Tracking and Pion Detectors

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MOLLER Director’s Review December 15, 2016

Breakout Session I:

Detectors

MOLLER

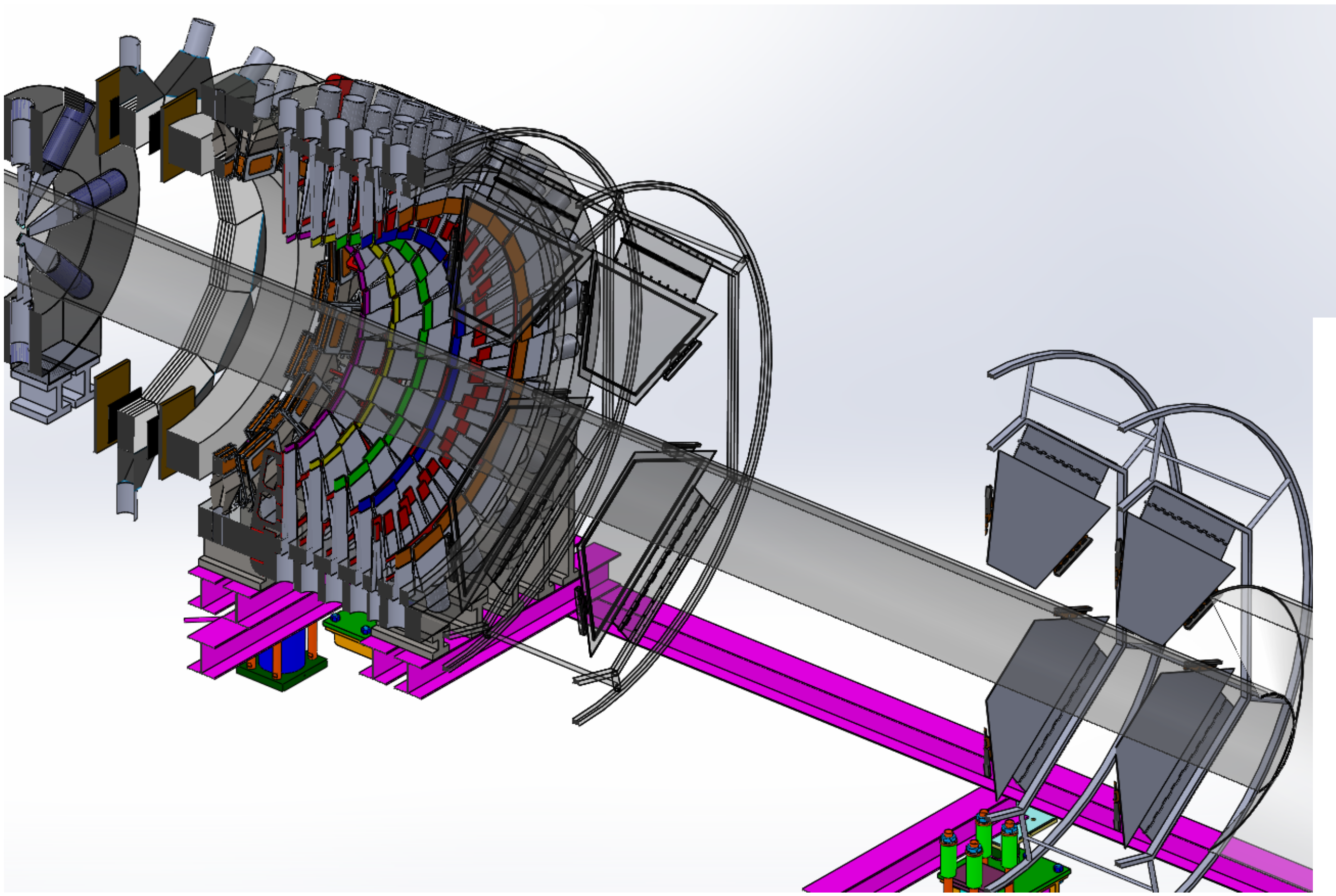
WILLIAM & MARY

CHARTERED 1693

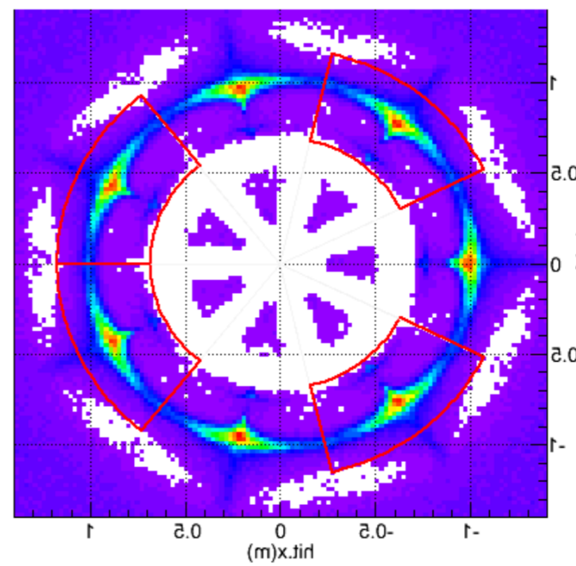
NSF

Tracking Hardware

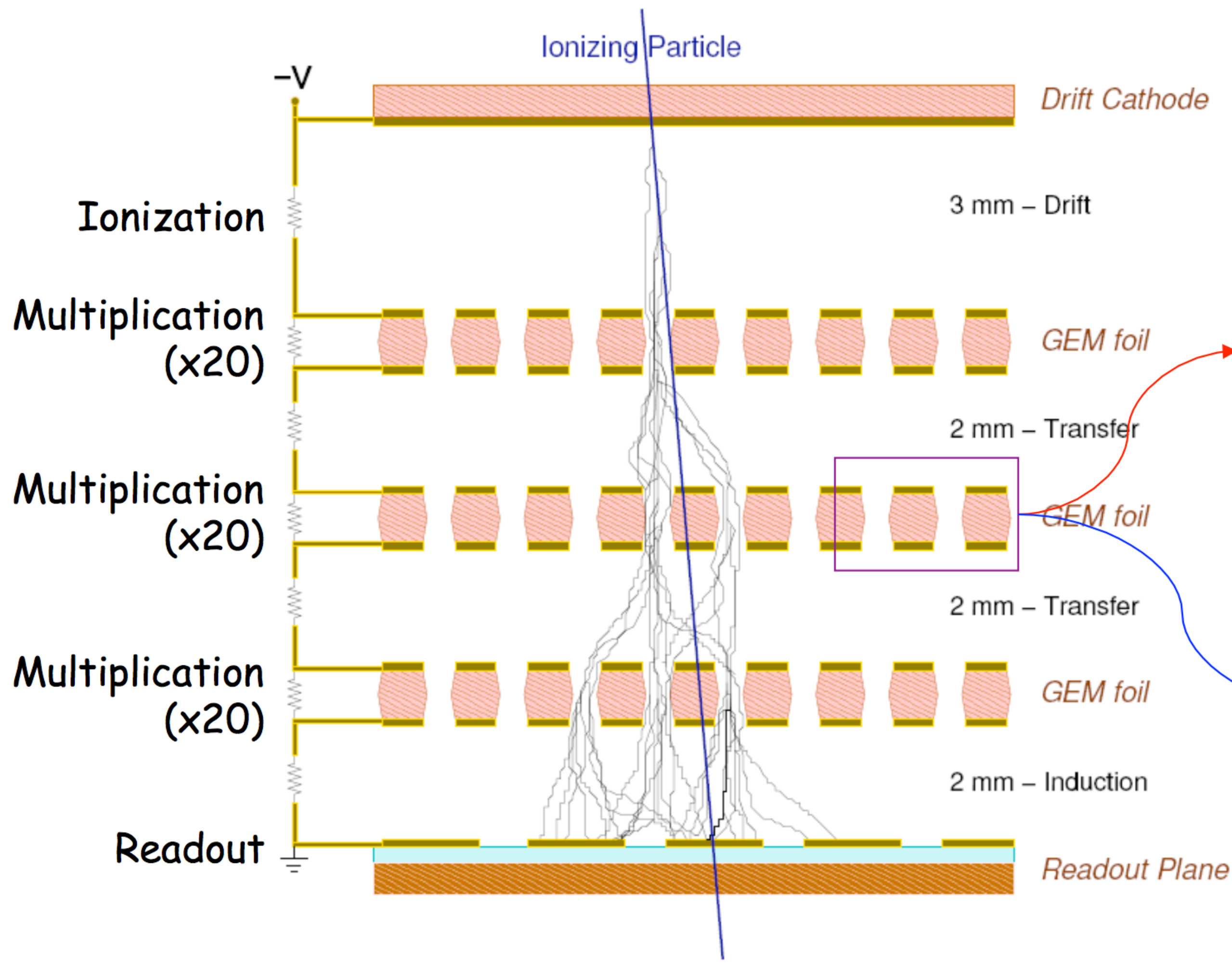
- Four layers of GEM chambers, upstream of quartz detectors, covering 4 septants
- Rotatable to allow redundant coverage of all septants, full acceptance
- Operated at low (~100 pA) beam currents
- Scintillator triggered



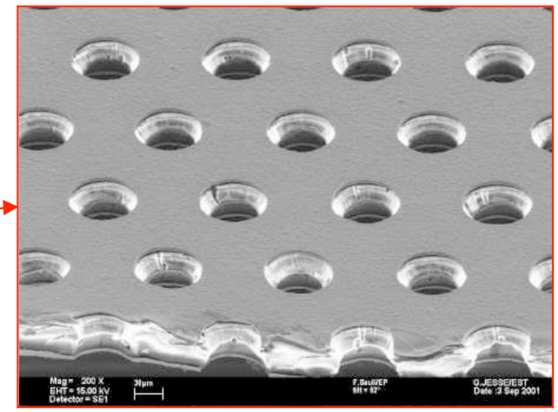
Desired septant coverage

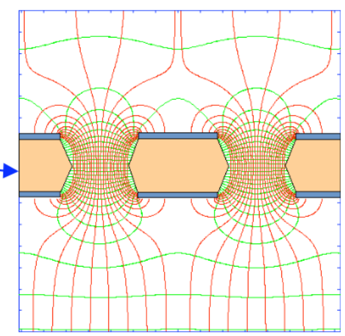


GEM Detectors



GEM foil: 50 μm Kapton + few μm copper on both sides with 70 μm holes, 140 μm pitch



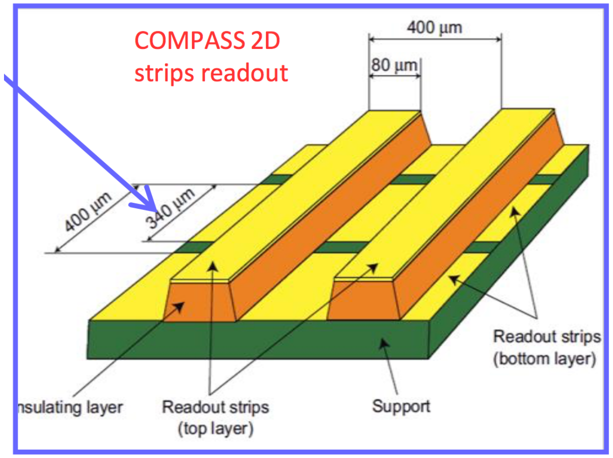


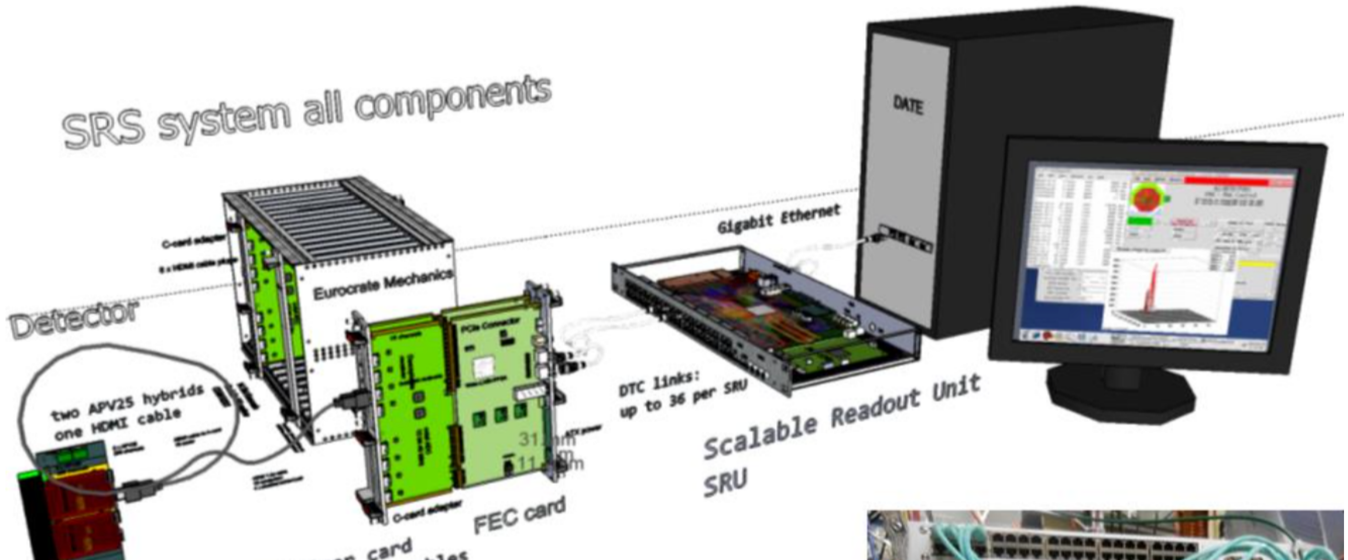
Strong electrostatic field in the GEM holes

Recent technology: F. Sauli, Nucl. Instrum. Methods A386(1997)531

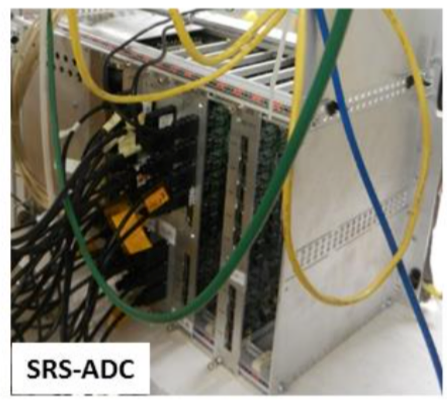
"Triple GEM" : Low mass, high rate capability, excellent position resolution

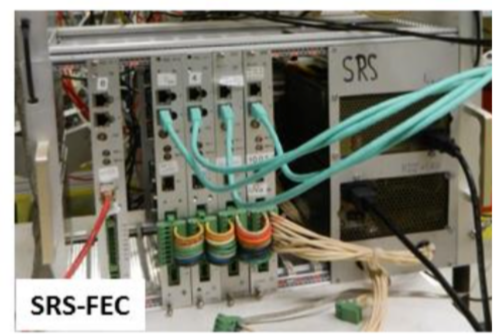
GEM Readout





- RD-51 Scalable Readout System (INFN)
  - commercial system
- APV25-S1 chip: developed for LHC





128 to 1 multiplexed

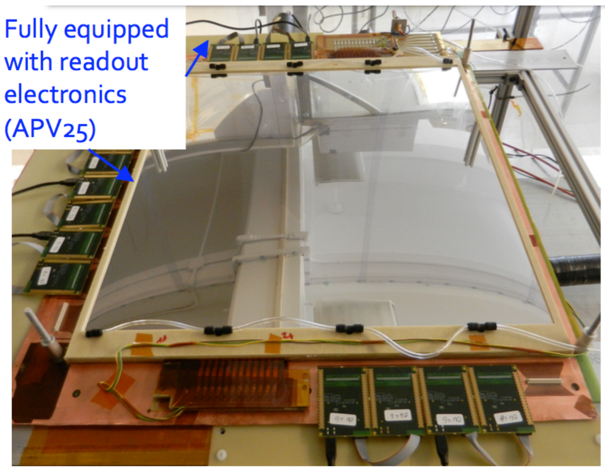
Choose 1 mm pitch;
Charge center of gravity gives σ_x<100 μm

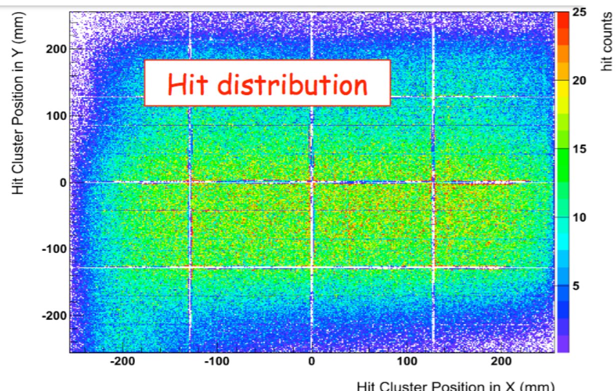
UVirginia GEM Lab

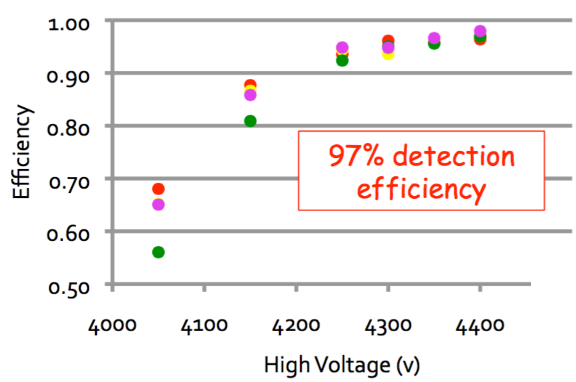
N. Liyanage *et al.*

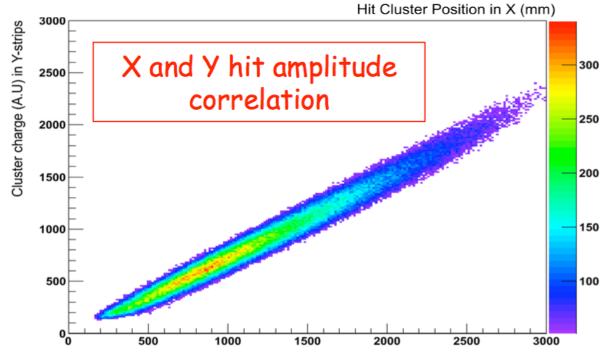
- World's largest-area (1.2 m^2) for PRad experiment
- 45 large-area GEMs for SBS project

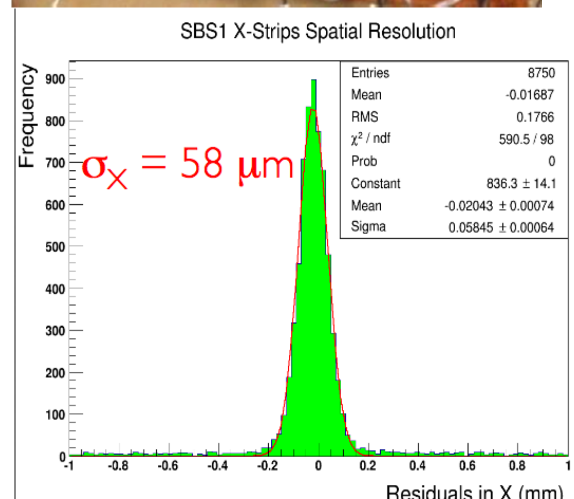
[36 built so far, all 36 operational]



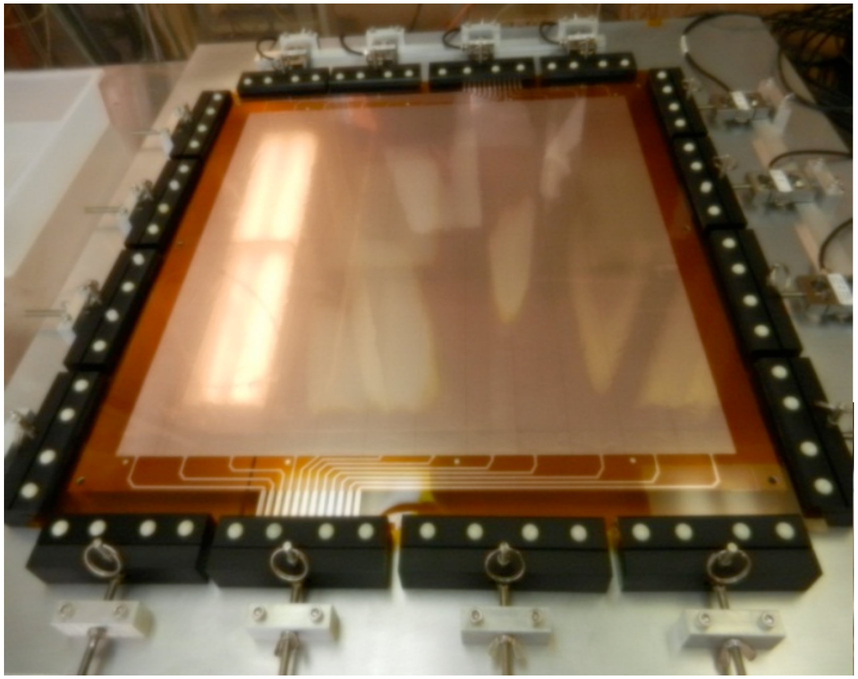








GEM Detectors



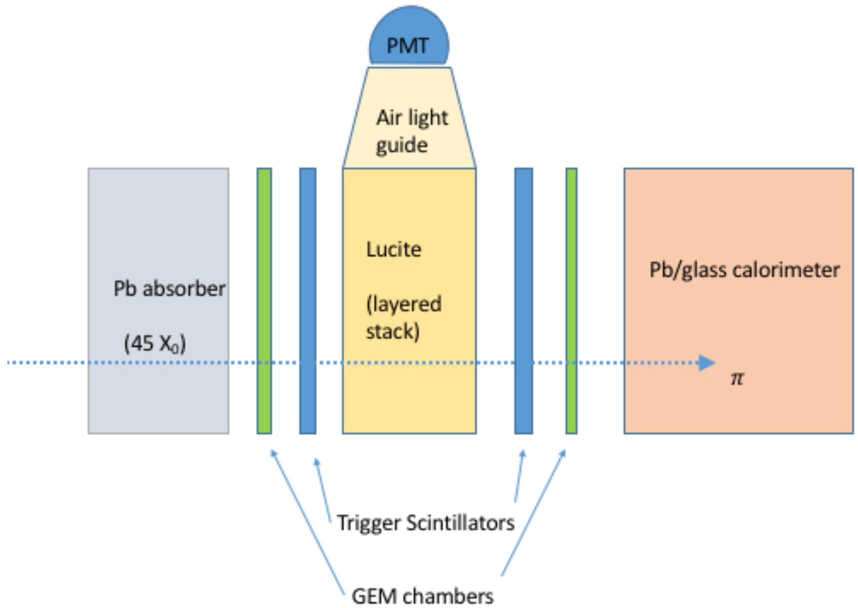
1 mm pitch: 36,000 readout channels.
Trapezoid shape

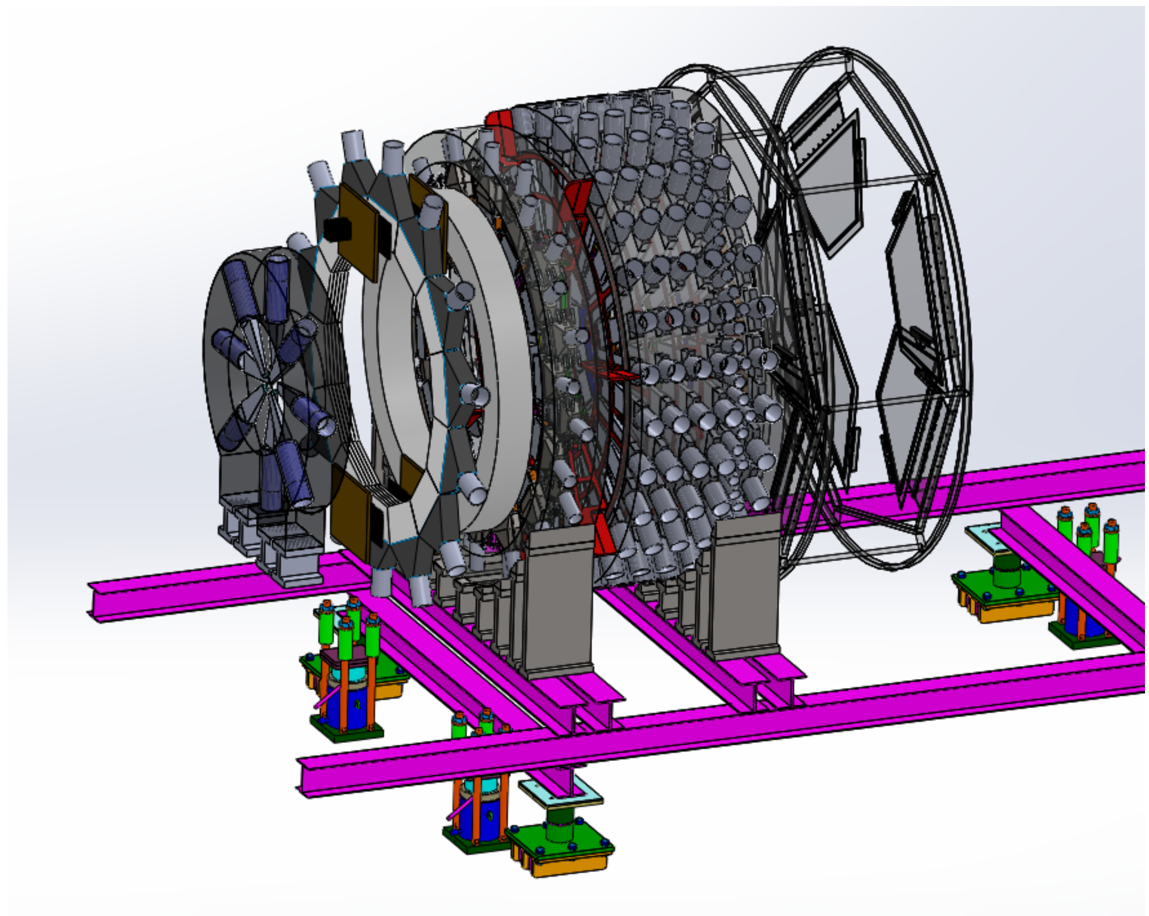
Conservative assumption of 500 μm resolution meets tracking requirements.

GEM chambers will be rotated 90° (parallel to beam axis) to be out of acceptance during main measurement – support/rotation to be designed.

	z(m)	Inner rad(m)	Outer rad(m)	$\pm\phi$(deg)	Area (m^2)
GEM #1	22.64	0.45	0.88	31.1	0.31
GEM #2	23.64	0.49	0.93	30.5	0.33
GEM #3	27.00	0.61	1.11	29.4	0.44
GEM #4	28.00	0.65	1.17	29.4	0.49

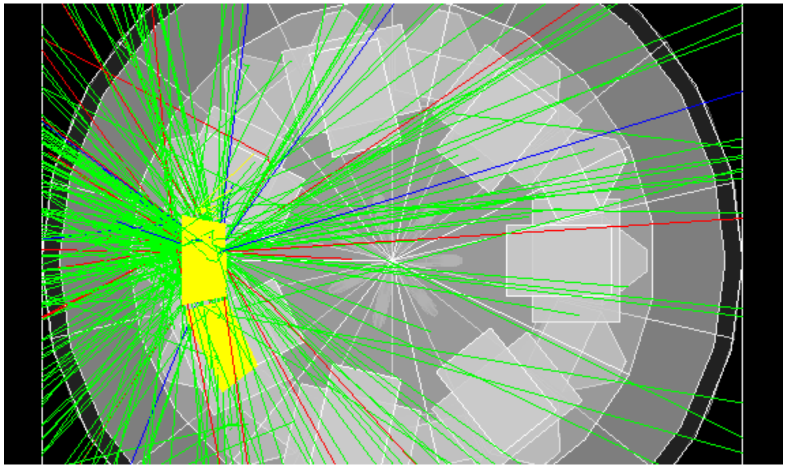
Pion Detectors



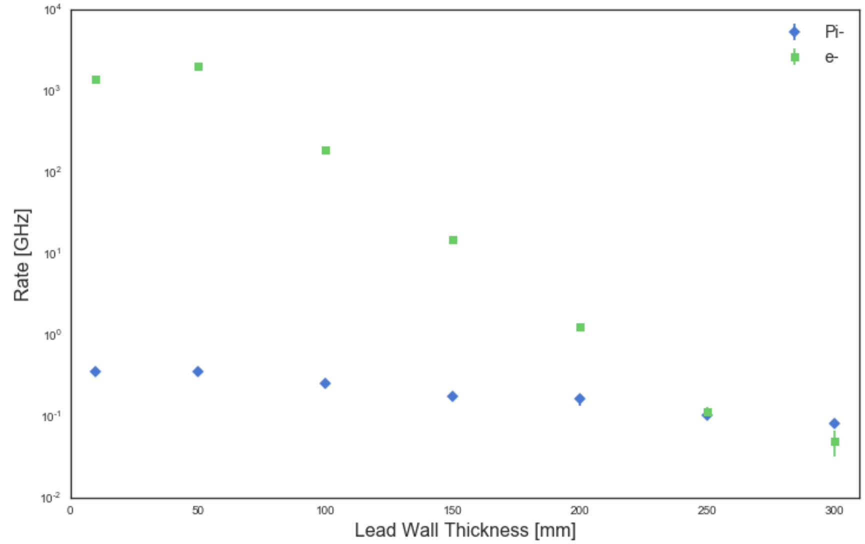


- 14 Lucite Cerenkov detectors:
  14 cm thick, read out by 5" PMTs
  Full azimuth, fixed locations, for
  A_π measurement
  cover Ring 5 (``Moller ring") only
- GEANT4-based optical design begun;
  initial estimate: 40 pe's/track
- Supplemented in 2 sectors by GEM/scintillator/calorimeter system for R_π measurement; connect tracks to MIP signal in ShowerMax detector

Pion Detectors



GEANT 4 simulations



- Pion flux: $\sim$10 MHz/sector
- Lucite sufficiently rad-hard (HAPPEx-I experience)

- δA_π = 0.34 ppm/day $\rightarrow$ 100 ppb (20% relative) in 10 days
  (detector resolution $\sigma = 30\%$)

Cost and Schedule

WBS	Dictionary	Estimate (k$)
1	The MOLLER project	
1.4	Tracking subsystem	1040
1.4.1	Gas electron multiplier (GEM) detectors	712
1.4.2	Trigger scintillators	53
1.4.3	Pion detector	146
1.4.4	Tracking electronics	54
1.4.5	Pre-amps/discriminators	75

1.4.1 **GEMs**:

20 modules + 4 spares @	$11,000/module	$264 k
FE & readout electronics	36,000 channels @ $4/channel	$144 k
Technical Manpower (24 FTE months)		$180 k
Design, Tooling, Prototyping		$124 k
[based on UVa actual costs for SBS GEMs]		$712 k

1.4.3 **Pion Detector system**

PMTs and bases (14)	$91 k
Lucite, machining	$8 k
Light guides, enclosure	$15 k
Pb-glass calorimeters	$33 k
	$146 k

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1.4.4 **Tracking electronics**
Event-mode readout for Quartz main detectors during Tracking
CAEN V792AC (11 modules) & VME crate $54 k

1.4.5 **Pre-amps/Discriminators**
Event-mode readout for Quartz main detectors during Tracking
330 channels: Phillips 779 and 707 modules $75 k

GEM rotator, Pb absorber, HV, cabling: costed in WBS 1.5

Tracking & Pion Detectors Summary

1) GEM-based Tracking System
   - build on expertise developed (U. Virginia) for SBS, PRad, SoLID
   - need to design support/rotation system

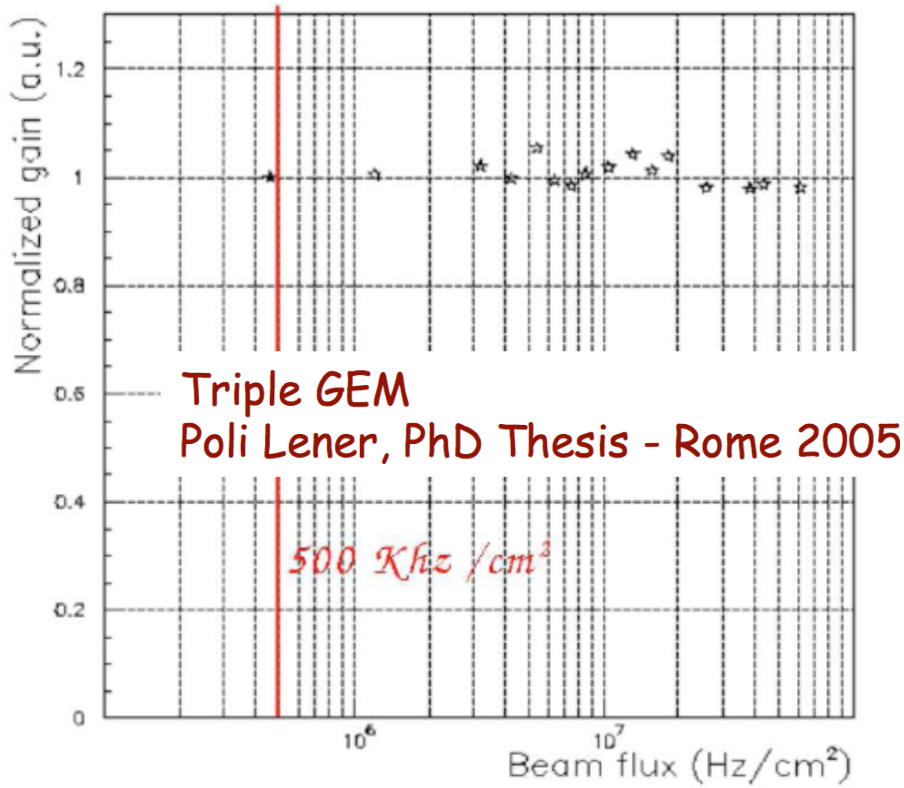
2) Pion Detector System
   - Lucite Cerenkov detector: detailed optical design begun
   - in-beam prototype tests (eg. SLAC 10 GeV beam) proposed

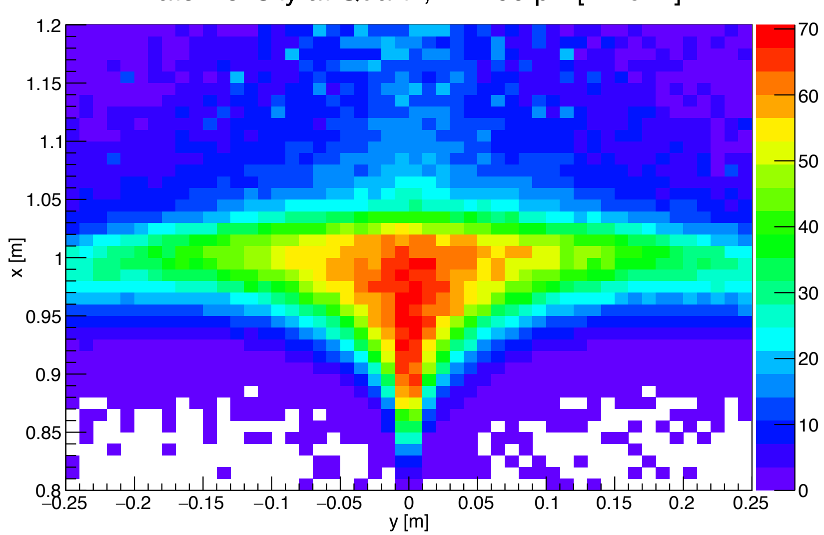
Backup

GEM – Rate Capability

High Rate capability

- Multiplication stages shielded from each other: much reduced feed back
- Slow moving positive ions localized to holes, away from the induction region
- Most of the created electrons contribute to signal: operate at low gains

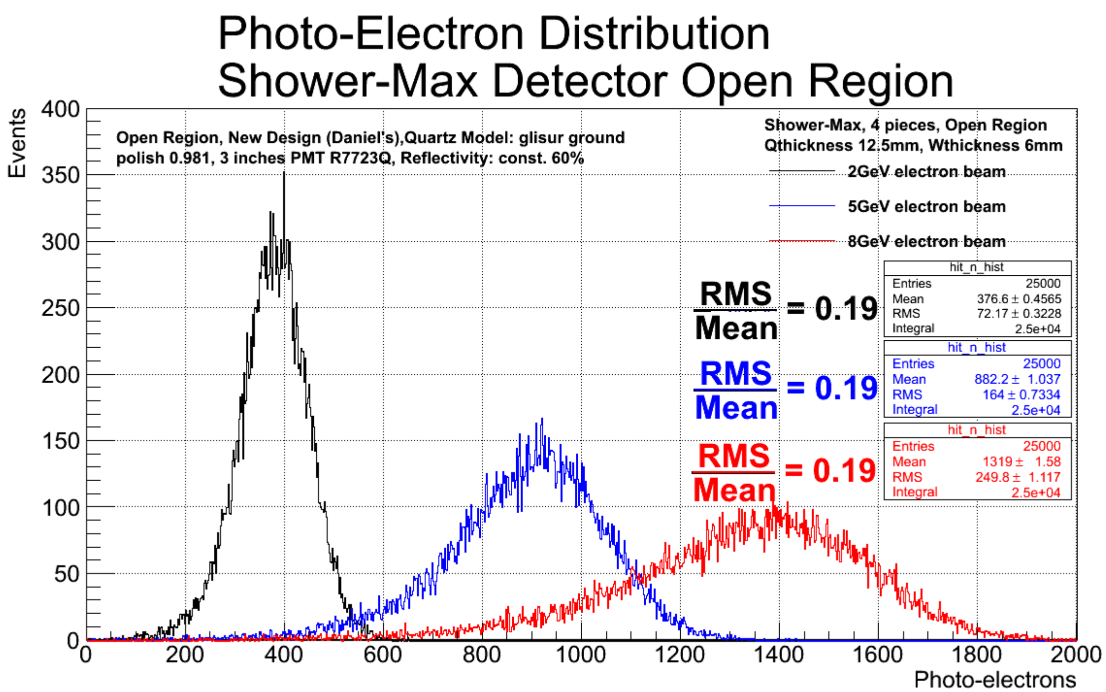




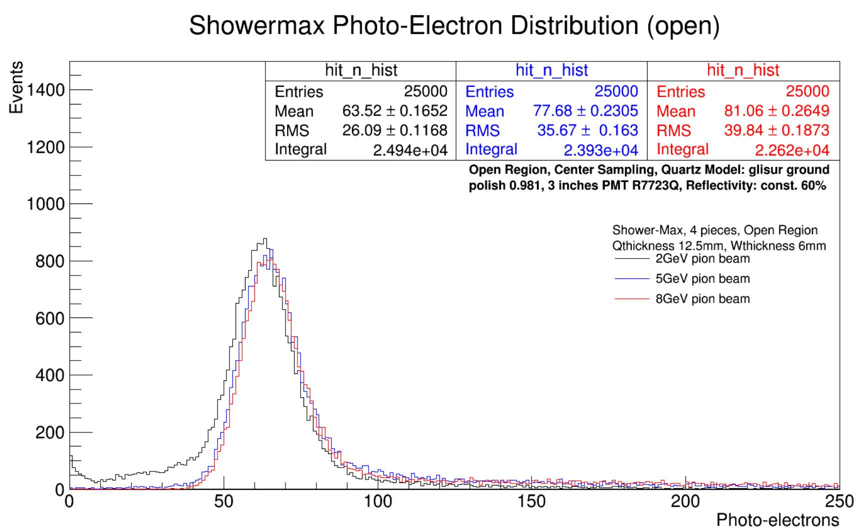
GEMs can operate up to > 10 MHz/cm^2

Max rate for Moller Tracking: 200 Hz/cm^2

Pion Identification in ShowerMax



electrons



pions

ShowerMax detector: clear e/pi discrimination – use in software coincidence with pion detector system

Ability to link track seen in pion detector GEMs to ShowerMax limited by mult. scatt. in Pb absorber (50 mrad for 2 GeV π)