Detector response simulation using lcsim

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Muon Collider meeting
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The Road to Telluride

Physics & Detector Goals

1. Outline physics scenarios potentially relevant to future lepton colliders at centre-of-mass energies from M_{Higgs} to multi-TeV and define their distinctive physics signatures. Characterise these physics scenarios in relation to the LHC and Tevatron data to be collected by the end of 2012 and highlight how these data may (or may not) help defining the energy (and luminosity) of interest for a future lepton collider.
2. Characterize the muon collider potential for the above physics scenarios. Assess how this potential depends on luminosity, beam energy resolution and forward cone angle. Assess how this physics reach might be affected by the machine induced backgrounds, by limitations tuning the beam energy, and expected small polarization of initial beams.
3. Propose an event simulation and reconstruction framework suitable for the MuC studies and determine its relation with the program being developed for the LC studies.
4. Propose a conceptual detector design suited for physics at a MuC sketch a program of benchmark studies for its optimisation, compare it to the LHC, ILC and CLIC detector concepts and determine how this design evolves with the collider energy.
5. Assess the areas where dedicated R&D on sensors and detector systems is required for a MuC and highlight the areas of synergy and complementarity with R&D ongoing or planned for an LHC upgrade, for the ILC and for CLIC.

slic & lcsim

- The detector response program slic and the event reconstruction package org.lcsim have been described a number of times at various Muon Collider meetings.
- This presentation builds on that knowledge and presents a path forward for Muon Collider Detector (MCD) studies.
- Expect this to culminate in detector designs which can be used to study the physics scenarios in the presence of the collider backgrounds.

Detector Designs

- Detector designs for the ILC, and to a somewhat lesser extent CLiC, are quite mature.
  - Based on a decade of studies starting from Snowmass 2001 to the ILC LOI
  - Continuing on to the CliC CDR and ILC DBD
  - Emphasis has been on precision physics in the presence of low and well-understood backgrounds.
- Muon Collider Detector design essentially just starting.
  - Major difference is the enormous machine backgrounds
  - Need to start from the basics.

Detectors in slic

- All details of the detectors are specified in a compact xml file format, allowing many designs to be studied without having to write or compile any C++ code or know anything about the details of Geant4.
- Generic Calorimeter and Tracker Hits are written out.
  - Charge evolution and digitization deferred to reconstruction phase.
  - Very detailed studies of readout technologies supported out-of-the-box.
    - Others can implement API.

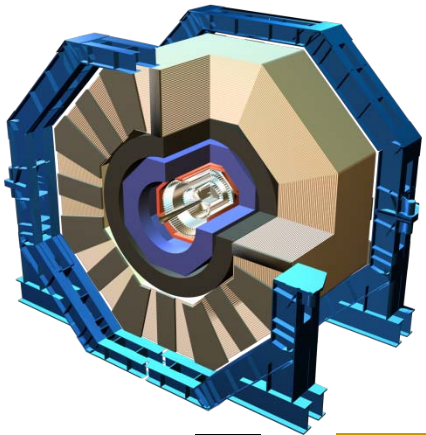
Detector Variants

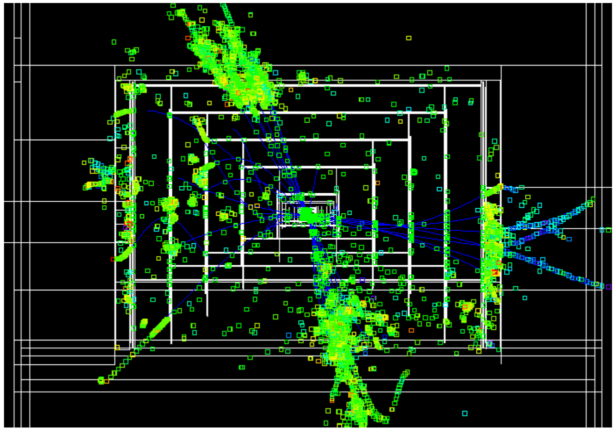
- Runtime XML format allows variations in detector geometries to be easily set up and studied:
  - Sampling calorimeters:
    - Absorber materials, dimensions
    - Readout technologies, e.g. RPC, GEM, scintillator
    - Layering (radii, number, composition)
    - Readout segmentation (size, projective vs. nonprojective)
  - Total absorption crystal calorimeters
    - Optical properties
  - Tracking detector technologies & topologies
    - TPC, silicon microstrip, silicon pixels

ILC Full Detector Concepts

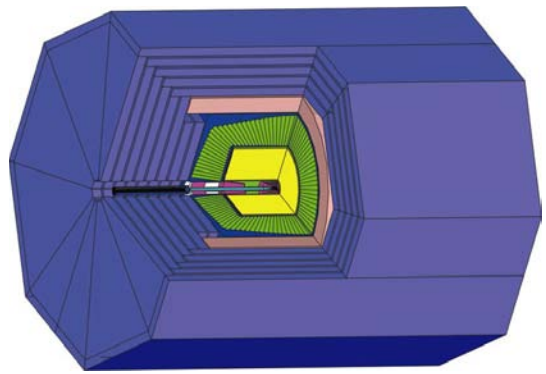
Same executable, different runtime input files

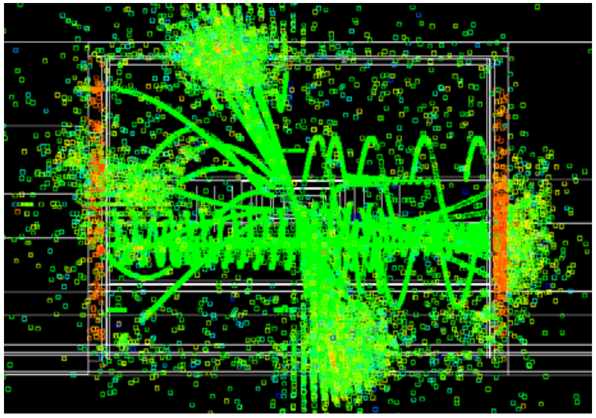
SiD



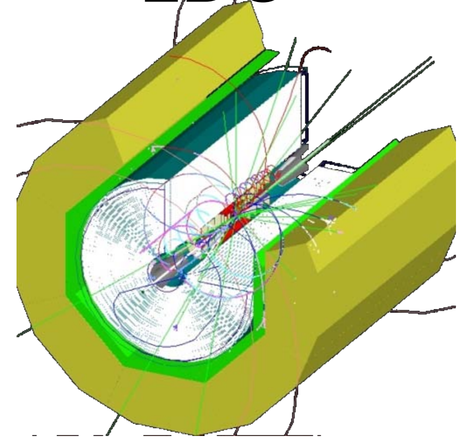


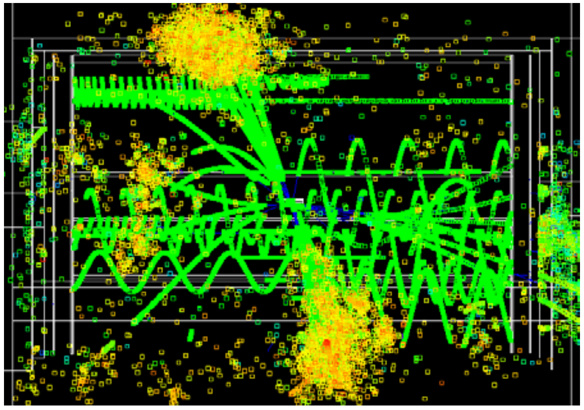
GLD



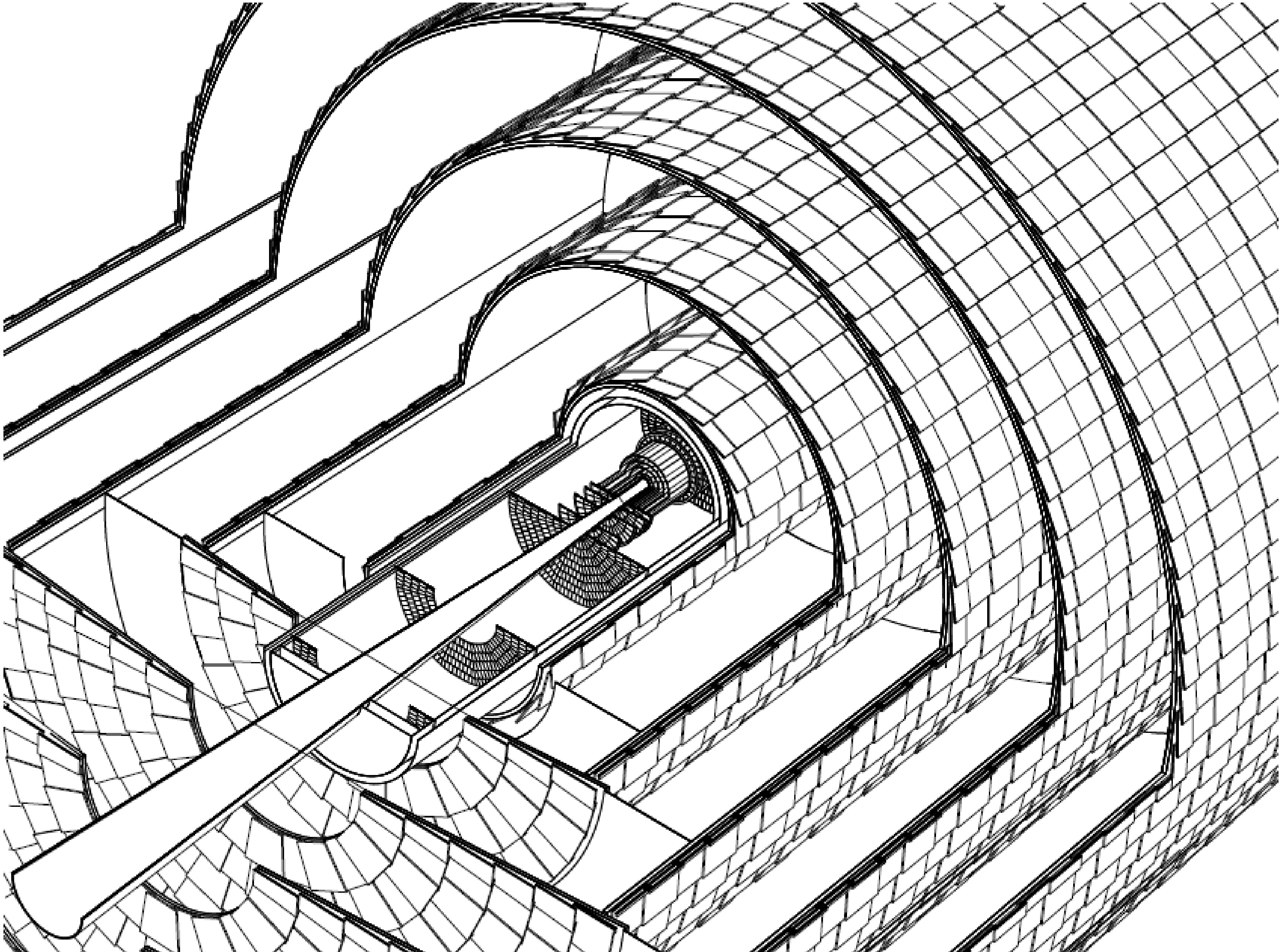


LDC





Level of Detail in Silicon Tracker



Design Strategy I

- Both SiD and ILD designs are very mature and simulations reflect a high level of detail.
  - based on years of simulations, hardware R&D and engineering
- CLiC detectors for the CDR are variations on the ILC design.
  - Environments are not too different
  - “Adopt, adapt, improve” workable paradigm

Design Strategy II

- Muon Collider environment, however, is quite different.
- Simply plugging in an ILC-like detector not appropriate for the extremely high backgrounds.
  - Radiation-hard trackers introduce significantly more material.
  - Higher occupancies from backgrounds require better segmentation than current designs.
  - Precision “imaging” calorimetry may not be possible in MuC environment

Design Strategy III

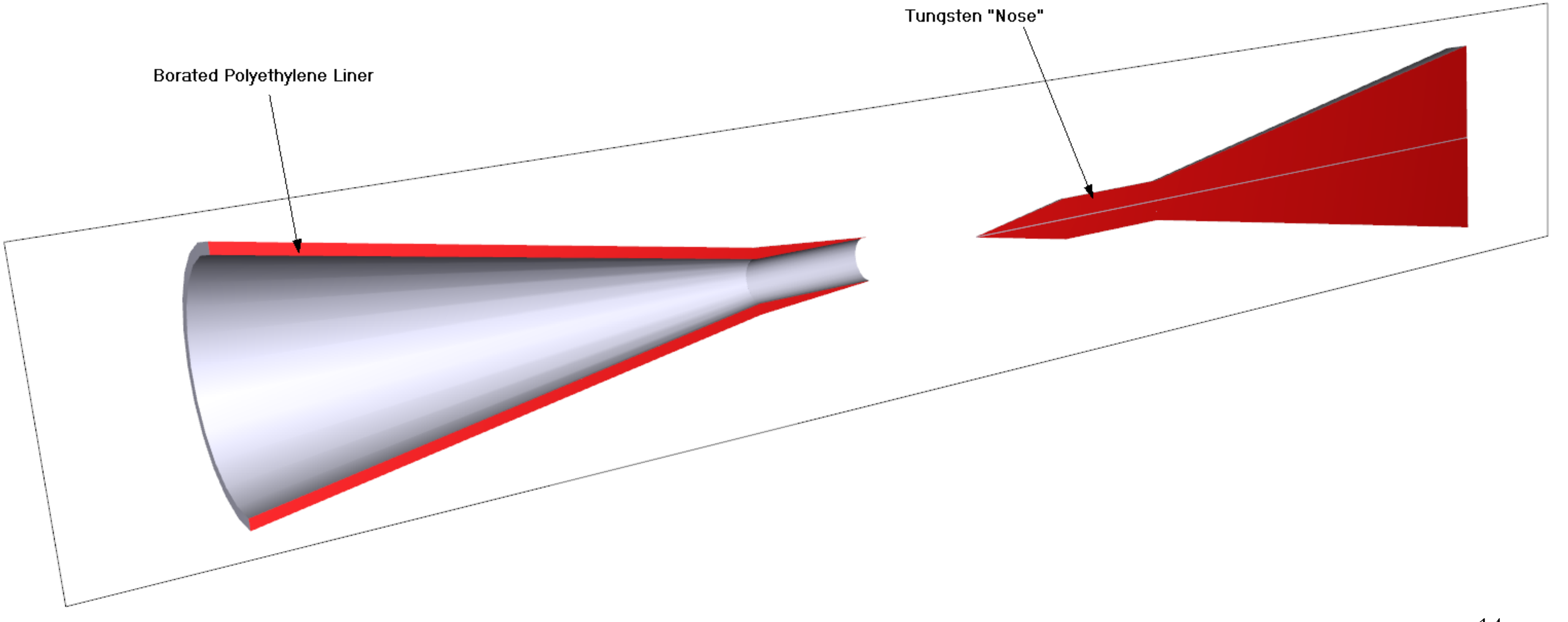
- Instead of trying to adopt a detailed ILC/CLiC detector design for the MuC studies for/at Telluride, suggest working from the ground up.
- Study simple detector designs in the presence of full machine backgrounds.
- Use information gained on particle fluxes and detector occupancies at each level of detail to inform detector technology choices for next level of realism.

mcd00 proposal

- Tracker
  - Cylindrical shells in barrel
  - Disks in forward regions
  - Simple “pixel” digitization
    - rφ-z and x-y smearing
- Calorimeters
  - Layered calorimeters composed of pure, but “live” absorber material.
    - Can be used to calculate energy deposits and study basics of reconstruction without worrying about details of readout.
- Forward Shielding
  - Tungsten “cone” with borated polyethylene cladding.

mcd00 Shielding

- “Nose” fully defined and configurable by specifying zplanes (z, r_{min}, r_{max}) for the surface of revolution about the z axis.
- Trivial to study multiple setups.



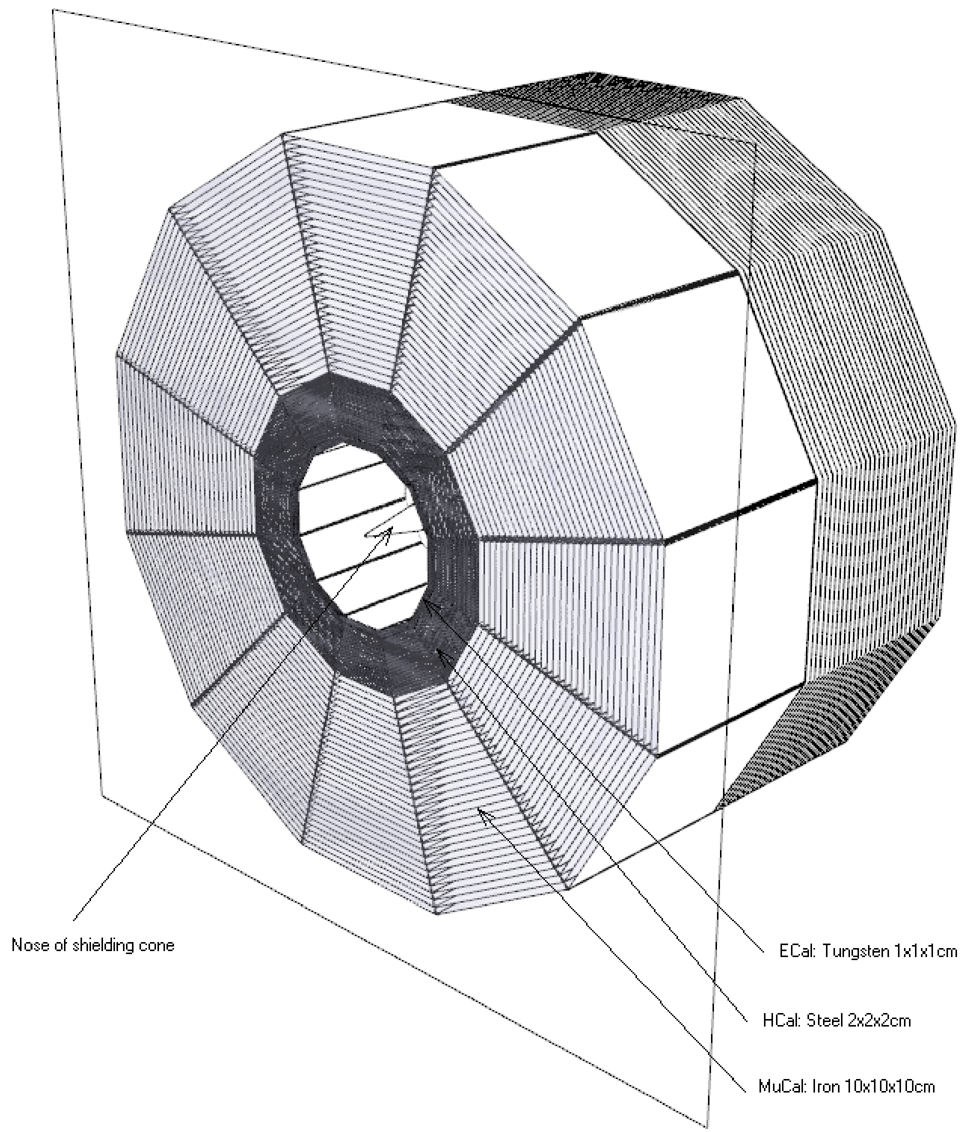
mcd00 Shielding

```
<detector name="ForwardM1" type="PolyconeSupport"
  insideTrackingVolume="true">
      <material name="Tungsten"/>
      <zplane rmin = "0.4*cm" rmax="0.4*cm" z="6.0*cm" />
      <zplane rmin="0.4*cm" rmax="17.3*cm"  z="100.0*cm"/>
      <zplane rmin="0.4*cm" rmax="17.0*cm"  z="100.0*cm"/>
      <zplane rmin="0.4*cm" rmax="17.0*cm"  z="199.99*cm"/>
   </detector>
   <detector name="ForwardM1Poly" type="PolyconeSupport"
  insideTrackingVolume="true">
      <material name="BoratedPolyethylene5"/>
      <zplane rmin = "17.0*cm" rmax="17.3*cm" z="100.0*cm" />
      <zplane rmin="17.0*cm" rmax="25.7*cm"  z="199.99*cm"/>
   </detector>
```

mcd00 Calorimetry

- ECal:
  - Tungsten, 10 1cm layers, giving 1x1x1cm cells
- HCal:
  - Steel, 40 2cm layers, giving 2x2x2cm cells
- MuCal:
  - Iron,30 10cm layers, giving 10x10x10cm cells
- Dodecagonal Barrels with endcaps
- HCal and Muon has projective staves
- ECal has overlapping staves

mcd00 Calorimetry



compact.xml Barrel Calorimeter

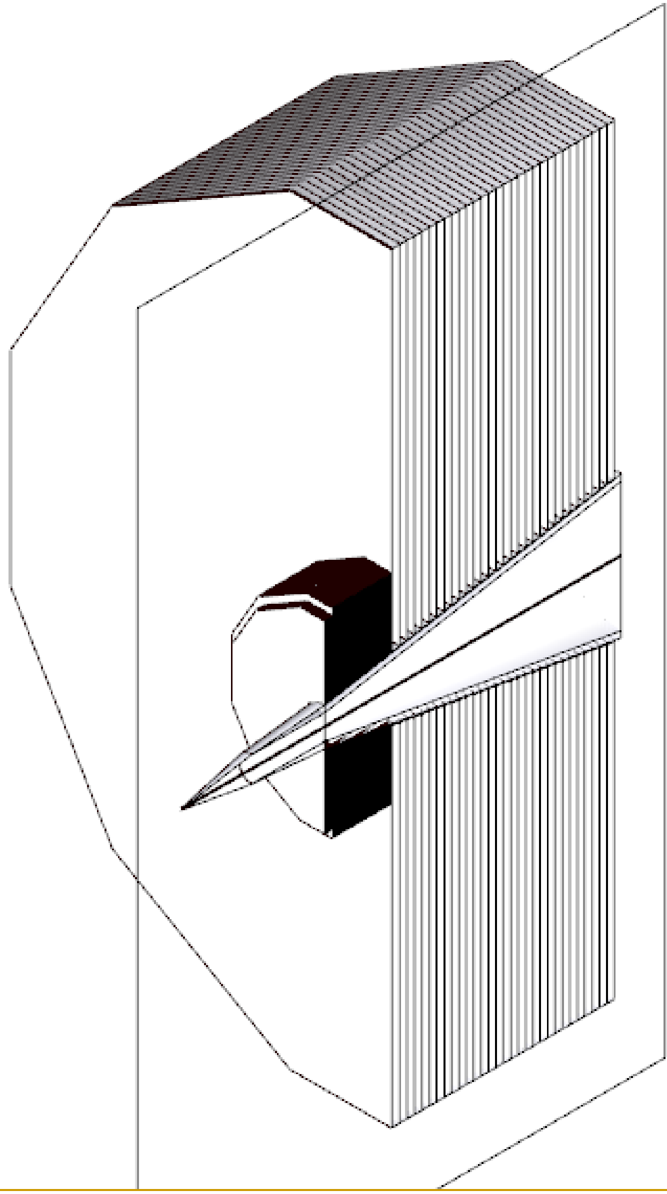
```
<detector id="7" name="HcalBarrel“
  type="PolyhedraBarrelCalorimeter2"
  readout="HcalBarrelHits"
  calorimeterType="HAD_BARREL" gap="0.*cm"
  material="Steel235">
  <dimensions numsides="12" rmin="135.5*cm"
  z="290.0*cm * 2"/>
  <staves />
  <layer repeat="40">
  <slice material="Steel235" thickness="2.0*cm"
  sensitive="yes" />
  </layer>
</detector>
```

compact.xml Readout Definition

```
<readout name="HcalBarrelHits">
        <segmentation type="CartesianGridXY" gridSizeX="2.0*cm" gridSizeY="2.0*cm" />

 <id>system:6,barrel:3,module:4,layer:6,slice:5,x:32:-16,y:-16</id>
</readout>
```

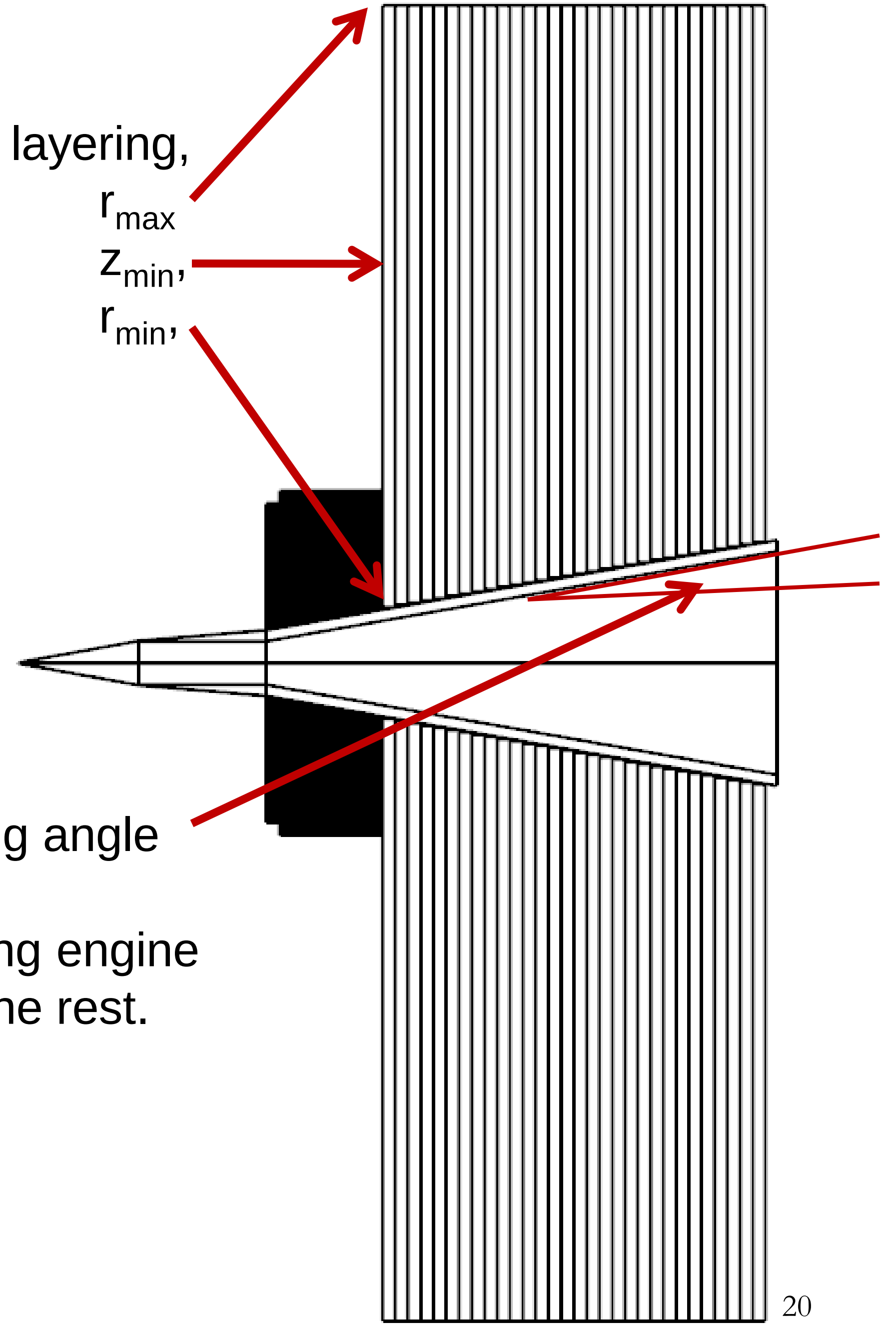
Endcaps



Define layering,
r_{max}
z_{min},
r_{min},

opening angle

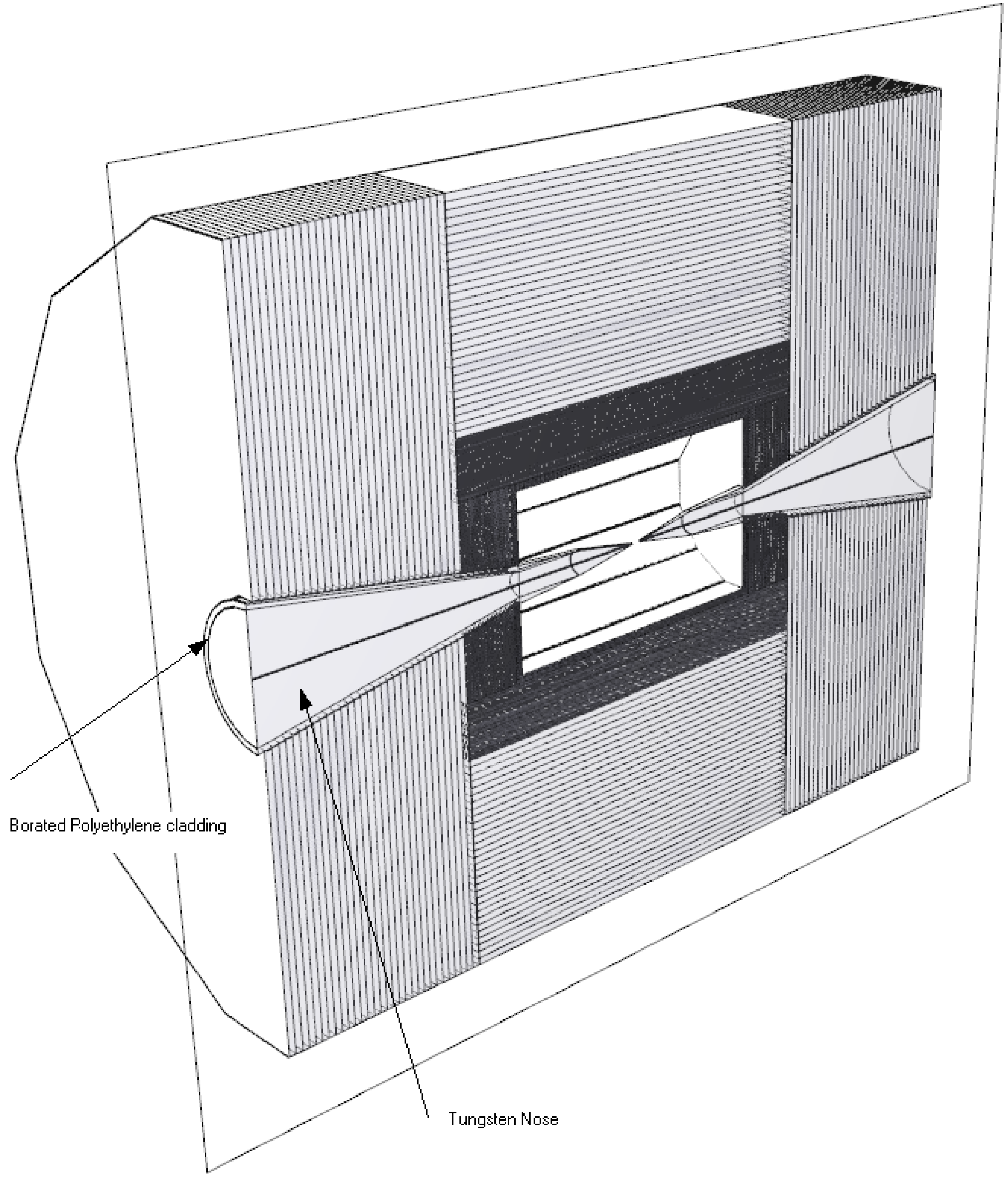
Layering engine does the rest.



compact.xml Endcap Calorimeter

```
<detector id="10" name="MuonEndcap"
  type="PolyhedraEndcapCalorimeter3"
  readout="MuonEndcapHits" reflect="true"
  calorimeterType="MUON_ENDCAP">
 <comment>Muon Calorimeter Endcaps</comment>
 <dimensions numsides="12" zmin="291.*cm"
  rmin="42.*cm" rmax="515.*cm" angle="10.*deg" />
   <layer repeat="30">
   <slice material="Iron" thickness="10.0*cm"
  sensitive="yes"/>
   </layer>
</detector>
```

mcd00 Calorimetry



mcd00 to mcdnn

- Less than 200 lines of text (including comments!) fully define this detector.
- Trivial to script a study of a whole series of detectors, varying
  - Calorimeter materials, layering, readout
  - Overall detector dimensions, aspect ratio
  - Shielding nose configuration
  - Tracker dimensions, layout, number of layers
  - Magnetic field strength
  - Any other detector parameters

Event Generation

- Concentrate on backgrounds
  - Signal events insignificant
- Input particles from muon bunches available from MARS simulations
- ASCII text files converted into stdhep files
  - Currently simply keep weights.
    - Can be modified to generate NWEIGHT additional particles
  - Break 40 million particle file into smaller files
    - Based on particle type
    - Based on the number that can be simulated in batch time
- Machinery to add and overlay events exists.

Detector Response Simulation

- Start with simple occupancies / fluxes
  - Can use Geant4-supplied scoring meshes to accumulate a number of different quantities.
  - runtime macros with no output.
- Conduct some basic shielding and detector design based on these simple scoring quantities
- Once a baseline detector has been sketched out, write out LCIO collections of SimTrackerHits and CalorimeterHits.
  - Proceed to reconstruction phase.

Getting started with mcd00

- Detector essentially sketched out, details being filled in.
- Once completed, background events will be processed and made available to the community.
- MuC-specific documentation, examples and tutorials being developed.
- Code and executables, along with data samples, will be updated on Fermi cluster.
- Need feedback from interested individuals and detector groups!