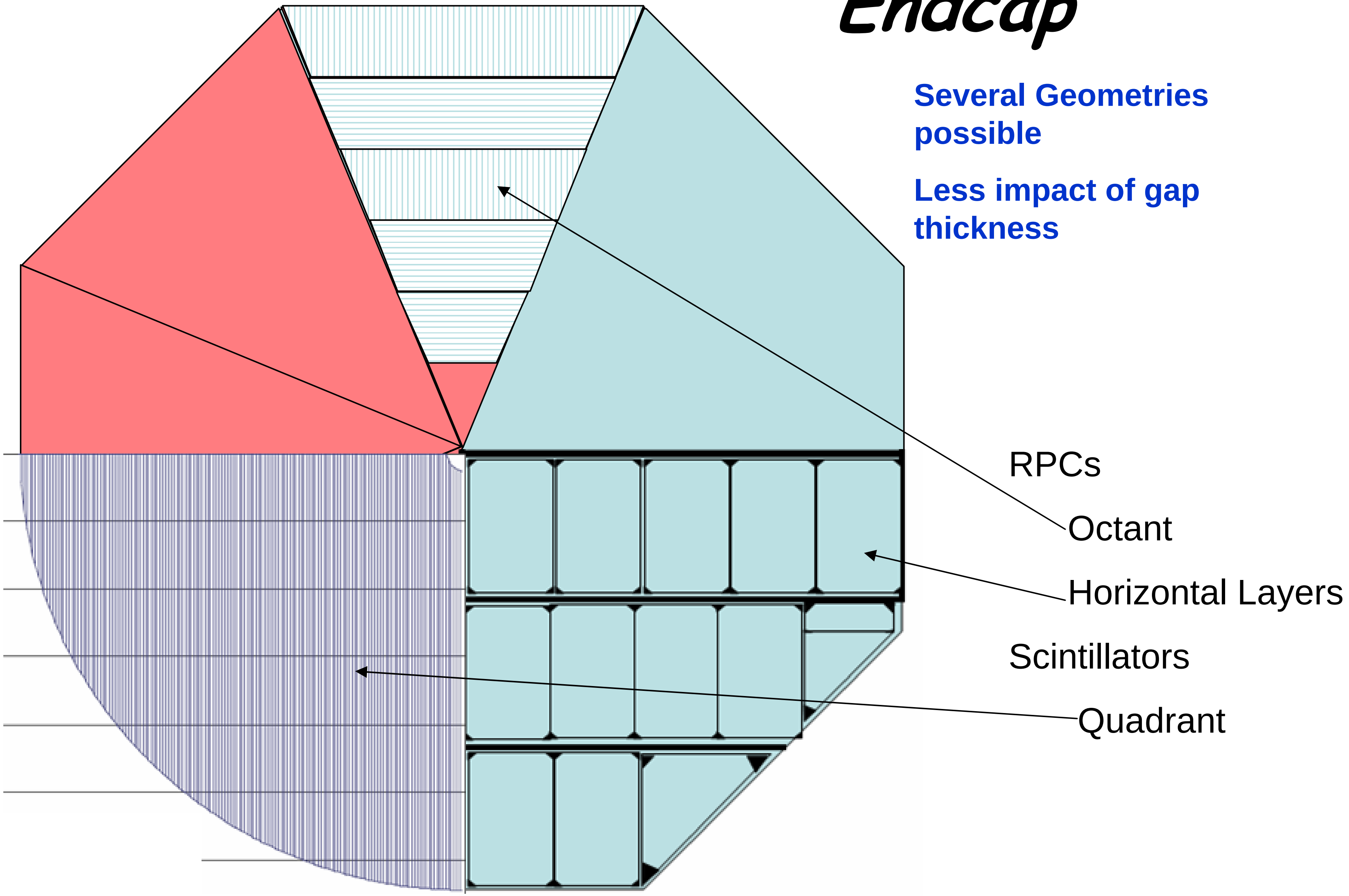




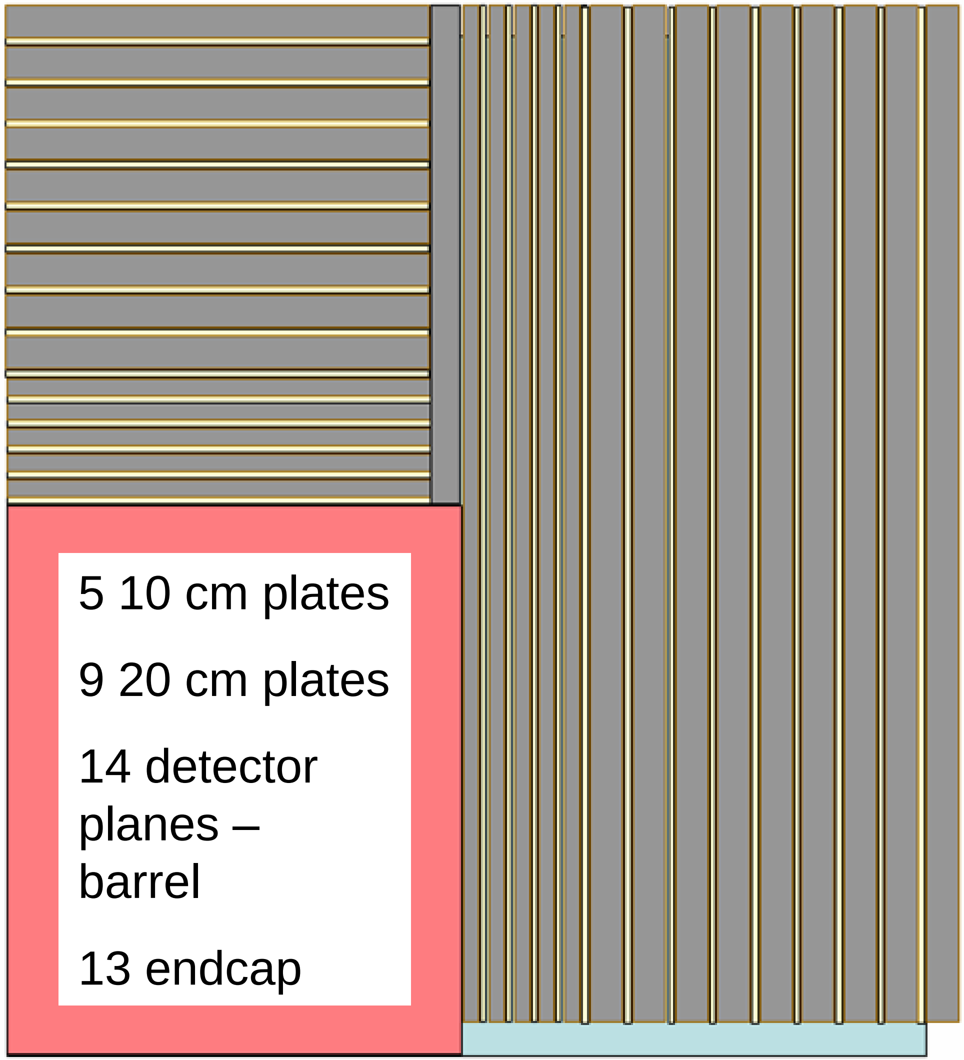
Endcap

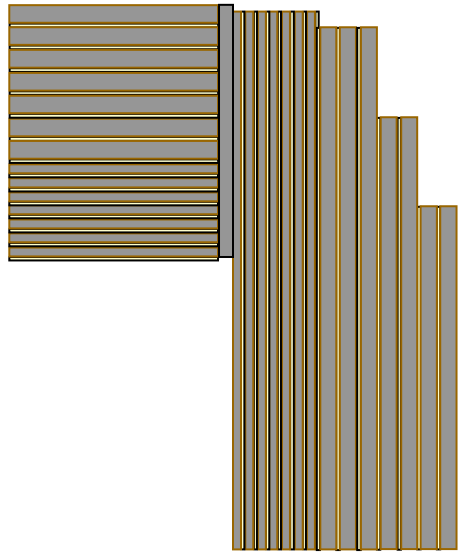
Several Geometries possible

Less impact of gap thickness



A Reference Design





Designs with Tapered Endcap steel save 10-20% of weight

Incremental Costs

- **Assuming 2.3 m of steel needed**
  - study weight + cost versus gap size & # layers

23 gaps

Gap cm	0	3	4	5		3	4
R_out m	5.63	6.32	6.55	6.78	14 gaps	6.05	6.19
Barrel Metric tons	3011	3253	3334	3414		3182	3239
Endcap Metric tons	3776	4758	5111	5476		4360	4564
Total Metric tons	6787	8011	8445	8890		7542	7833

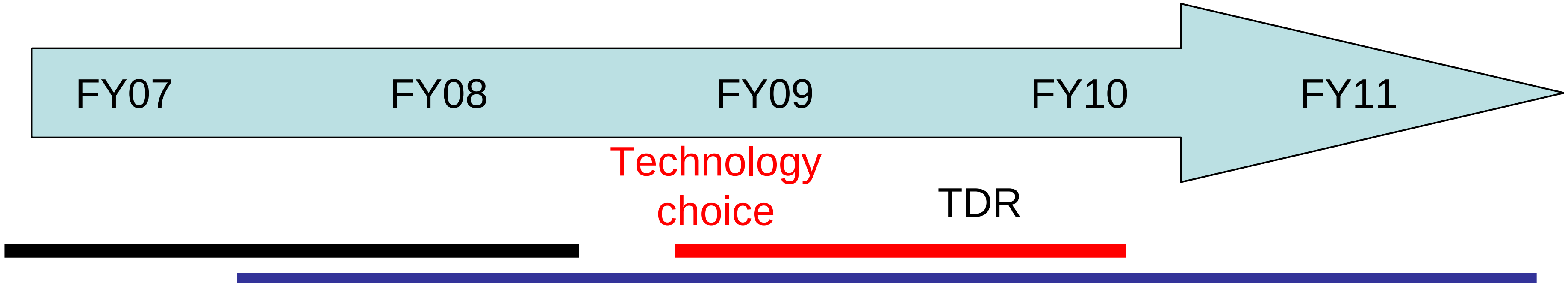
27.5 M$

@ 3.5$/kg

5.4% / cm

0.927 ~.87% /layer

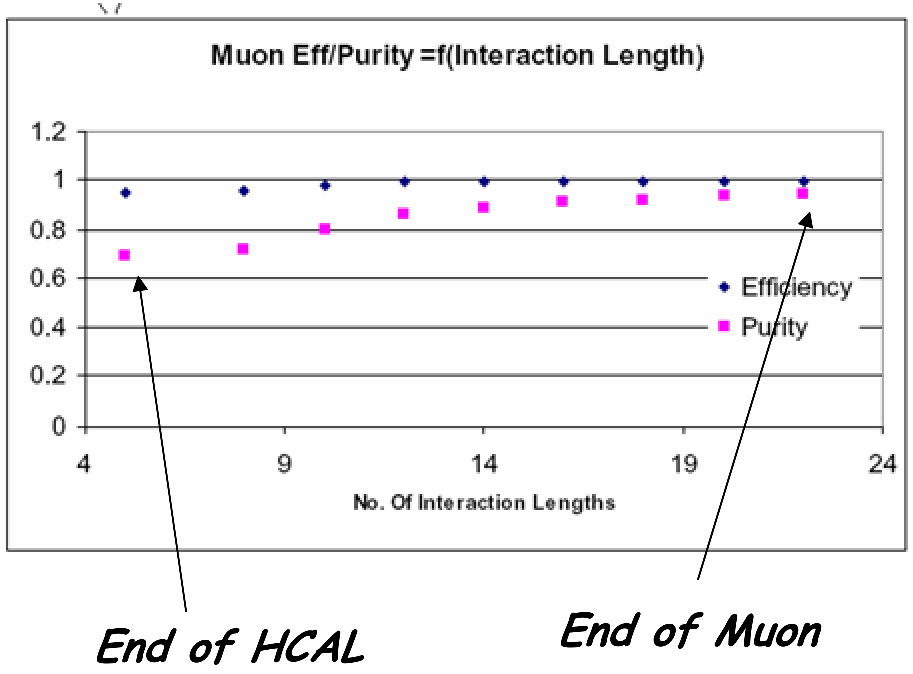
R&D - Simulation



- ***Generic Detector studies -***
  - *# layers?*
  - *Position resolution needed to match HCAL tracks?*
  - *Tail-catcher to aid HCAL?*
- ***Specific technology designs***
  - *Steel geometry*
  - *Maximize coverage*
- ***Muon particle ID in Hcal/muon***

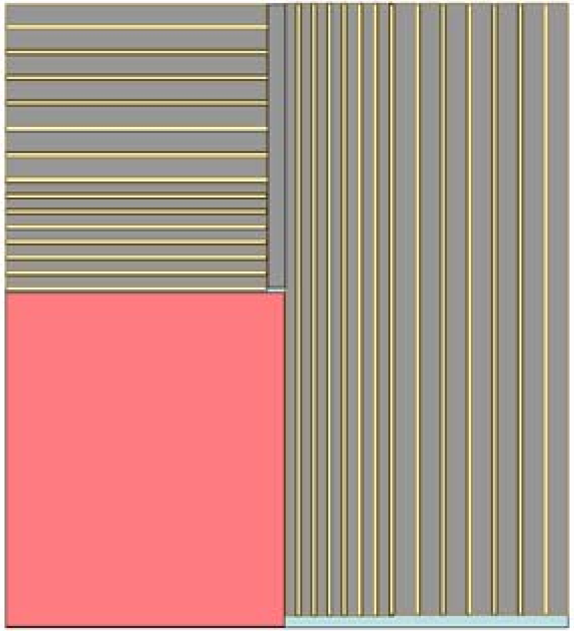
Simulation Studies

- Hadron rejection vs λ- C. Milstene
- bb jets at 500 GeV/c in barrel
- Only 3% of tracks > 3 GeV/c are muons
- Above study used a det. layer every 10 cm
- Extend study for coarser segmentation



Purity of "muon" sample improves from 69% to 94% for tracks traversing entire muon system

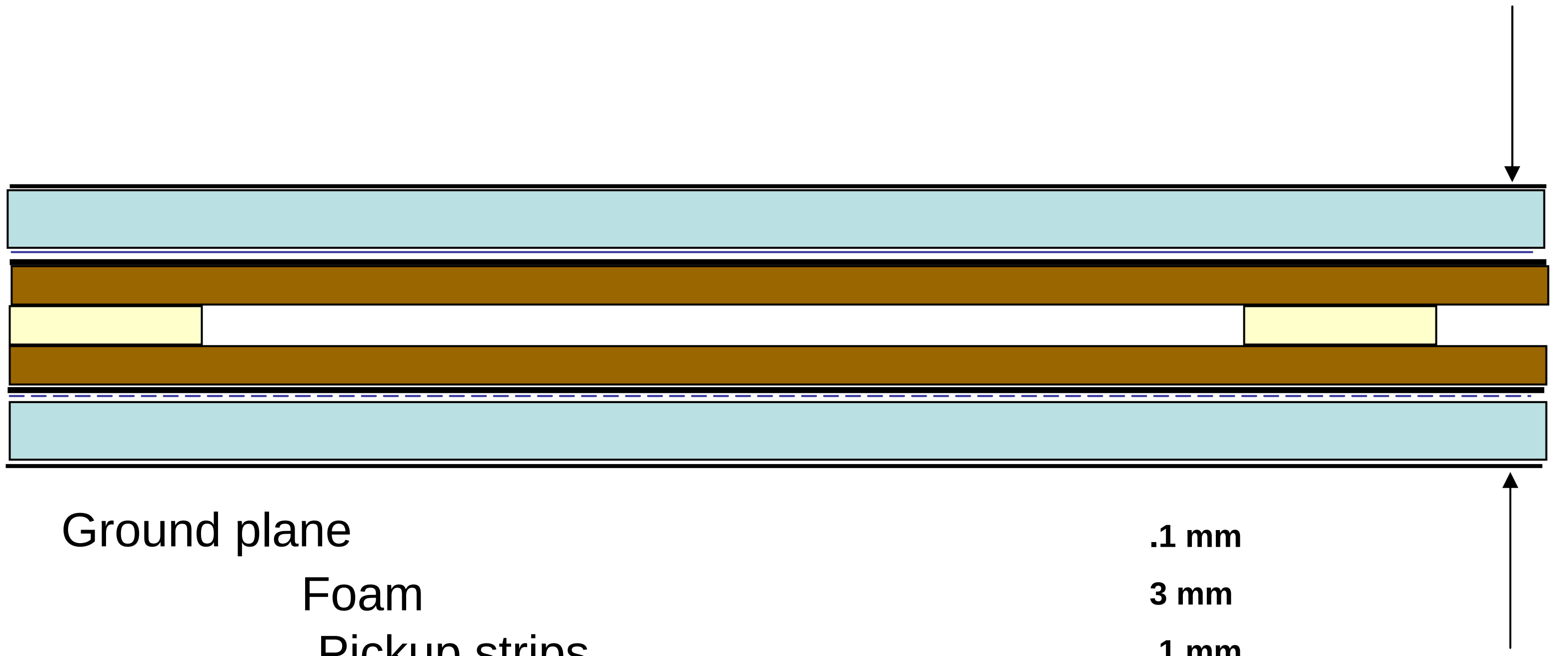
SiD - RPC Design



- Barrel
  - Size ~2.9X5.9 - 5.6X5.9 m
  - With (14 layers) 10 RPCs per layer per octant for a total of 1120 RPCs in the barrel with area of ~ 2500 m^2.
- Endcaps
  - 54 RPCs in 13 layers per endcap would have 1736 RPCs with a area of 3300 m^2.
- 5800 m^2 (13-14 layers) - 2500 chambers @ 2-3 m^2
- 350,000 channels
- 10^4 Digitizing chips (KPIX?)

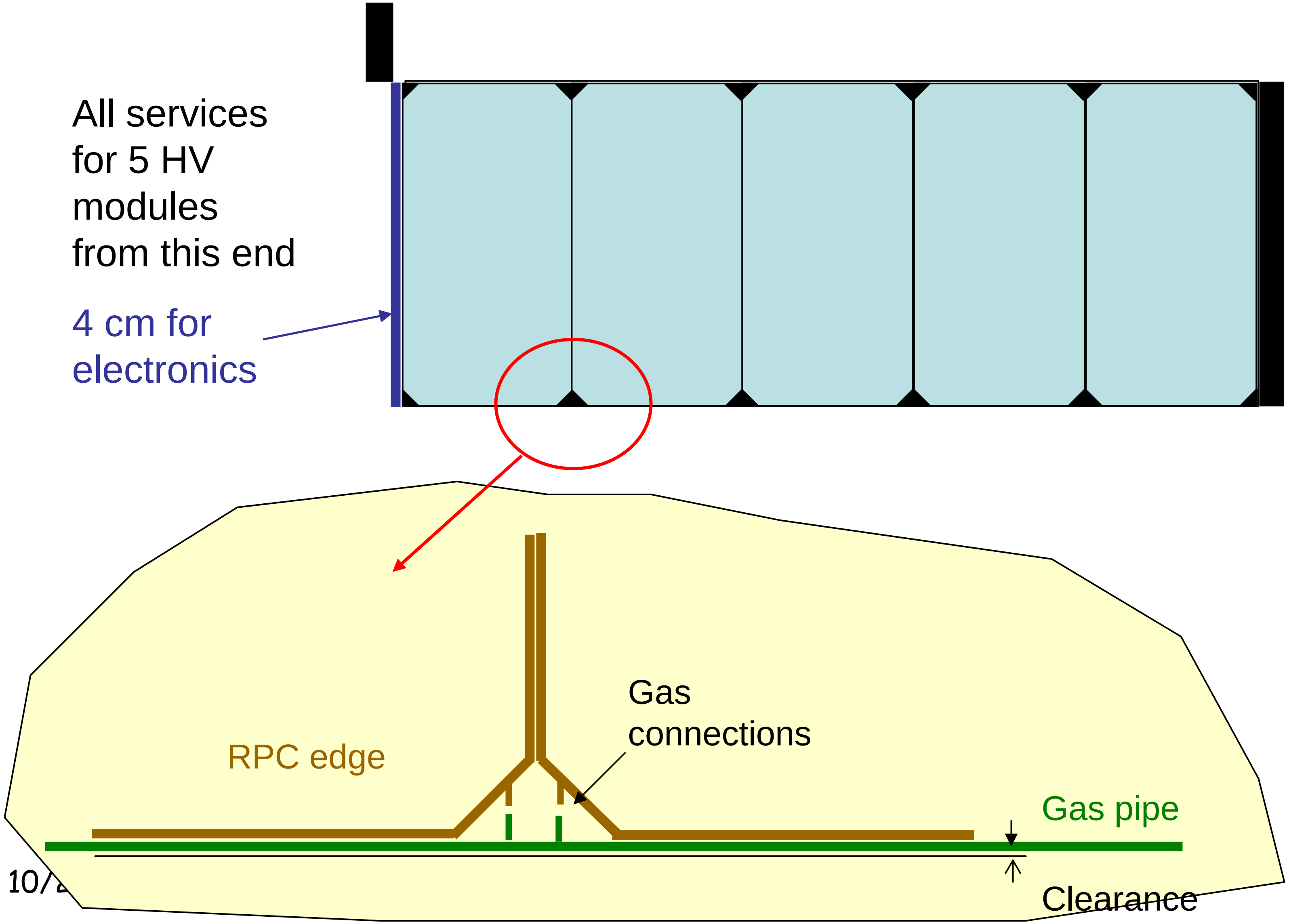
- RPCs
  - 3 cm pitch ~ 1cm resolution
  - XY readout
  - Single or double gap?
  - Glass or Bakelite ?

RPC Profile



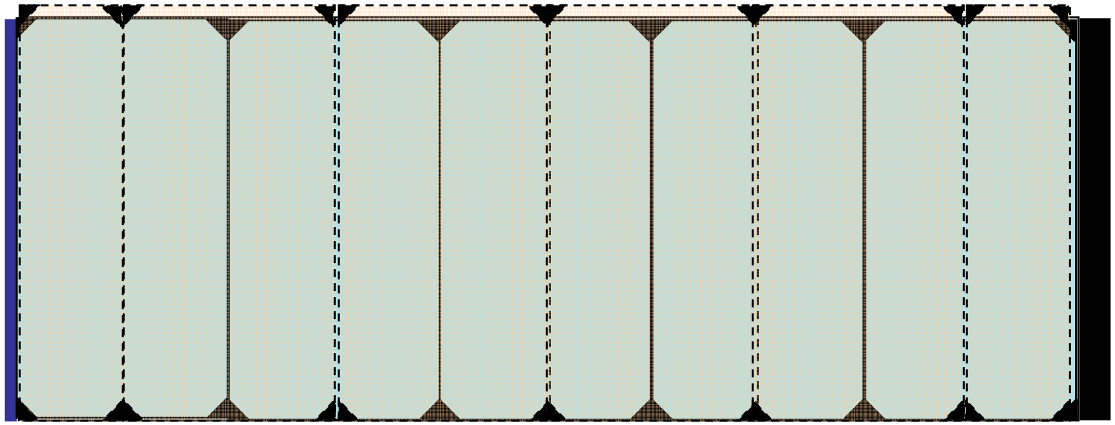
Ground plane	.1 mm
Foam	3 mm
Pickup strips	.1 mm
PET Film	.1 mm
Graphite	.1 mm
Bakelite	2 mm
RPC gas	2mm
	13 mm total

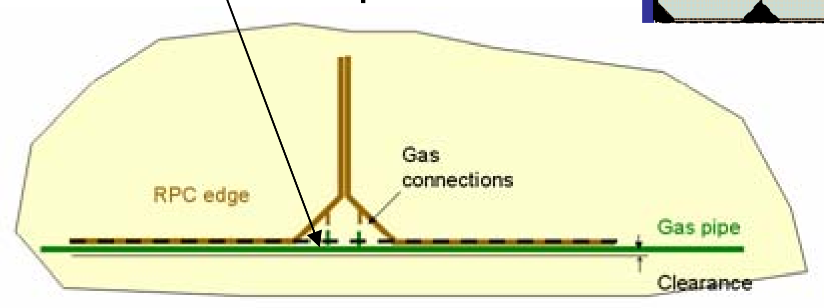
RPC Chamber = ½ of Octant Layer



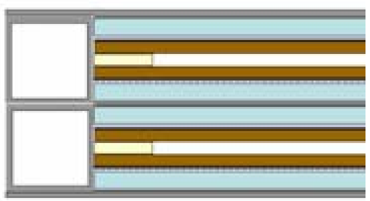
Double Gap

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

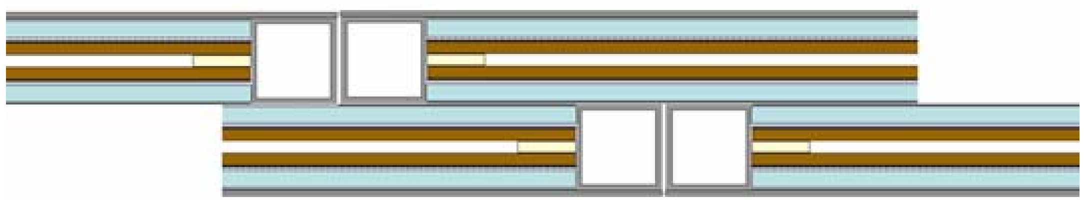




Outside edge



Mid-layer Overlap



Effective Efficiency - RPCs

- **Estimate insensitive area**

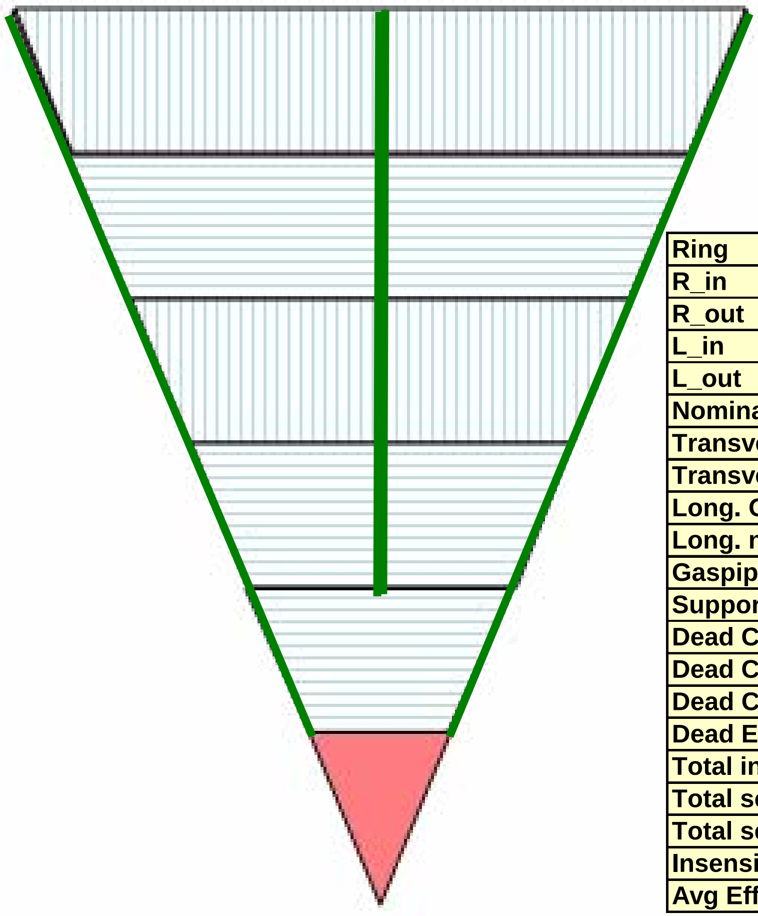
Edge_RPC	0.02	m
Clearance	0.01	m
Gaspipe	0.015	m
Electronics	0.1	m
Length	5.6	m
Corner	0.005	m^2
Efficiency	90	%

Single Gap

	Layer 1	8	8
R_avg	3.35	5.03	5.03
width	2.78	4.1671	4.167
Nominal area	15.542	23.335	23.335
Transverse overlapping	0.555	0.833	0.167
Transverse nonoverlapping	0	0	0.667
Long. Overlapping	0.448	0.448	0.224
Long. nonoverlapping	0	0	0.224
Gaspipe dead overlapping	0.336	0.336	0.168
Gaspipe dead nonoverlapping	0	0	0.168
Dead Corner overlapping	0.2	0.2	0.04
Dead Corner nonoverlapping	0	0	0.16
Dead Clearance	0.179	0.2126	0.213
Dead Electronics overlapping	0.335	0.503	0.503
Total insensitive area	2.053	2.533	1.314
Total sensitive area (2)	0.000	0.000	1.219
Total sensitive area (1)	13.488	20.802	20.802
Insensitive Fraction	0.152	0.122	0.056
Avg Efficiency	0.781	0.802	0.930

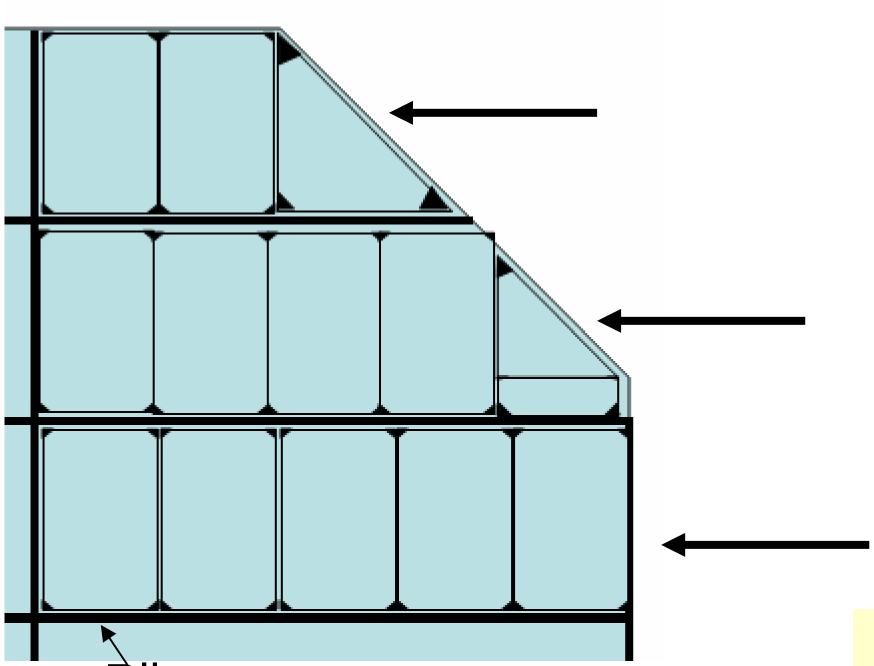
Double Gap - assume all internal joints are non-overlapping

Endcap Effective Area - Octant



Ring	1	2	3	4	5	total/laye
R_in	0.35	1.5	2.65	3.8	4.95	
R_out	1.5	2.65	3.8	4.95	6.1	
L_in	0.290	1.243	2.195	3.148	4.101	
L_out	1.243	2.195	3.148	4.101	5.053	
Nominal area	0.881	1.977	3.072	4.168	5.264	15.362
Transverse overlapping	0.050	0.096	0.096	0.096	0.096	0.433
Transverse nonoverlapping						0.000
Long. Overlapping	0.031	0.069	0.107	0.145	0.183	0.534
Long. nonoverlapping						0.000
Gaspipe dead overlapping	0.037	0.072	0.072	0.072	0.072	0.325
Support steel	0.037	0.072	0.072	0.072	0.072	0.325
Dead Corner overlapping	0.02	0.04	0.04	0.04	0.04	0.180
Dead Corner nonoverlapping						0.000
Dead Clearance	0.025	0.025	0.025	0.025	0.025	0.124
Dead Electronics overlapping					0.000	0.000
Total insensitive area	0.200	0.373	0.411	0.449	0.487	1.921
Total sensitive area (1)	0.681	1.604	2.661	3.719	4.776	13.441
Total sensitive area (2)						
Insensitive Fraction	0.227	0.189	0.134	0.108	0.093	0.125
Avg Efficiency	69.572	73.013	77.954	80.297	81.665	78.745

6 Levels



Single

Double

Vertical layer	1	2	3	4	5	6	total/layer	Double total/layer
Upper	2.54621	4.6129	6.2	6.2	6.2	4.6129		
Lower	4.61291	6.2	6.2	6.2	4.6129	2.5462		
Nominal area	7.39787	11.174	12.814	12.8135	11.174	7.3979	62.770	62.770
Horiz overlapping	0.143	0.216	0.248	0.248	0.216	0.143	1.215	1.215
Horiz nonoverlapping							0.000	0.000
Vert. Overlapping	0.265	0.413	0.413	0.413	0.413	0.265	2.183	0.530
Vert. nonoverlapping							0.000	1.587
Gaspipe dead overlapping	0.107	0.162	0.186	0.186	0.162	0.107	0.911	0.911
Support steel	0.107	0.162	0.186	0.186	0.162	0.107	0.911	0.911
Dead Corner overlapping	0.06	0.1	0.1	0.1	0.1	0.06	0.520	0.160
Dead Corner nonoverlapping							0.000	0.400
Dead Clearance	0.092	0.129	0.145	0.145	0.129	0.092	0.731	0.731
Dead Electronics overlapping					0.000		0.000	0.000
Total insensitive area	0.775	1.183	1.278	1.278	1.183		6.472	6.446
Total sensitive area (1)	6.623	9.991	11.536	11.536	9.991		56.298	1.987
Total sensitive area (2)								58.312
Insensitive Fraction	0.105	0.106	0.100	0.100	0.106		0.103	0.071
Avg Efficiency	80.572	80.473	81.024	81.024	80.473		80.721	0.917

RPC Cost Estimates

Preliminary

- Input
  - BaBar $500/m² (single gap + strips+cables+shipping+(QC?))
  - CMS 500 euro/m² (double gap + strips +cables+electronics)
  - BES III $230/m² (double gap+strips+enclosure)
  - BaBar LST HV $50/channel (6kV)
  - CMS HV ~65$/channel (12kV)
  - 4 KPIX($40) &4 header($100)/chamber

- Assume
  - 14 layers(barrel), 13(endcap)
  - 10% spares
- Double gap RPCs
  - 6300 m² @ $500/m² = 3.2M$
- Electronics
  - 2720 @$560/chamber = 1.5M$
- HV
  - 2720 @ $100/channel = 0.3M$
- QC
  - 2720@ 10 hr/chamber = 1.4M$
- Gas
  - Guess 1 M$

+ Installation & ? 7.4 M$

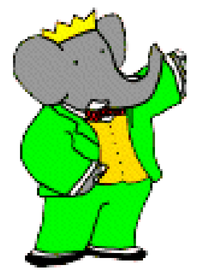
RPC R&D Issues

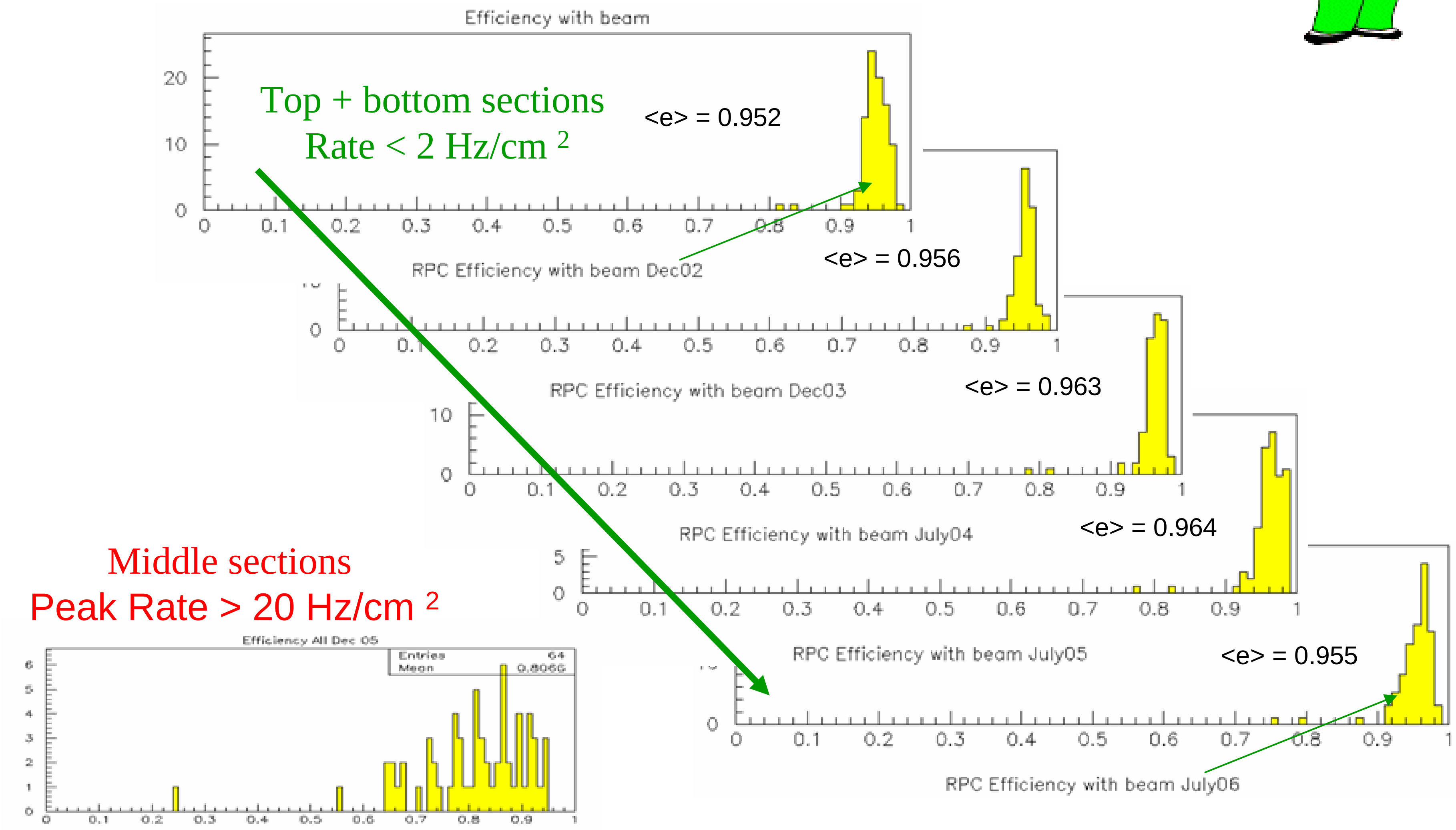
- RPCs have proven to be less robust than initially promised
- Many observed failure modes
  - Improperly cured linseed oil
  - Eroded graphite coatings
  - Too much humidity - BELLE glass RPCs
  - Too little humidity - BaBar bakelite RPCs
- However, extensive R&D has led too a better understanding of aging mechanisms
  - Improved construction techniques
  - Avalanche mode
  - Humidified gas
  - Aging tests to 10 LHC year equivalents
- Will know in several years from the operational experience of CMS, ATLAS, BELLE, BaBar, BESIII if RPCs can be made reliable

Status of present streamer mode RPCs

- BELLE glass RPCs doing well after changes to gas plumbing
  - No signs of aging when rates are limited (< 0.2 Hz cm$^{2)}$
  - Outer endcap layers turned off
- 2nd generation BaBar Bakelite RPCs
  - < 2 Hz/cm^2 few problems in 4 years
  - >20 Hz/cm^2 losing efficiency
- BES III installing ~2000 m^2 of Bakelite RPCs
  - Innovative plastic film surface - no linseed oil
  - Prototypes show stable performance

BaBar Efficiency with μ pairs

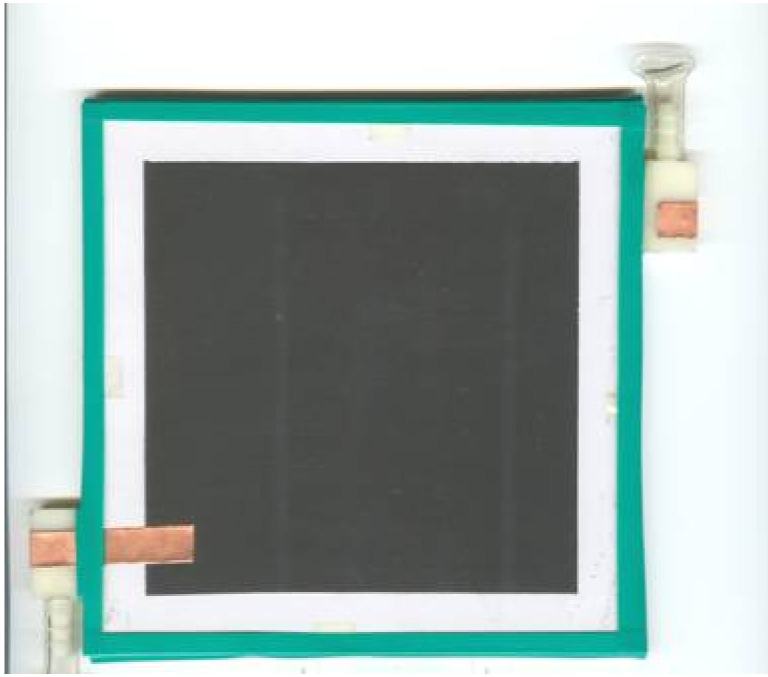




RPC Aging Studies

- BaBar(Wisconsin&Roma)
  - Avalanche mode
  - Fluorine production (HF) & absorption
  - Humidity
  - High Rate effects
- Princeton
  - Avalanche mode
  - Surface quality studies
  - Gas
  - Fluorine production (HF) & absorption
- Bakelite Experience
  - Need glass RPC tests

- Study BES III RPC response to humidity and HF

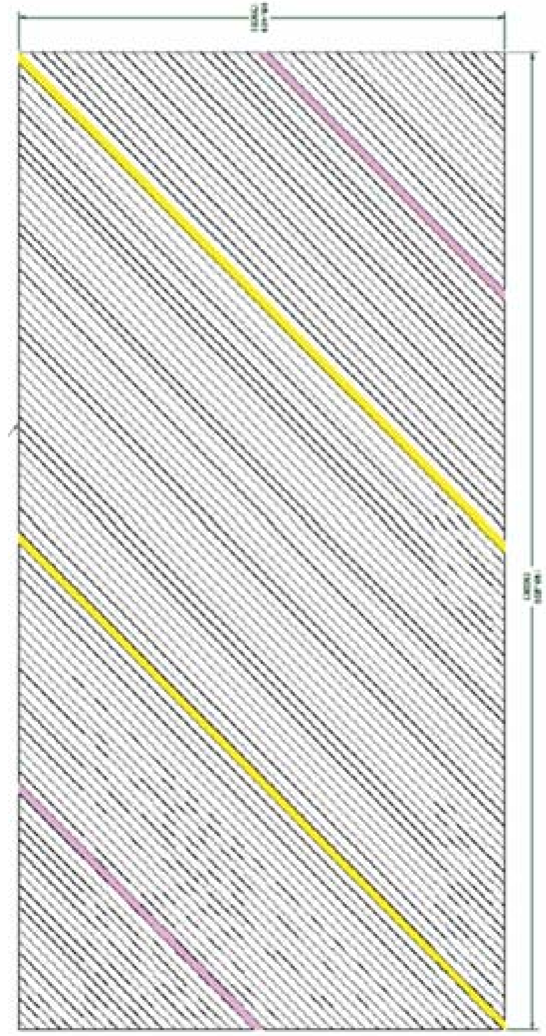


Scintillator Strip Muon System

- Design
- Prototype in testbeam
  - Details in linked talk
  - Status of Tests
  - ADC Calibration
  - Pulse height Spectra/Min-I Response
  - First data with Italian SiPM
- Scintillator Muon System Cost Estimate

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

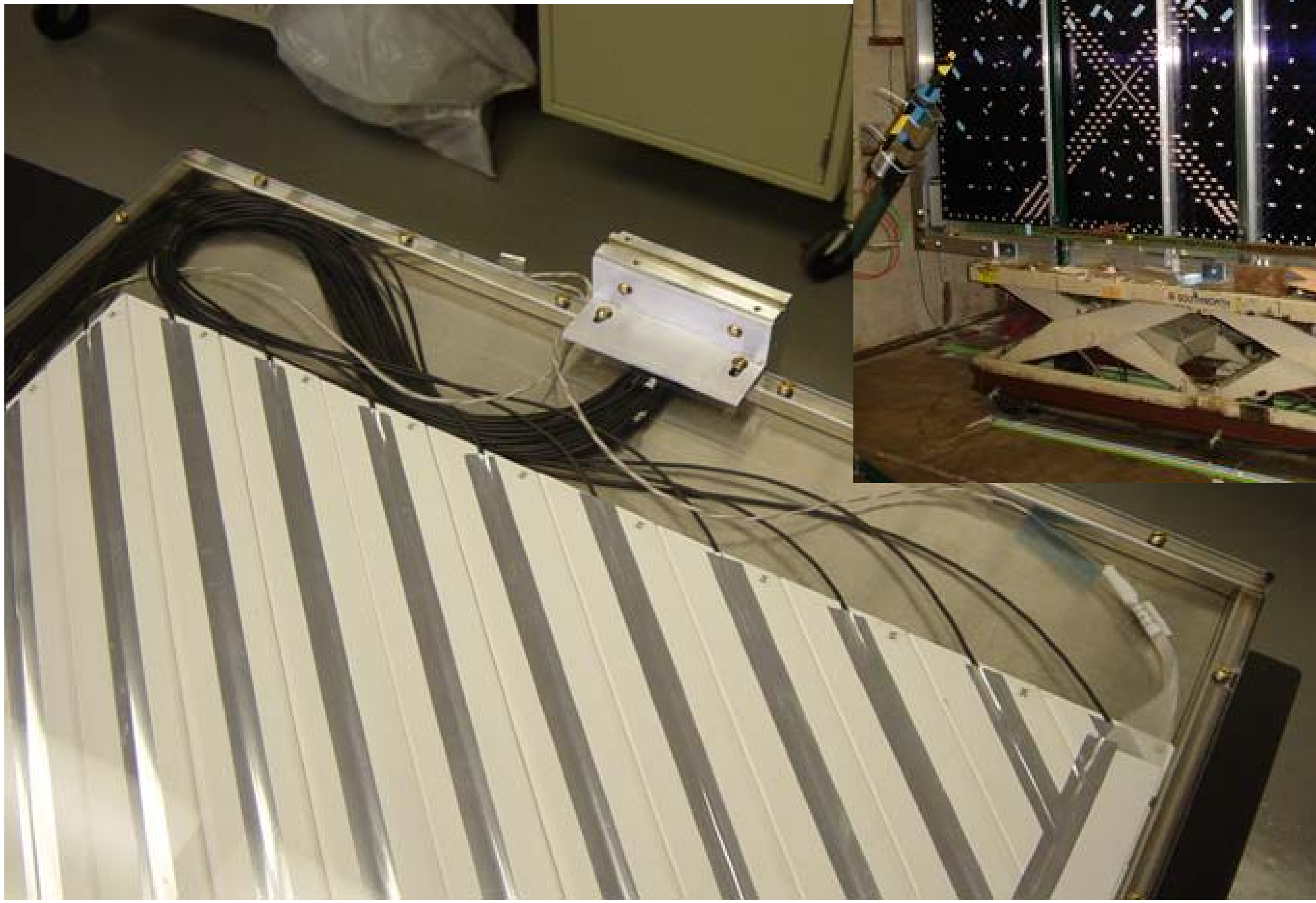


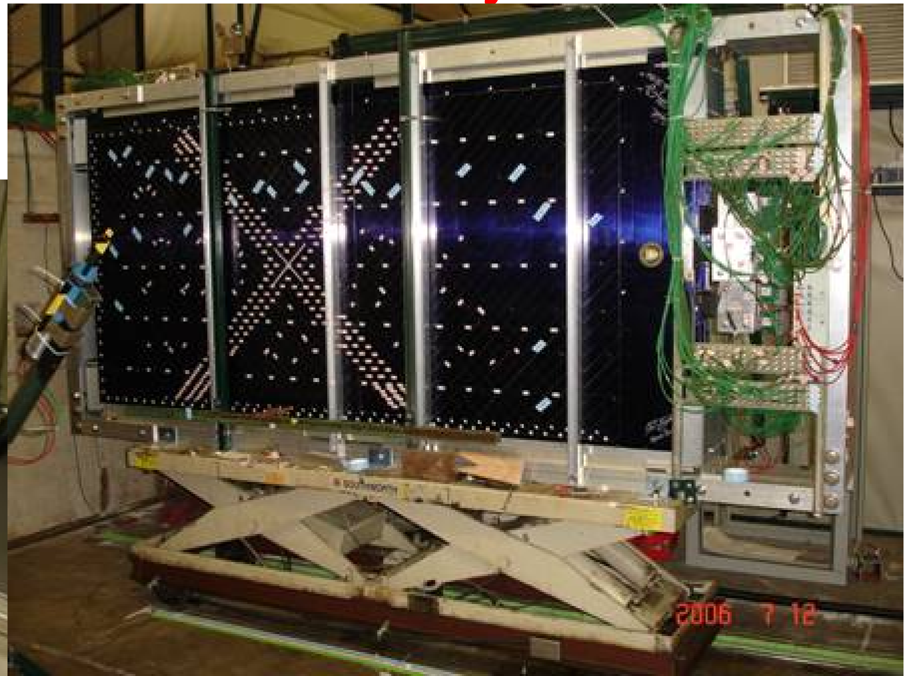
Prototype Status

- Four (1.25m X 2.5m) prototype modules with 64 strips built at Notre Dame in 2005.
- Planes set up in Fermilab MTest beam (aka MTBF).
  - Test run in February
  - Running resumed from end of June to mid-July and then from mid-August through mid-September.
  - Many problems, mostly DAQ-related, were solved and good data were obtained on pulse height vs. position.

MTest is off for modifications;
will return to an operational state in 2007.

Muon Detector Setup





Monitoring and Positioning

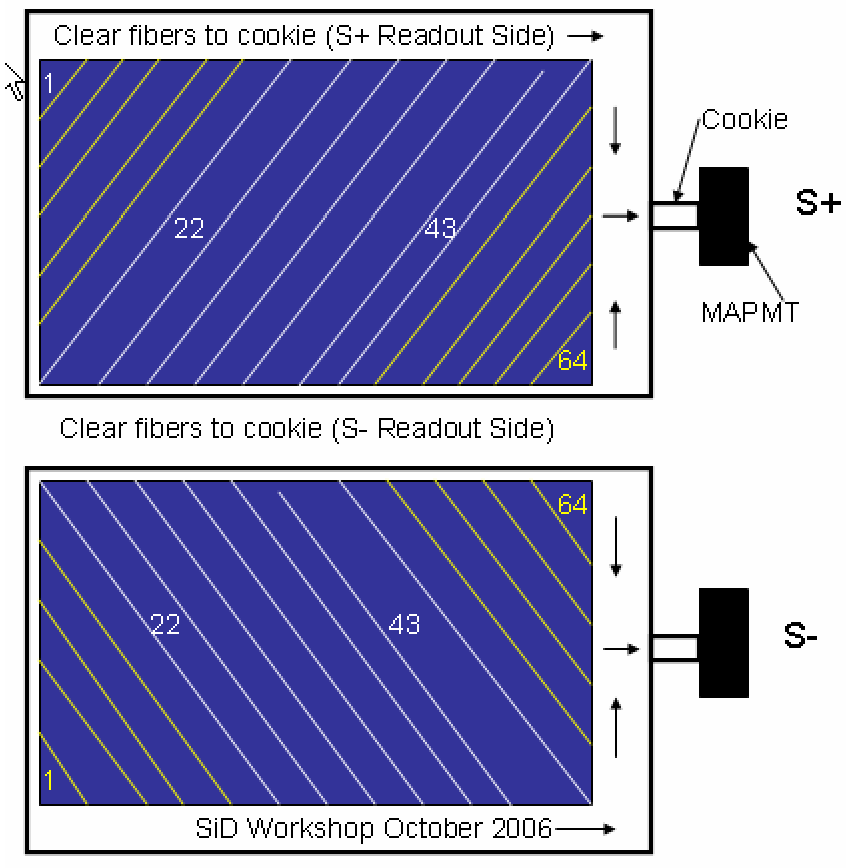
Beam position is established on the detector planes with horizontal and vertical laser levels.

Video monitor and Motor controls for remote adjustment of the cart's position.

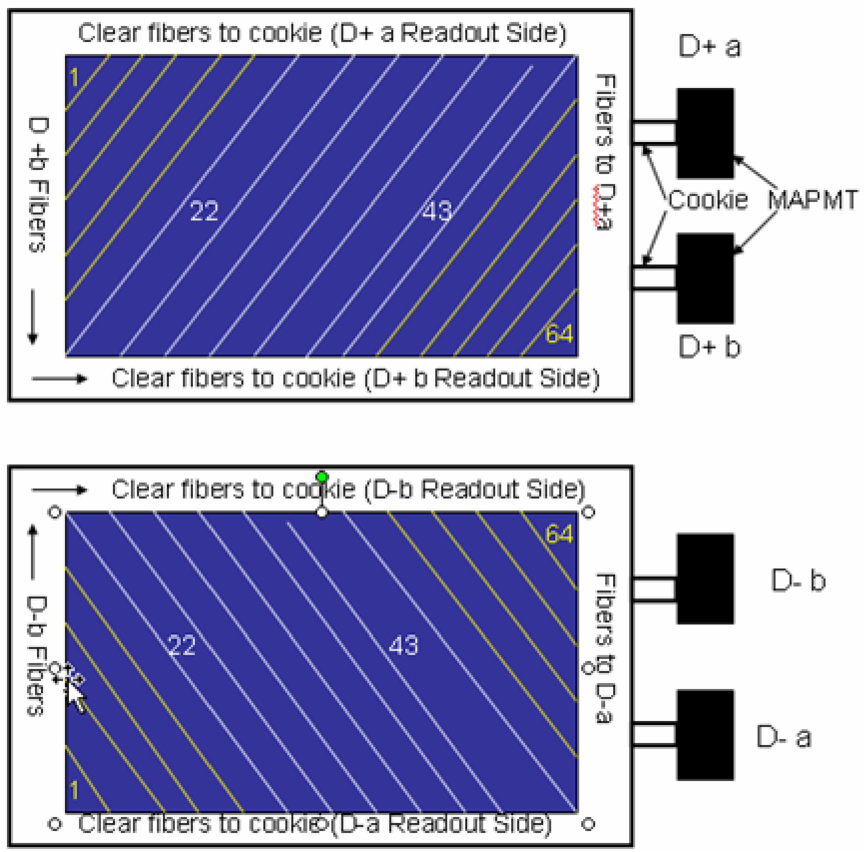
96 inch horizontal motion along rail, Hydraulic scissors jack cart has 45 inch vertical travel.

4 Detector planes

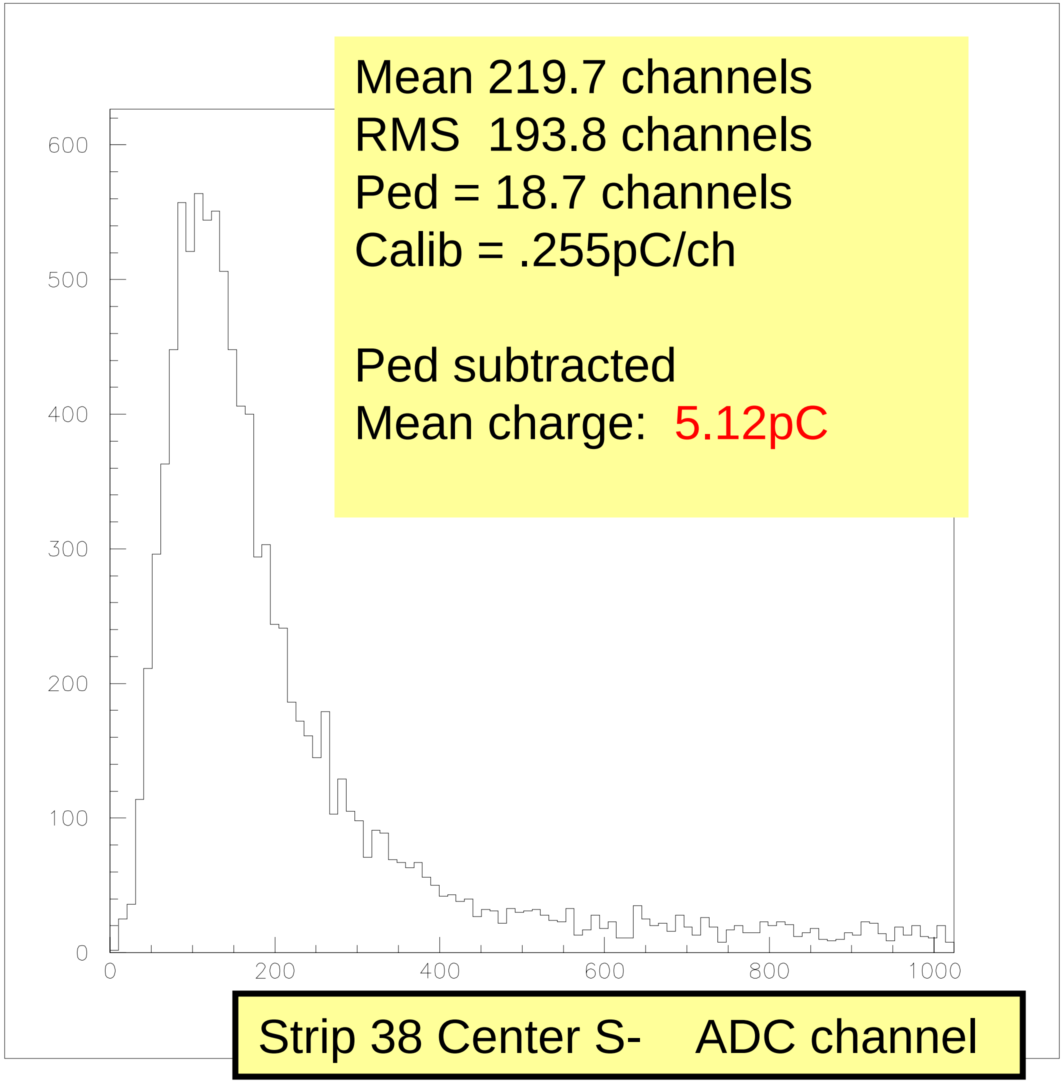
Single ended readout

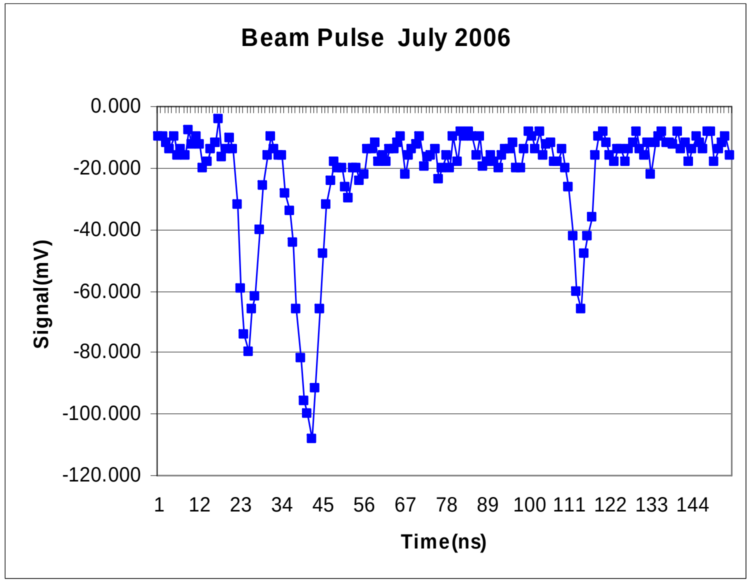


Dual readout



Pulse Height Spectrum



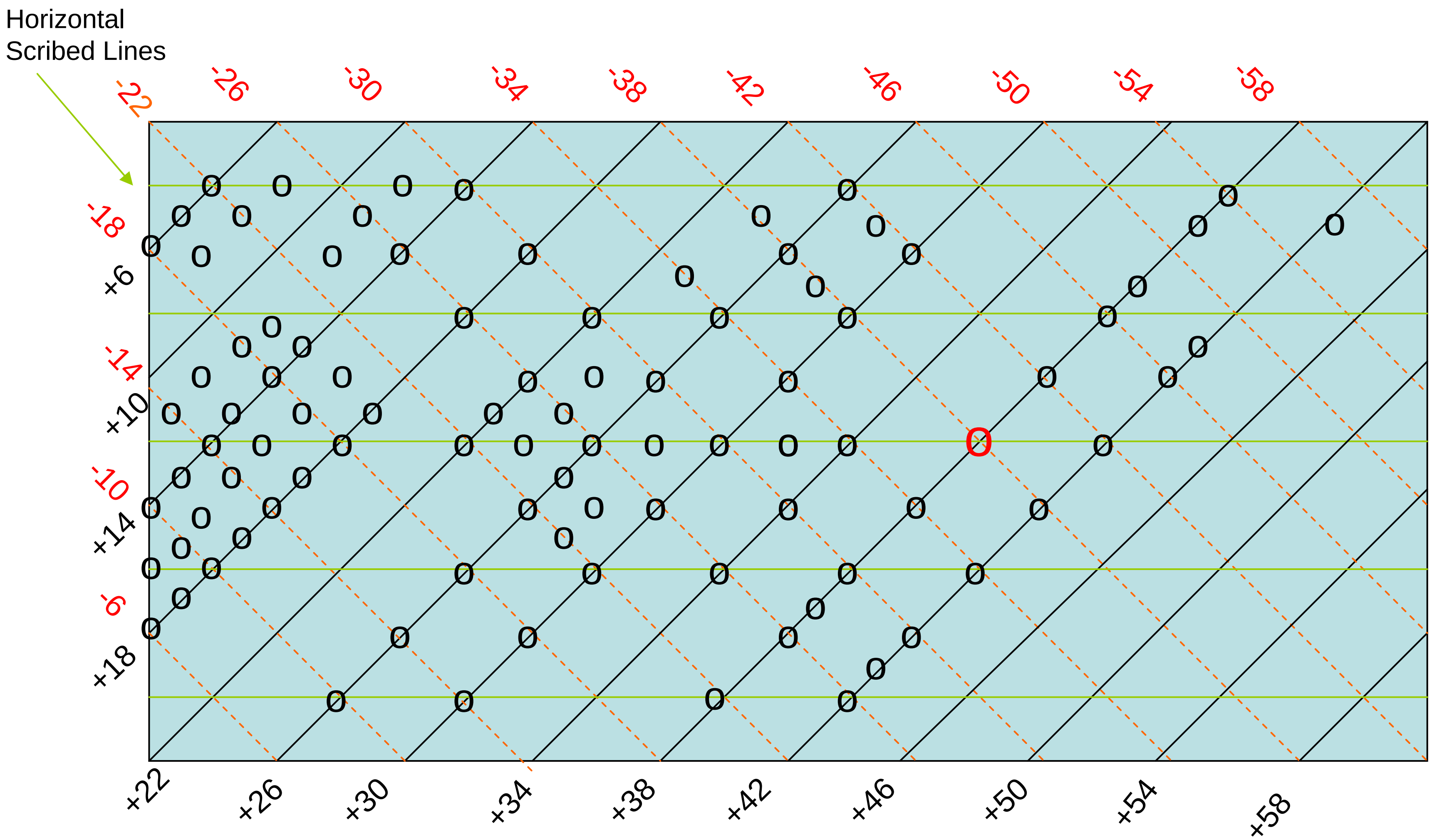


Typical MAPMT Pulse

Measurements

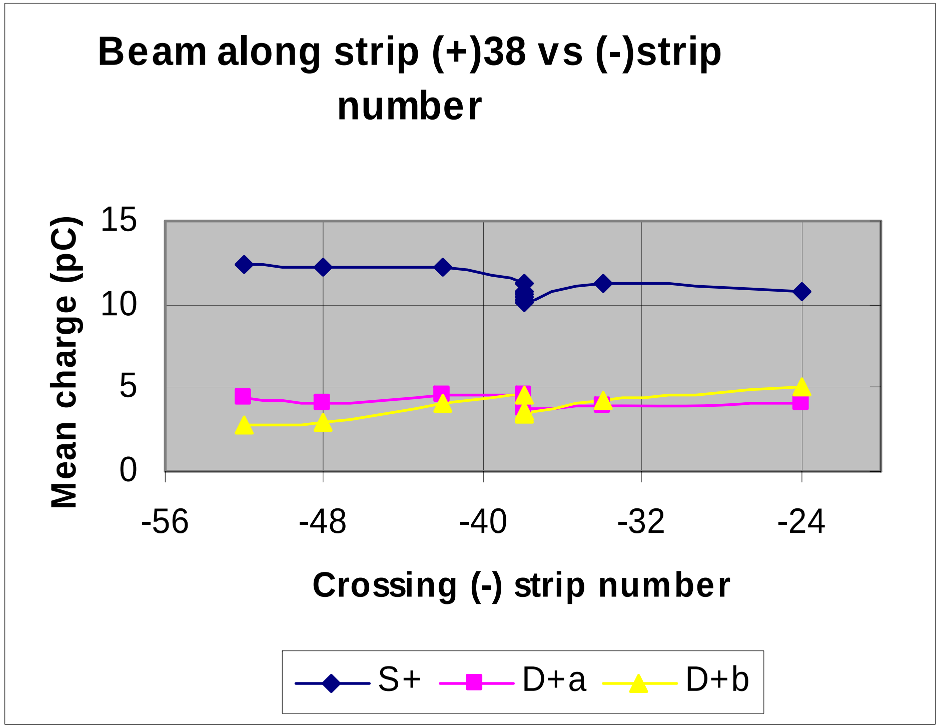
- Position detector so that beam hits particular (+, -) pairs of counters.
- Measure:
  - multiple strips with beam at center or comparable points
  - at different positions along strips.
  - near boundaries between strips
- Also record coincidence rates of each signal with beam with CAMAC scalers.

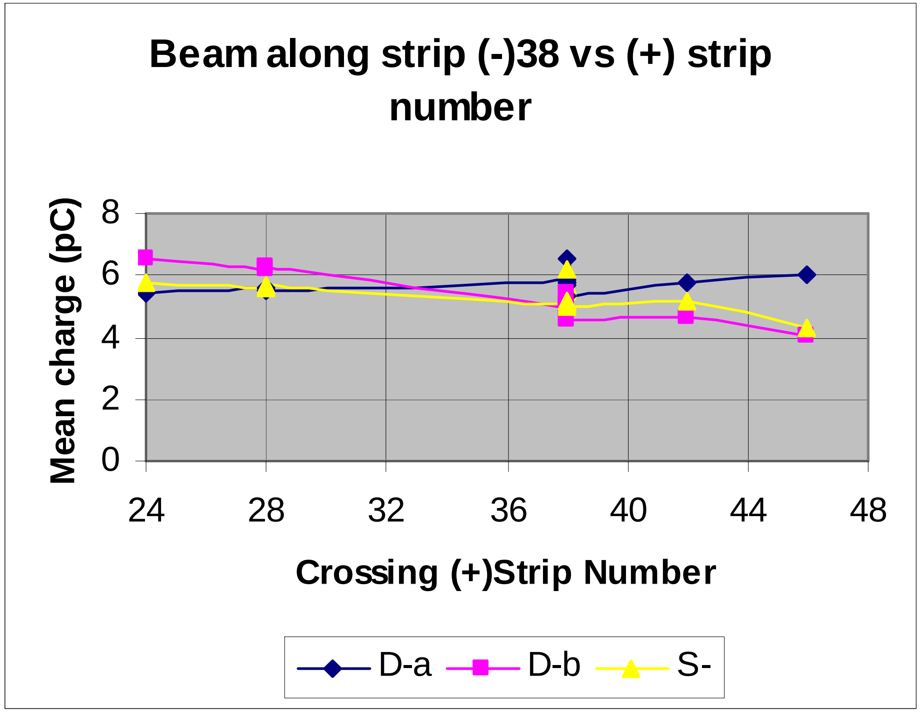
Schematic Measurement Grid



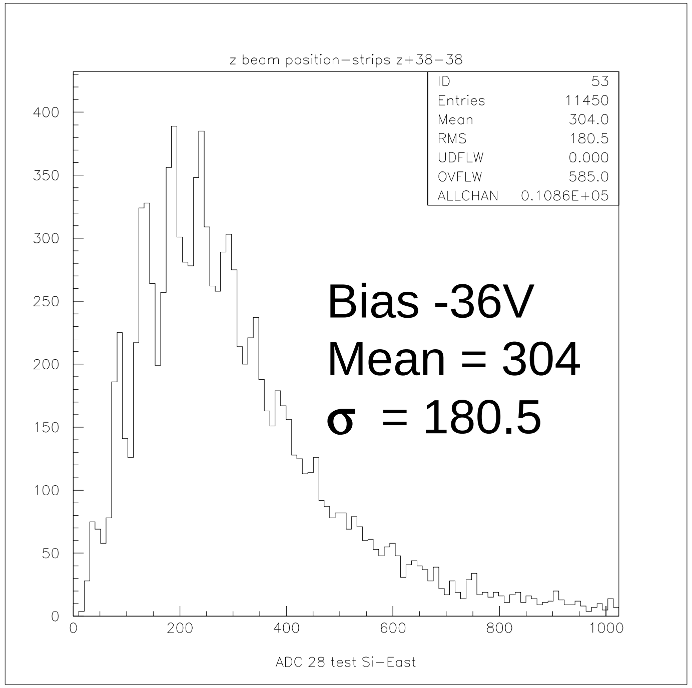
Circles show points that were measured. Numbers indicate strip numbers

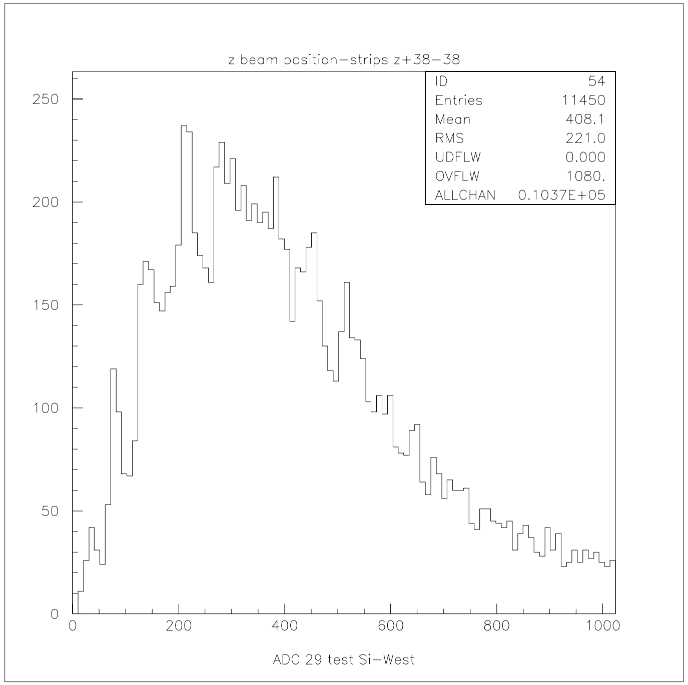
Scans along strips





Italian SiPM Beam Test



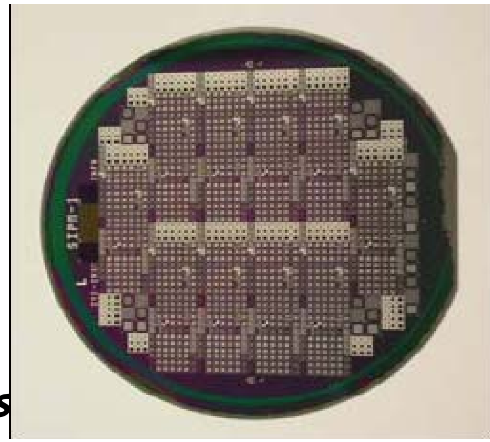


A. Driutti and G. Pauletta – INFN Trieste/Udine

INFN/Udine test of ITC-Irst SiPM's at SiDet using prototype LC muon scintillator plus WLS fiber. MTest data Sept 2006.

25 x 25 pixels with each pixel 40µ X 40µ

Gain = 1.6 x 10^7; Noise ~ 0.7 MHz; http://sipm.itc.it



Conclusions - Scintillator

- Collected good sets of test beam data.
- Data collection rate limited to ~40/sec by CAMAC/DAQ. Requires 1-2 hours per 12000 events.
- Plan to replace aging CAMAC system.
- Additional running is planned with Minerva electronics: statistics from all strips?
- Useful information is being derived from our data.

Scintillator Cost

Under Construction