Instrumented Cone and other MC Detector Issues

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The Background Issue

Sources of background at Muon Collider

- beam halo, Bethe-Heitler muon flux
- Muon beam decays is the major source: detector irradiation by particle
- fluxes from beam line components and accelerator tunnel.
- For 750 GeV muon beam of $2*10^{12}$ - $4.3*10^{5}$ decays/m per bunch crossing, or $1.3*10^{10}$ decays/m/s for two beams.
- IP incoherent e+e- pair production, ~$3*10^{4}$ e+e- pairs per bunch crossing
- IP $\mu+\mu-$ collisions – negligible at large radii –

Background mitigating measures

- Collimating nozzle at IP, detector magnetic field
- ~10T dipole magnets to sweep decay electrons in IR (interaction region), with tungsten masks in between
- Currently achieved reduction of machine background from MARS study is ~ 3 orders of magnitude (depends on the nozzle angle)
- Super-cooling and Low emittance MC design (Muons, Inc.) – same luminosity, factor of 5-10 teim fewer muons.

1996 Muon Collider Detector

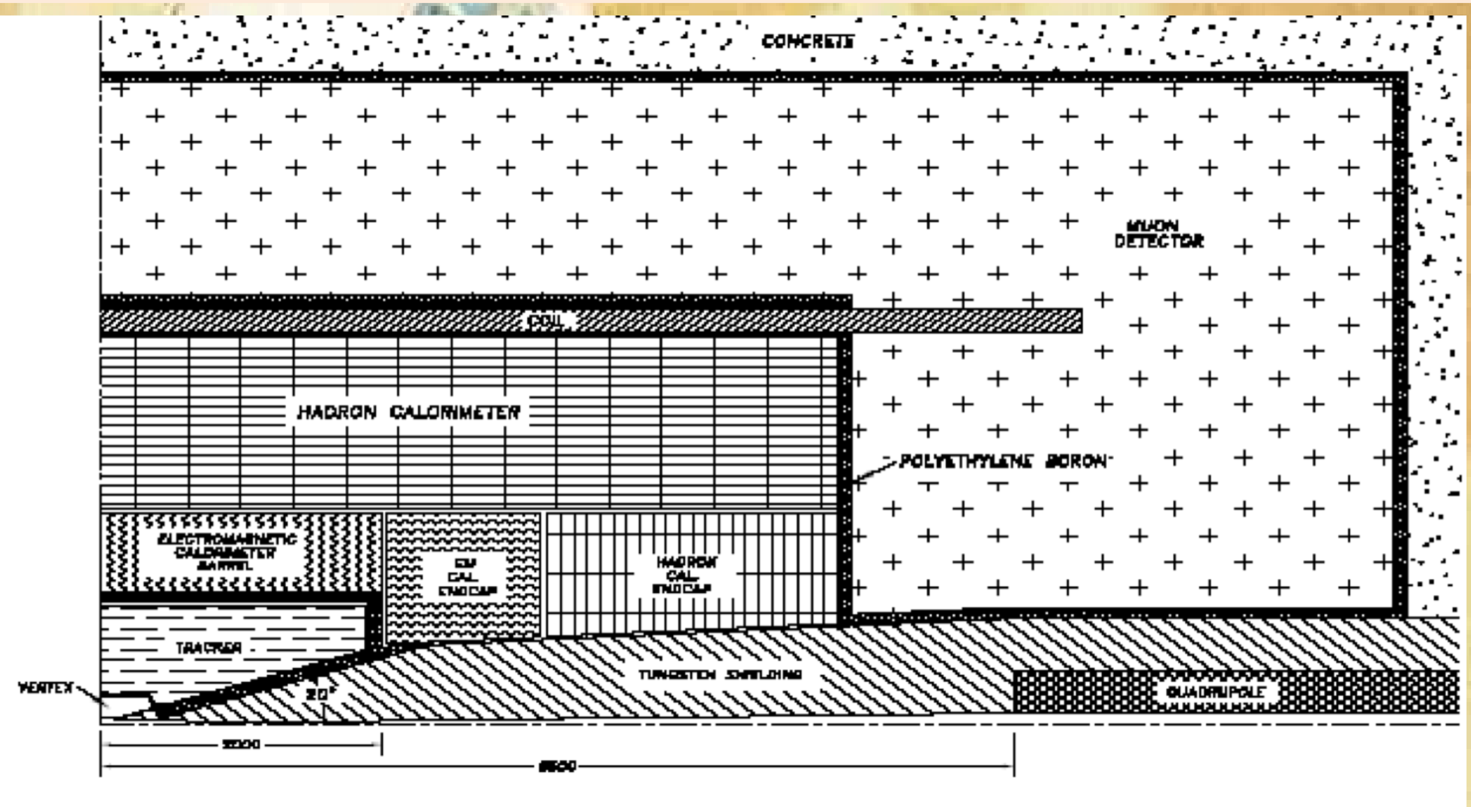
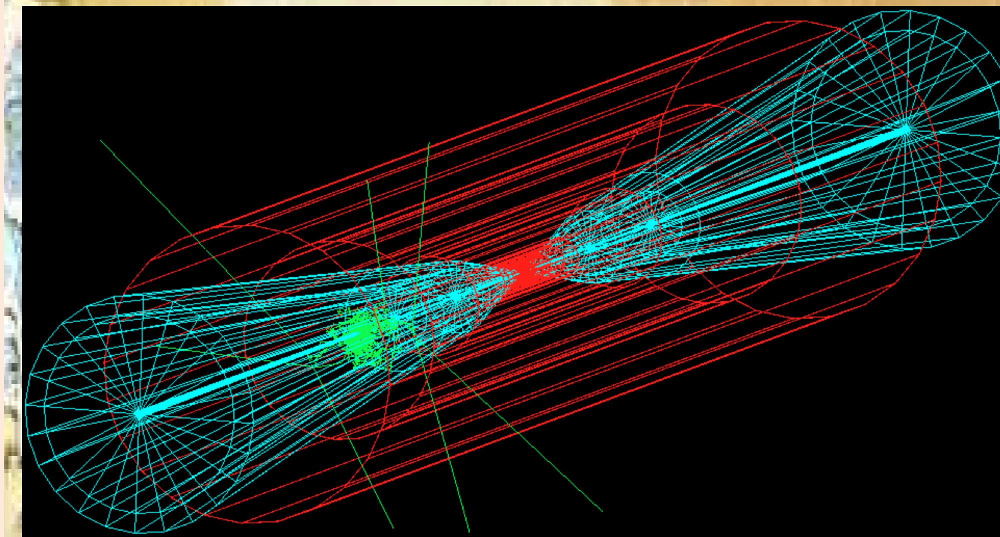
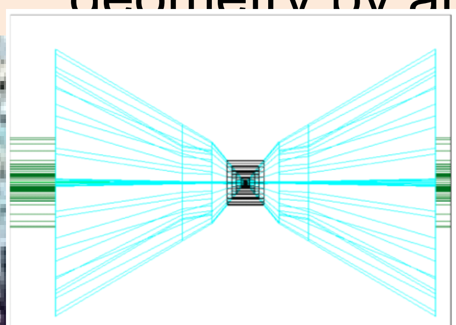


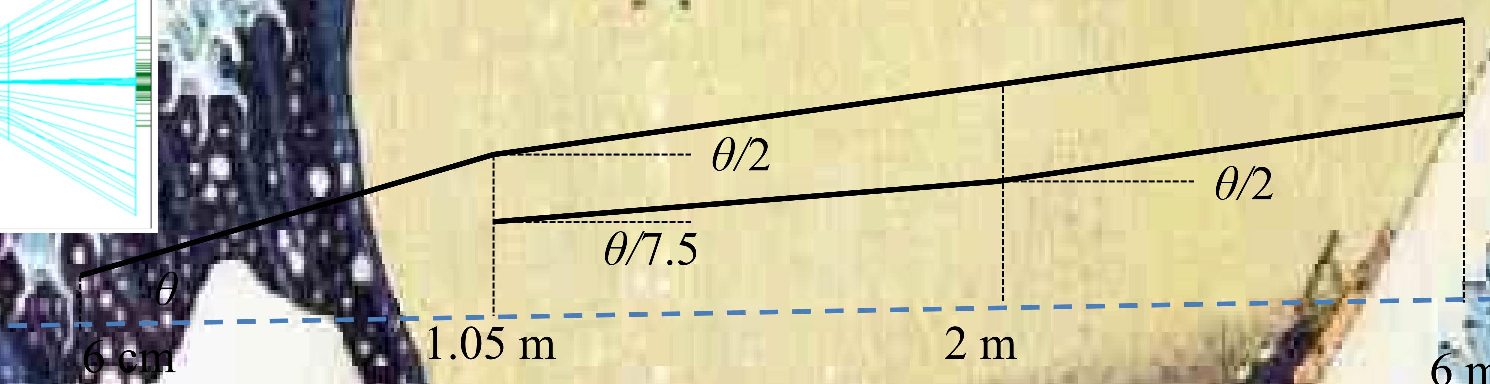
Illustration of a quadrant of a typical detector at a muon collider. The forward region, within a 20° cone, is filled with dense shielding, and is not instrumented. Newer studies can reduce the cone size and investigate the feasibility of this forward area to be instrumented for particle detection.

Scaling the Cone

- We wish to investigate the dependence of the detector backgrounds with respect to the shielding cone angle.
- We have left inner radii and segmentation in z alone.
- We have scaled the cone geometry by angle as

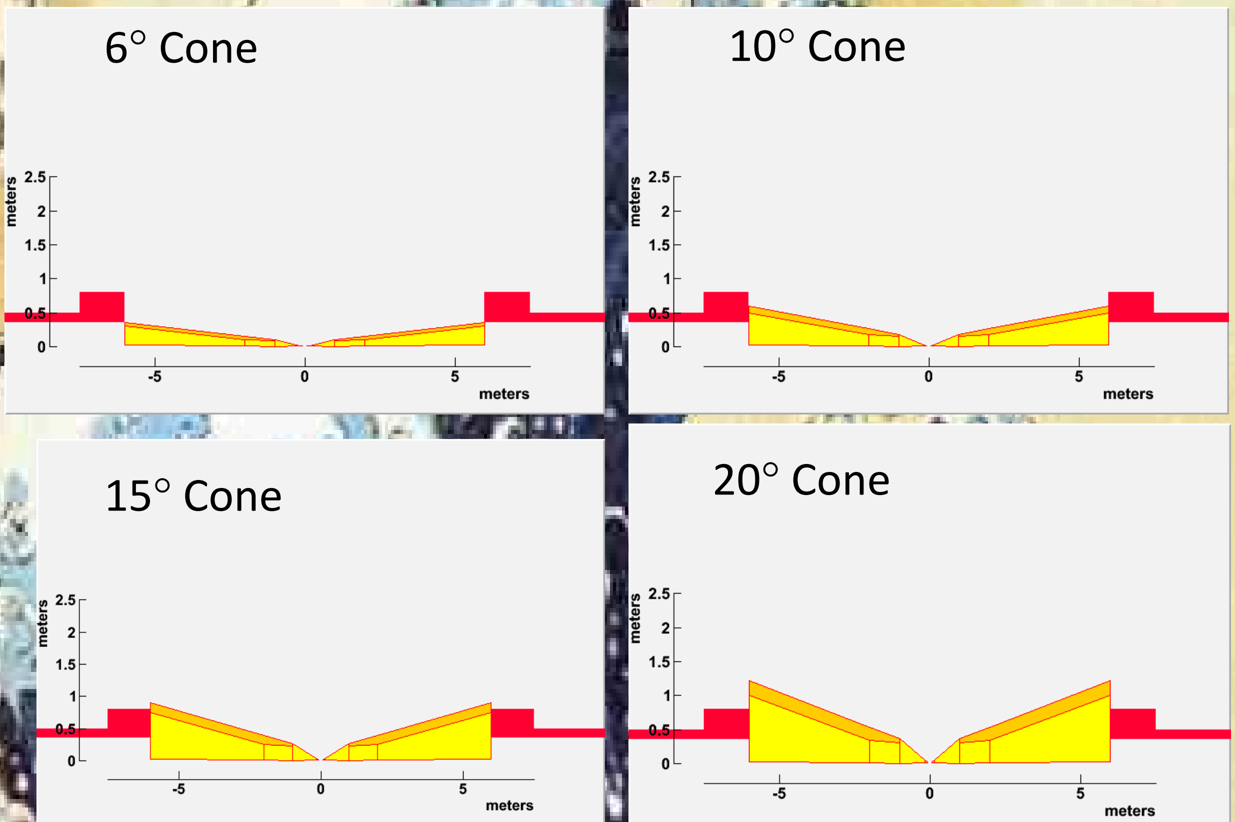






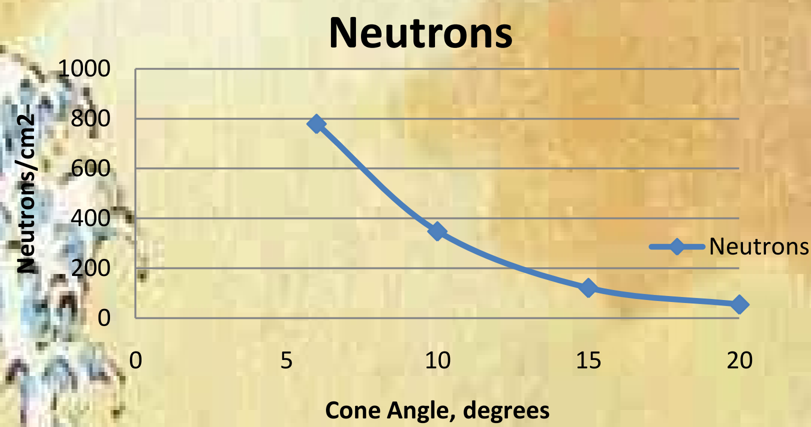
J. Kozminski

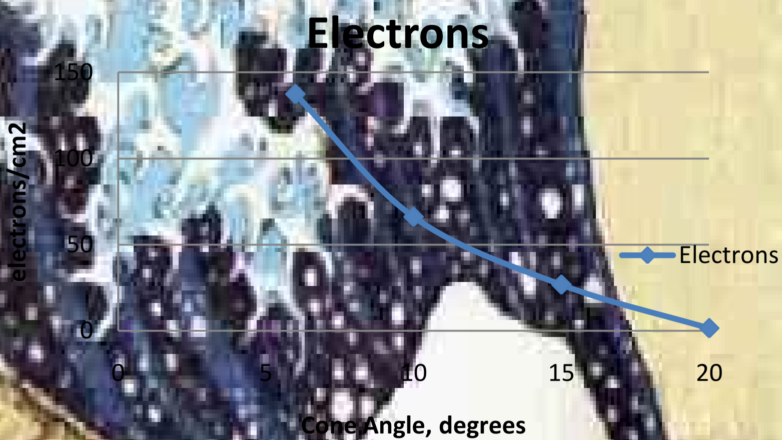
Using G4BL for Shielding Simulations



- Examine conical shielding with angles from 6° to 20°
- For each configuration we run 10 K e^+ and e^-.
    - Each run takes 3 days on the NICADD cluster
    - Minimum energy cut of 200 keV to stop tracking.
- Fluxes are scored at a 47 cm cylindrical plane.

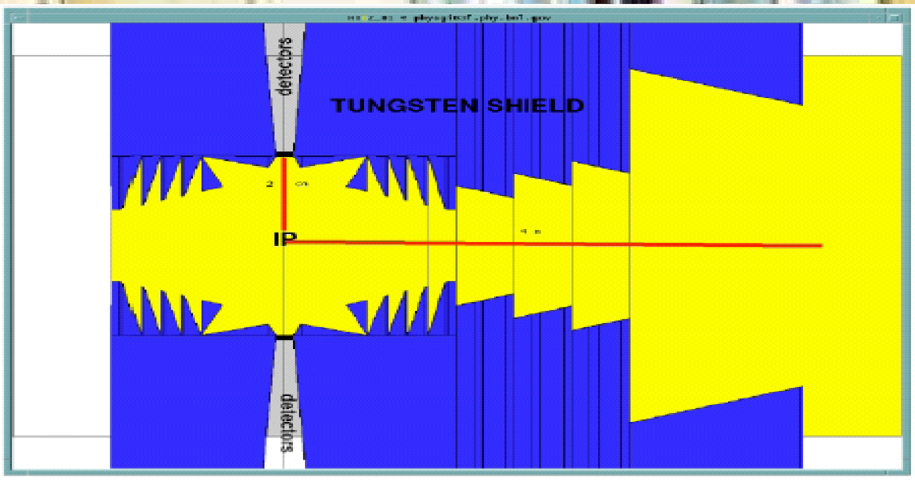
G4BL Fluxes as a Function of Conical Angle

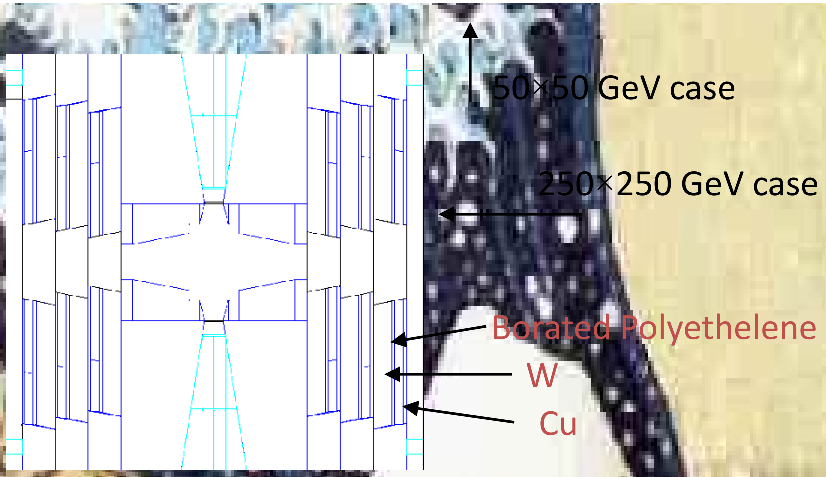




Particle fluxes at R=47 cm
Minimum particle kinetic energy: 200 keV

Interior Design of the Tungsten Shielding





- The tungsten shielding is designed so that the detector is not connected by a straight line with any surface surface hit by a decay electron in forward or backward direction.

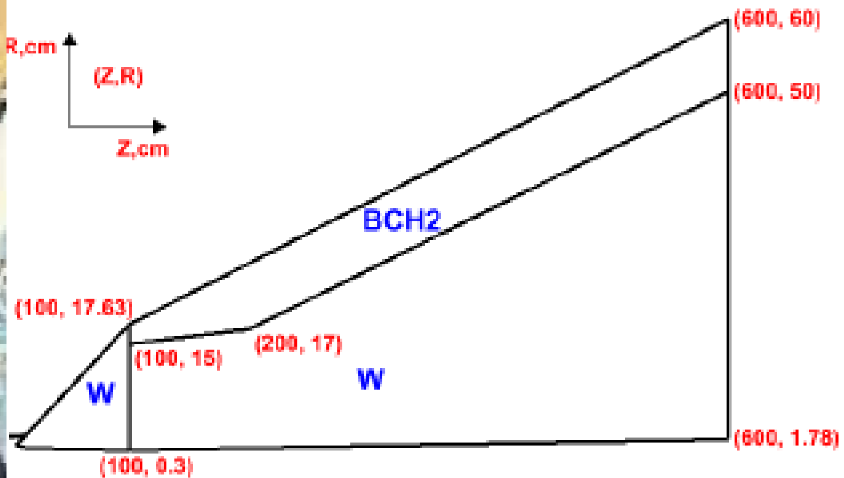
- This is from the 1996 Snowmass Muon Collider Study   6 cm by 4 m from IP

MARS simulation model

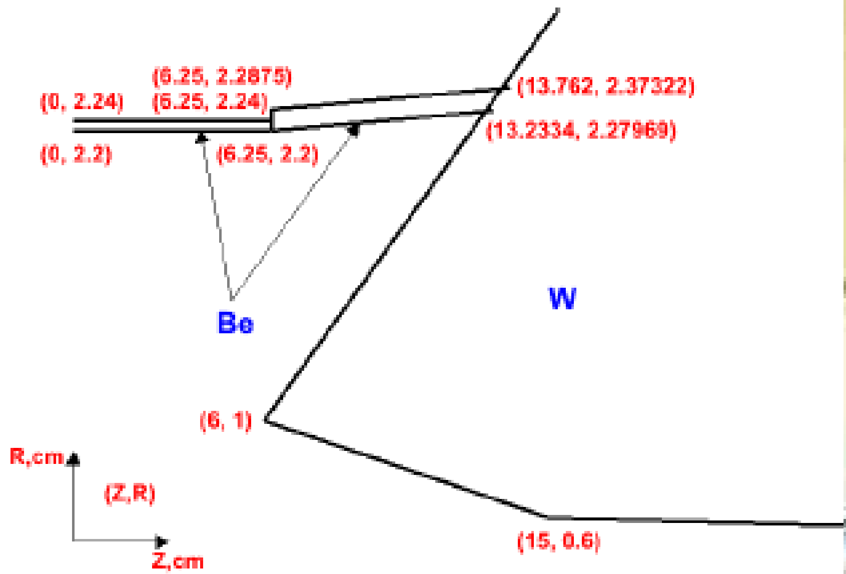
- 10^0 nozzle geometry

Nikolai Terentiev
(Carnegie Mellon U./Fermilab)

General view



Zoom in beam pipe



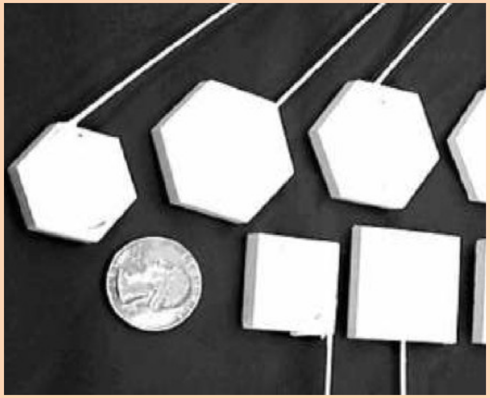
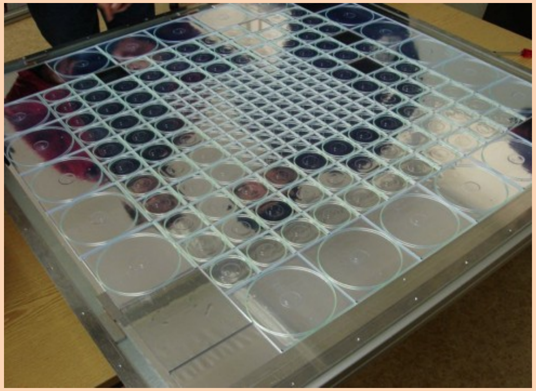
W – tungsten
Be – beryllium
BCH2 – borated polyethylene

Detector Upgrades relevant to instrumented shielding...

- Challenges:
  - Radiation hardness
  - Granularity (cross talk)
  - Time resolution
  - Temperature change

- Developments:
  - Photon detectors: Geiger-mode avalanche photo-diode
  - Calorimeters: instrumented tungsten, Fast gas-cerenkov calorimeters
  - Large-scale “pico-second” detectors: microchannel plates
  - Diamond detectors

CALICE: instrumented tungsten prototype

- Northern Illinois University (NIU) has been involved with the design and operation of a silicon-tungsten electromagnetic calorimeter and a steel-scintillator hadron shower imager as part of the CALICE test beam program at the H6B area at CERN.
- (a)  
- Figure 3 (a): Examples of plastic scintillator tiles for use in calorimeters made by the NIU group; (b): Array of scintillating tiles arranged on 1m x 1m plate of a prototype CALICE hadron calorimeter.
- Solid state detectors such as MPPCs and integrated electronics, more compact highly efficient calorimeters are now being used. Prototypes of “instrumented shielding” that could comprise a forward region muon collider detector will be designed.

Prototype Large scale "ps" timing

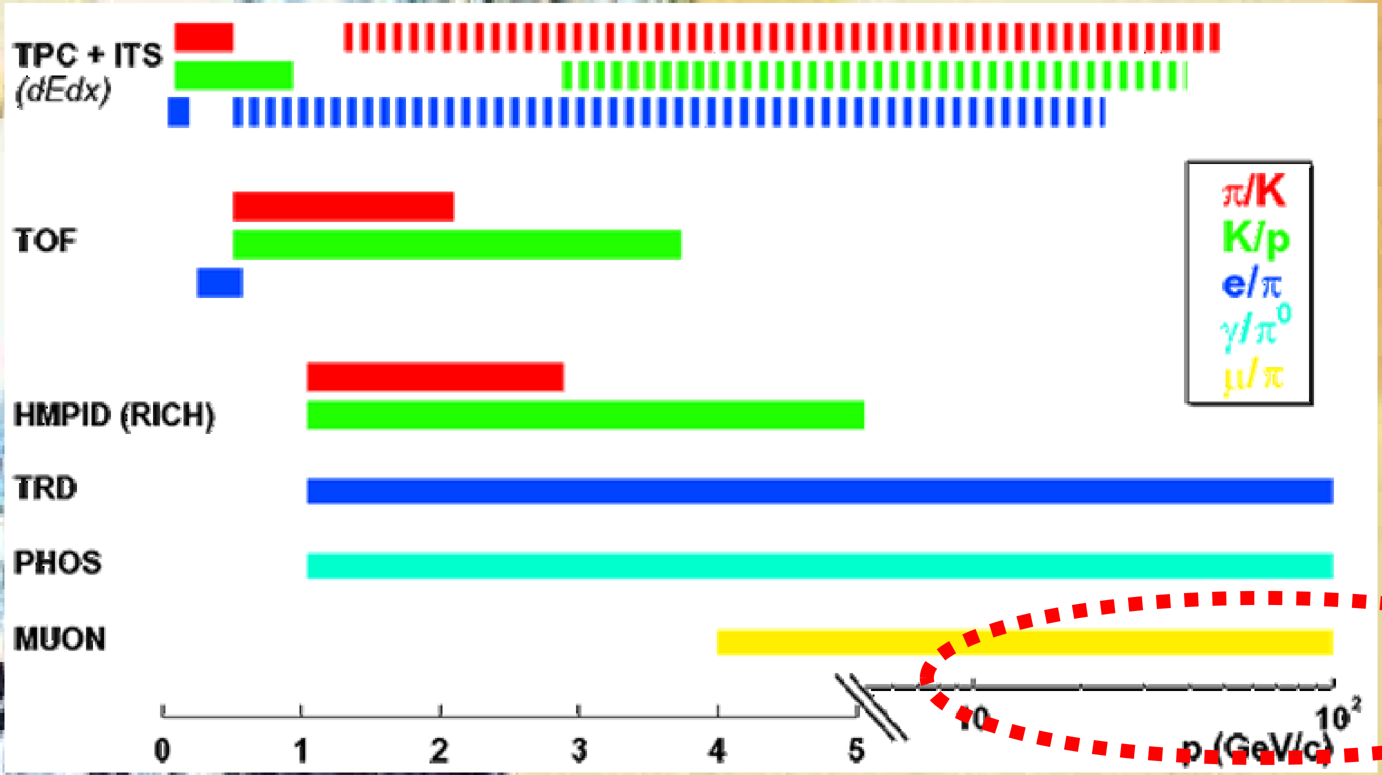
- Glass
- Cherenkov radiator
- A pair of MCPs
- 80 electronics channels
- Transmission line readout

1 tile: 20 cm by 20 cm
1 tray: 2 tiles by 3 tiles

* Developed by LAPPD (Large Area Picosecond Photo-Detectors) collaboration, lead by the University of Chicago
* See LAPPD presentations at this conference

Timing and particle ID

Detector performance in ALICE at the LHC



The ability to distinguish electrons from muons can discriminate certain SUSY events from background

Run in less than optimized mode for partial particle ID in forward cone

Luminosity Monitoring at a Muon Collider

In principal, Muon Collider physics reach can be very competitive with an ILC/CLIC...

Experiments at the e^+e^- colliders LEP and SLC have shown that the calibration of the **luminosity** and **beam energy** and **polarization** is crucial for the physics results obtained.

At LEP the luminosity was measured with small angle silicon based calorimeters, counting Bhabha events to a precision of **$\Delta L/L = 10^{-3}$**, measured down to angles of about 30 mrad with respect to the beam direction.

For muon collider, measuring the muon Bhabha cross section down to small angles will be a challenge . This will require a novel redesign of the forward shielding, and other options for luminosity monitoring!

Diamond and Gas Cerenkov detectors

ATLAS

- Diamond was chosen as the detector material because of the fast signal collection and radiation hardness required
- The sensors are required to tolerate doses up to 500 kGy and in excess of 10^{15} charged particles per cm^2 over the lifetime of the experiment
- Detectors plus electronics must have excellent time resolution (~1 ns rise time, 2-3 ns pulswidth, 10 ns baseline restoration in ATLAS required ~ 80 ps for MC)

- LUCID forward detector gas cerenkov …how far to push to the rates?

Ending notes on these efforts…

- Much progress toward Muon Colliders since the 1996 Study.
- Background studies are tackling the primary drawback to a MC vs. e+ e- machine.
- The detector design and the MC lattice design are critically dependent on each other.
- Robust simulations will be critical – and the methods are facilitating collaboration between machine, detector and theorists (unique feature of the MC group!)
- Many promising technologies… but much more innovation needed.