

Muon Collider Detector Studies

A. Mazzacane

On behalf of MARS15 simulation group:

N. Mokhov, S. Striganov

And the ILCroot simulation group:

V. Di Benedetto, C. Gatto,

F. Ignatov, N. Terentiev

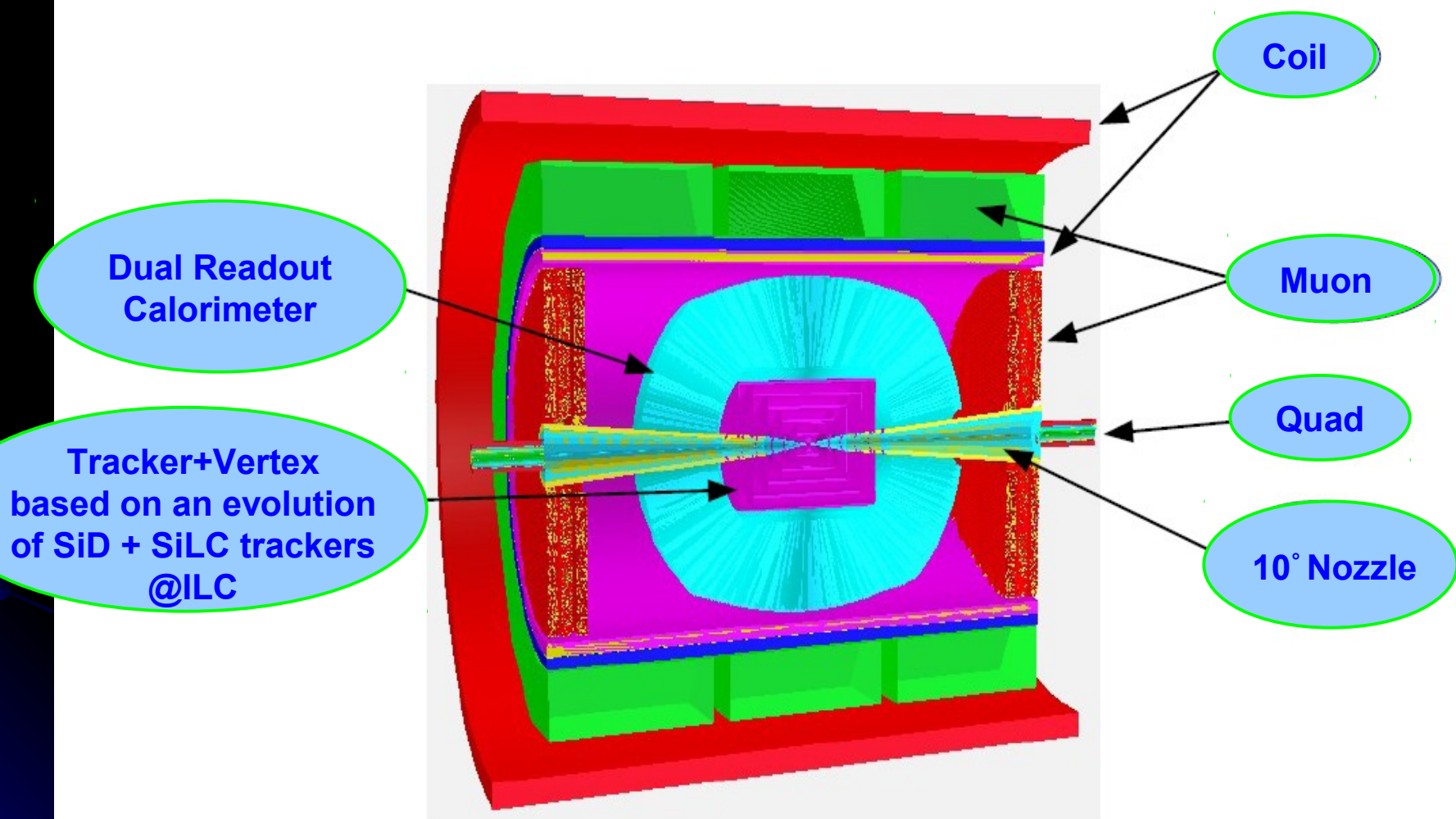
Outline

- Detector challenges at a Muon Collider experiment.
- Baseline detector for Muon Collider studies + MDI.
- ILCroot and MARS frameworks.
- Beam background studies in:
 - Si Tracking system.
 - Dual-Readout calorimeter.
- Preliminary physics studies at 1.5 TeV machine.
- Future prospects.
- Conclusions.

Main Detector Challenges

- Many challenges to build an experiment at a precision machine.
- One of the most serious technical issues in the design of a Muon Collider experiment is the background.
- The major source come from muon decays:
for 750 GeV muon beam with 2×10^{12} muons/bunch $\sim 4.3 \times 10^5$ decays/m.
- Large background is expected in the detector.
- The backgrounds can spoil the physics program.
- The Muon Collider physics program and the background will guide the choice of technology and parameters for the design of the detector.

Baseline Detector for Muon Collider Studies

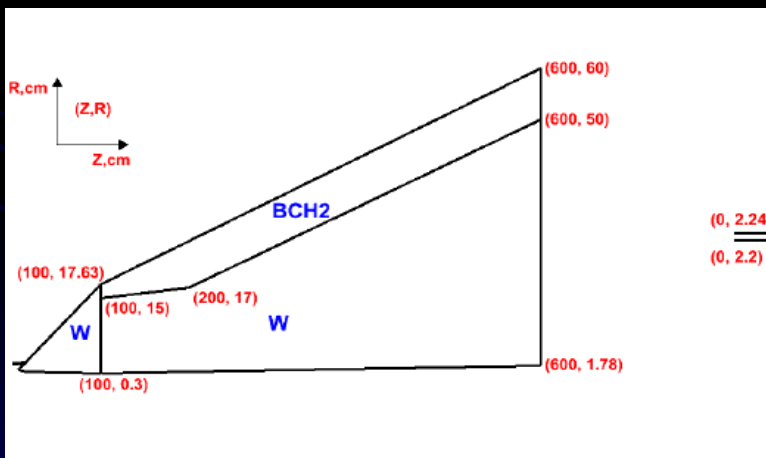


Vertex Detector (VXD)

10° Nozzle and Beam Pipe

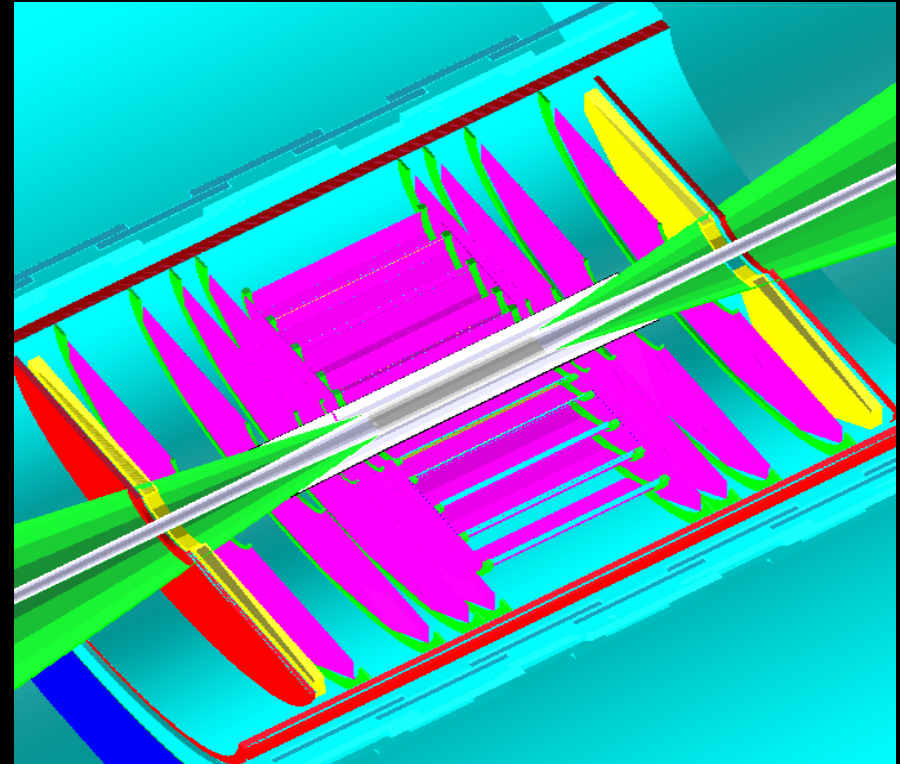
VXD

- 100 μm thick Si layers
- 20 μm x 20 μm Si pixel
- Barrel : 5 layers subdivided in 12-30 ladders
- $R_{\min} \sim 3 \text{ cm}$ $R_{\max} \sim 13 \text{ cm}$ $L \sim 13 \text{ cm}$
- Endcap : 4 + 4 disks subdivided in 12 ladders
- Total length 42 cm



NOZZLE

- W - Tungsten
- BCH2 – Borated Polyethylene



PIPE

- Be – Beryllium 400 μm thick
- 12 cm between the nozzles

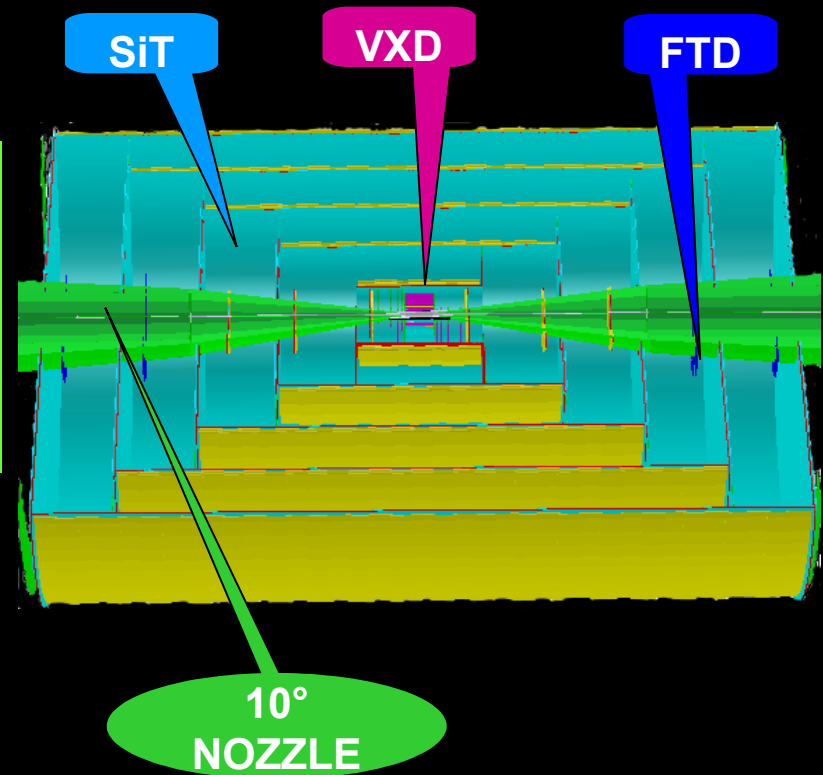
Silicon Tracker (SiT) and Forward Tracker Detector (FTD)

SiT

- 100 μm thick Si layers
- 50 μm x 50 μm Si pixel (or Si strips or double Si strips available)
- Barrel : 5 layers subdivided in staggered ladders
- Endcap : (4+2) + (4+2) disks subdivided in ladders
- $R_{\text{min}} \sim 20 \text{ cm}$ $R_{\text{max}} \sim 120 \text{ cm}$ $L \sim 330 \text{ cm}$

FTD

- 20 μm x 20 μm Si pixel
- Endcap : 3 + 3 disks
- Distance of last disk from IP = 190 cm



- Silicon pixel for precision tracking amid up to 10^5 hits
- Tungsten nozzle to suppress the background

MARS and ILCroot Frameworks

MARS – the framework for simulation of particle transport and interactions in accelerator, detector and shielding components.

- New release of MARS15 available since February 2011 at Fermilab (N. Mokhov, S. Striganov, see www-ap.fnal.gov/MARS)
- Among new features:
 - Refined MDI (Machine Detector Interface) with a 10° nozzle
 - Significant reduction of particle statistical weight variation
 - Background is provided at the surface of MDI (10° nozzle + walls)

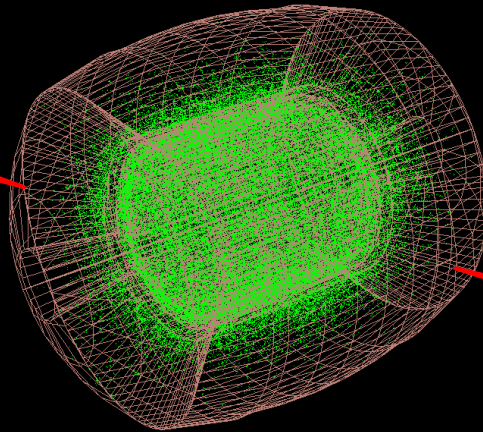
ILCroot - Software architecture based on ROOT, VMC & Aliroot

- All ROOT tools are available (I/O, graphics, PROOF, data structure, etc)
- Extremely large community of ROOT users/developers
- It is a simulation framework and an offline system:
 - Single framework, from generation to reconstruction and analysis!!
 - Six MDC have proven robustness, reliability and portability
 - VMC allows to select G3, G4 or Fluka at run time (no change of user code)
- Widely adopted within HEP community (4th Concept, LHeC, T1015, SiLC)
- It is publicly available at FNAL on ILC SIM since 2006

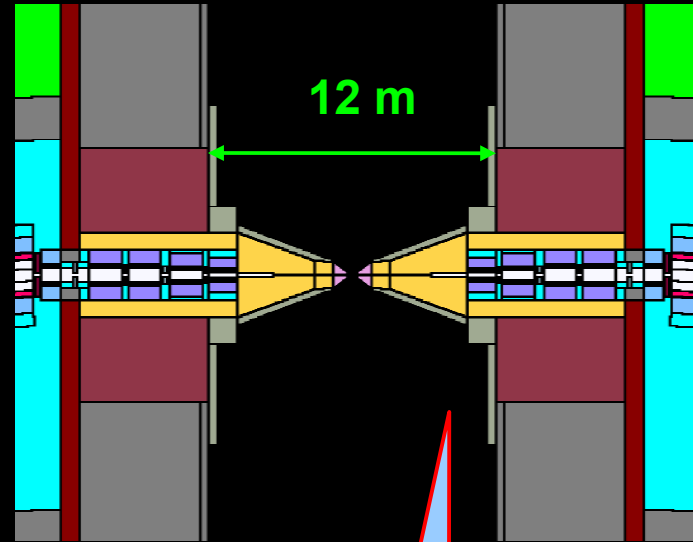
Ingredients for these Studies

- MARS background provided at the surface of MDI (10° nozzle + walls)
- GEANT4 simulated particles in the detector (background + single muons from the I.P.)

Only 4% background pictured



Hits in the calorimeter



- Reconstructed tracks from a parallel Kalman Filter in a 3.5 T B-field
- Reconstructed energy towers from a Dual Readout calorimeter

Source term at black hole to feed detector simulation

Tracking System Studies: Nozzle Effects on Tracking Performance

Hits densities in the vertex and the tracker detector

See N. Terentiev's talk

Reconstruction Efficiency & Resolutions

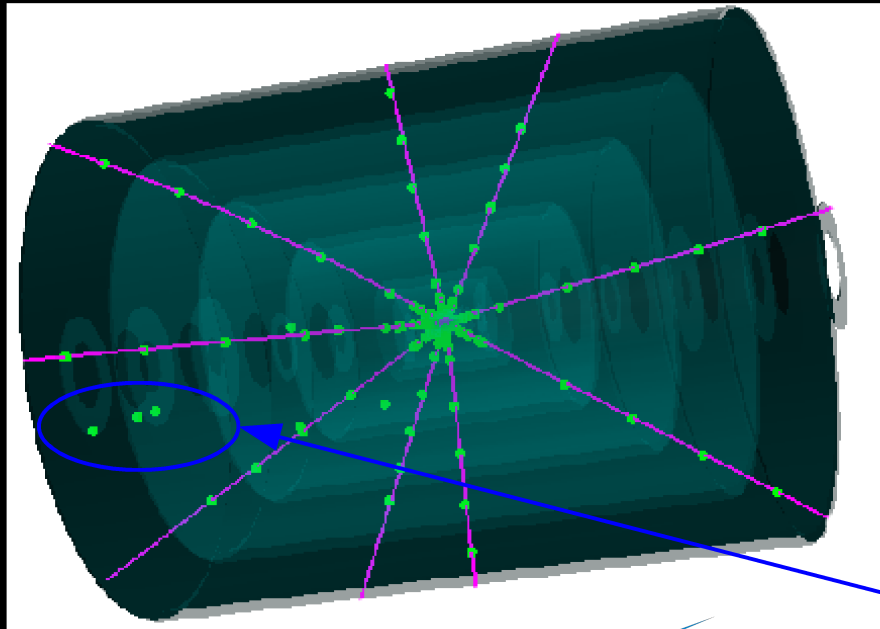
$$\epsilon_{tot} = \frac{\text{reconstructed tracks}}{\text{generated tracks}} = \epsilon_{geom} * \epsilon_{track}$$

$$\epsilon_{geom} = \frac{\text{reconstructable tracks}}{\text{generated tracks}}$$

$$\epsilon_{track} = \frac{\text{reconstructed tracks}}{\text{reconstructable tracks}}$$

Defining “reconstructable tracks” (candidate for reconstruction)
tracks with $DCA(true) < 3.5$ cm
AND
at least 4 hits in the detector

Effect of the 10° nozzle

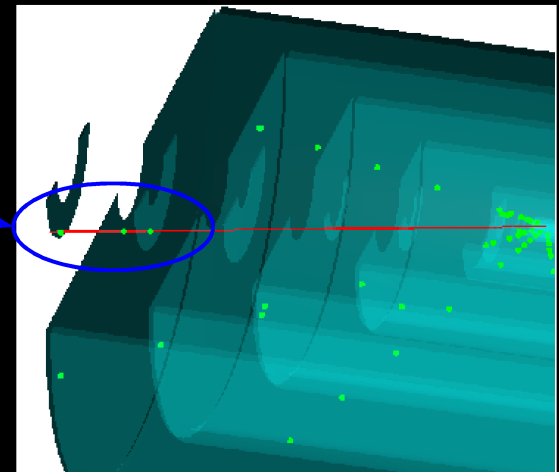


ILCroot event display
for 10 muons up to 200 GeV

green - hits

purple - reconstructed tracks

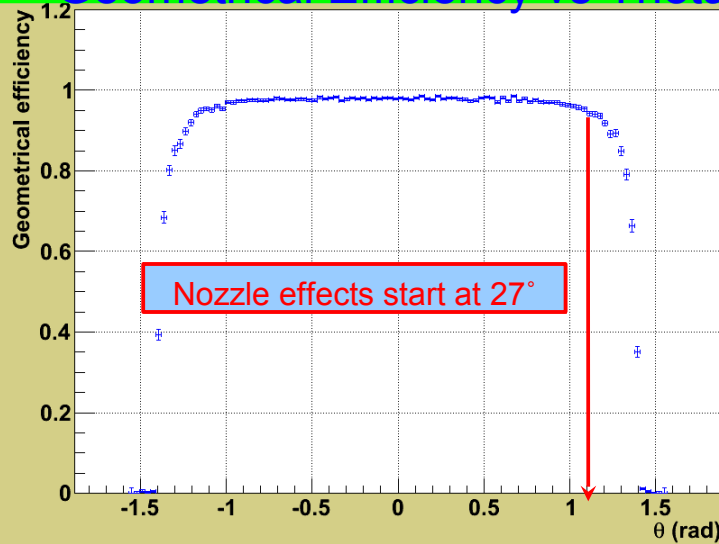
red - MC particle



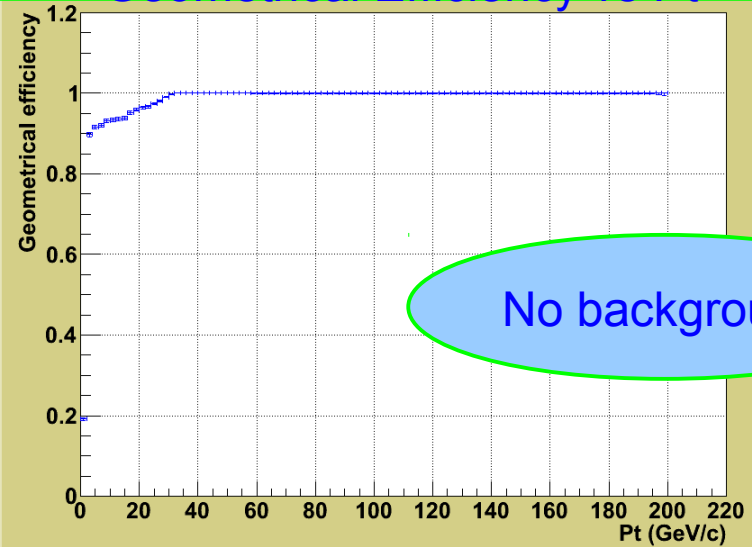
10 generated muons
9 reconstructed tracks

Reconstruction Efficiency for Single Muons

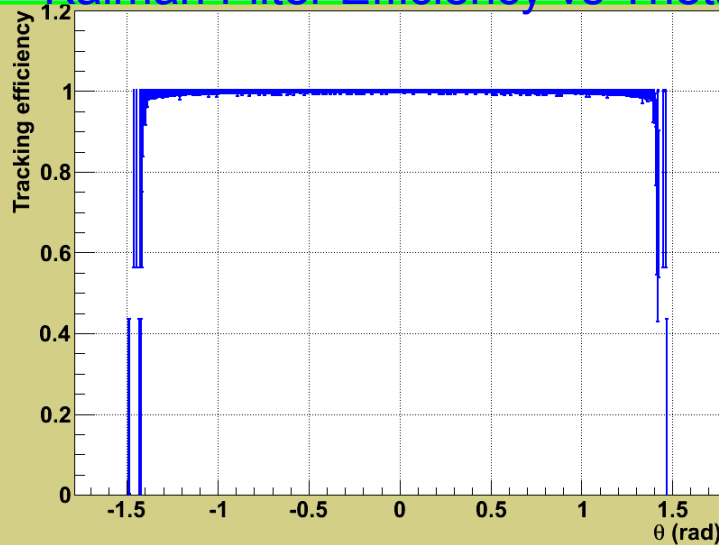
Geometrical Efficiency vs Theta



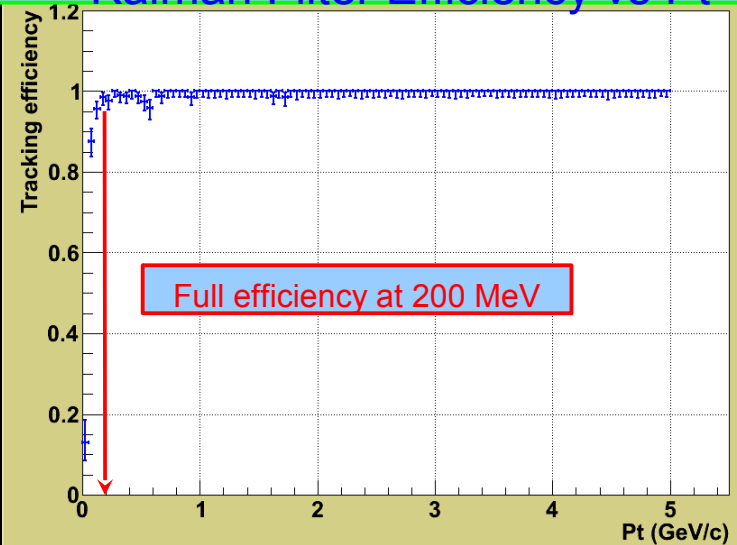
Geometrical Efficiency vs Pt



Kalman Filter Efficiency vs Theta

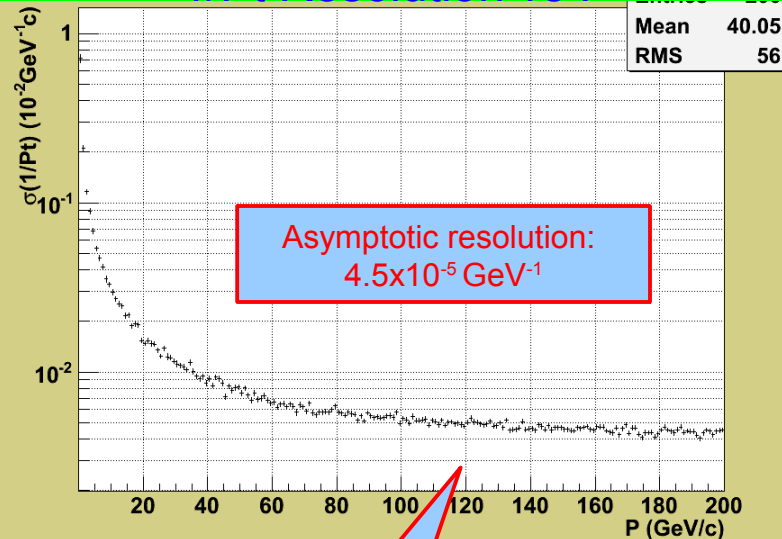


Kalman Filter Efficiency vs Pt

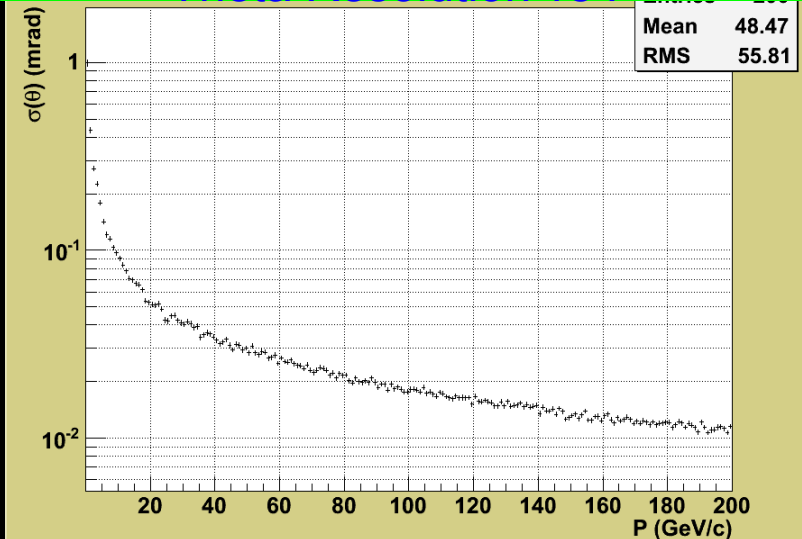


Resolutions for single muons

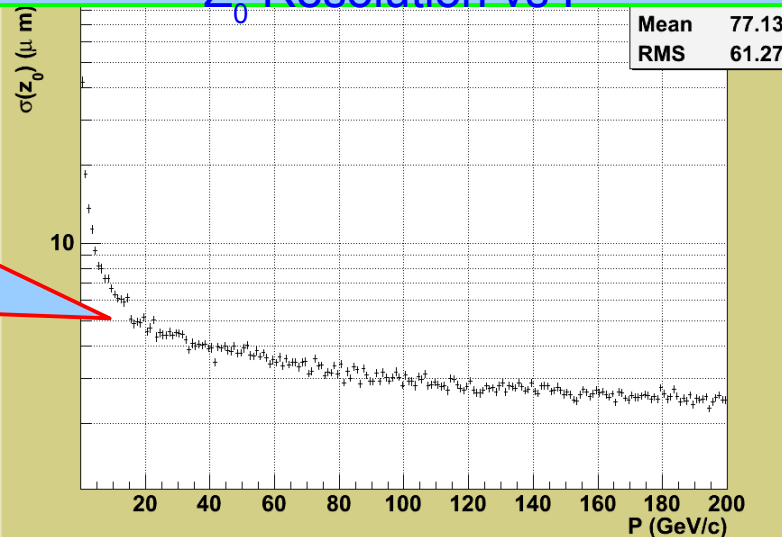
1/Pt Resolution vs P



Theta Resolution vs P



Z_0 Resolution vs P

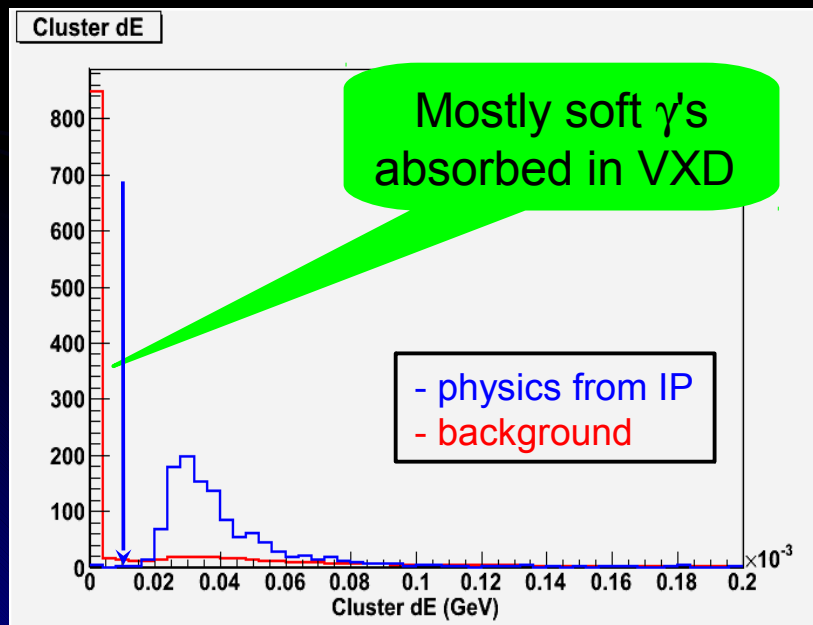


Well within requirements for precision physics

No background

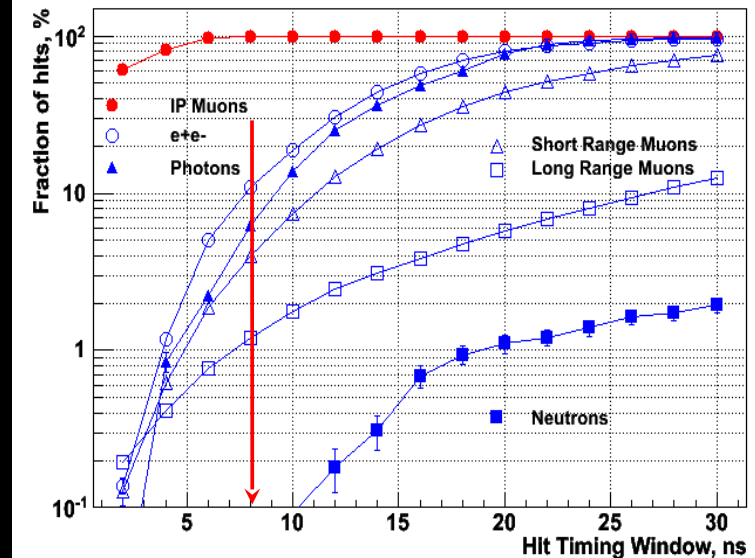
Strategies to reduce clusters in the tracking system produced by the background

	Kalman Reconstruction	Clusters
Physics: 100 μ (0.2-200) GeV/c	92 (include geom. eff.)	1166
Machine Background	-	4×10^7



ΔE threshold 10 KeV (2400 e-)

See N. Terentiev's talk



Cluster timing cut:: 7ns

Beam Background Studies in Tracking System

- Simulated in ILCroot 4 detectors with different timing capabilities:
 - **Det. A** – No time information (integrates all hits).
 - **Det. B** – Acquires data in a fixed 7 ns time gate (minimal timing capabilities).
 - **Det. C** - Acquires data in a 3 ns time gate tuned to distance from IP (advanced timing capabilities).
 - **Det. D** - Acquires data in a 1 ns time gate tuned to pixel distance from IP (extreme timing capabilities.)

Reconstructed Background Tracks (from Kalman filter)

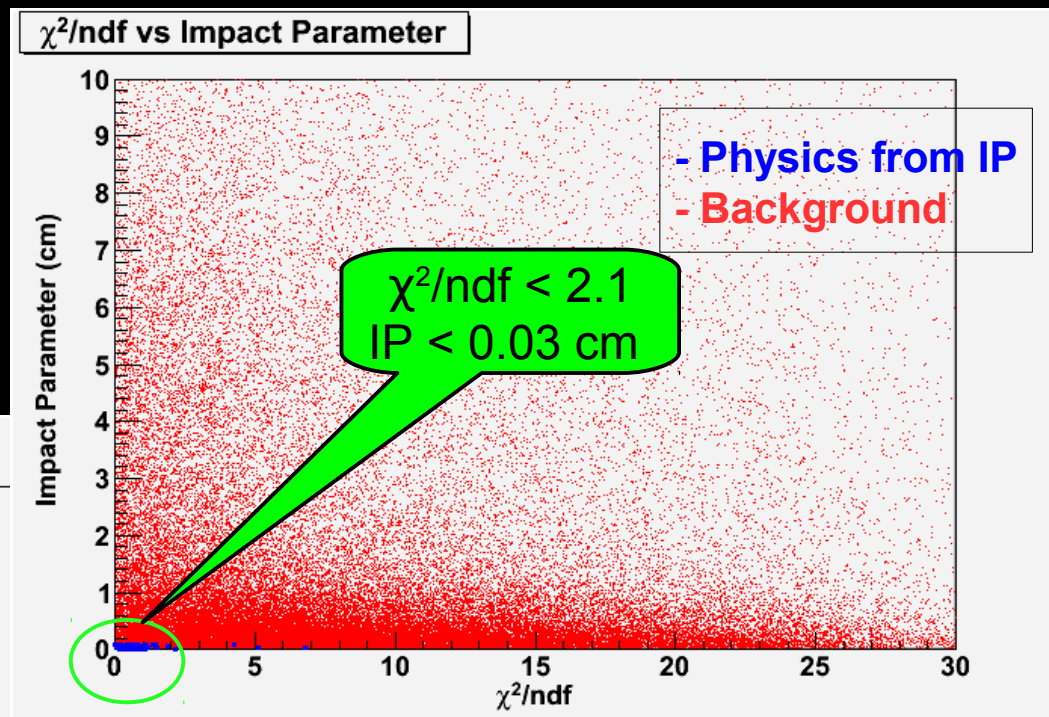
Full vs Fast simulation
of the bkg

Detector type	Reconstructed Tracks (full simu)	Reconstructed Tracks (fast simu)
Det. A (no timing)	Cannot calculate	Cannot calculate
Det. B (7 ns fixed gate)	75309	64319
Det. C (3 ns adjustable gate)	6544	4639
Det. D (1 ns adjustable gate)	1459	881

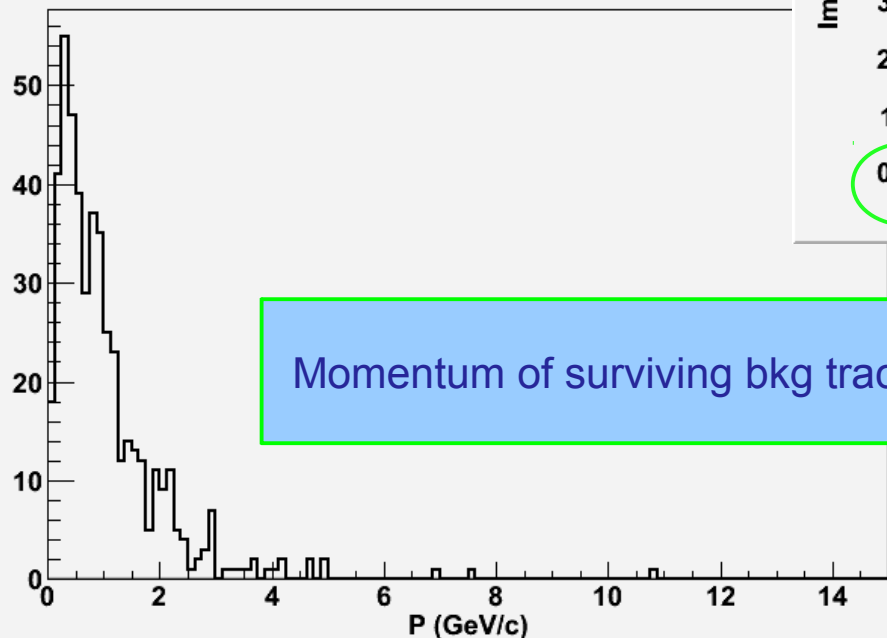
Full reconstruction is
paramount when combinatorics
is relevant

Physics vs Background in Det. B: A strategy to disentangle reconstructed tracks from IP

Full simulation of
physics + bkg



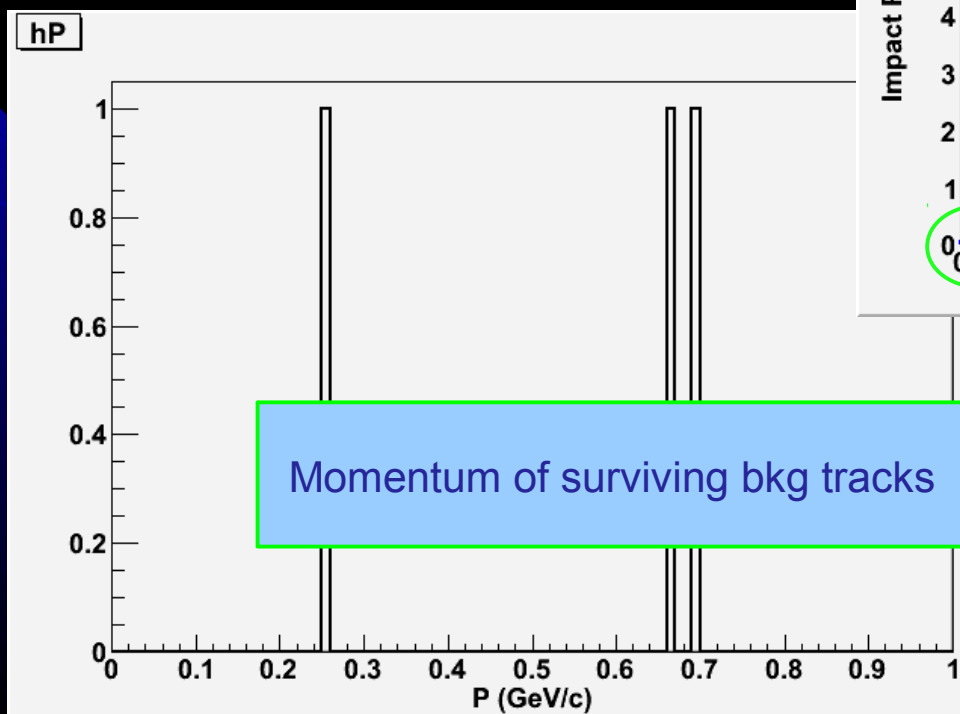
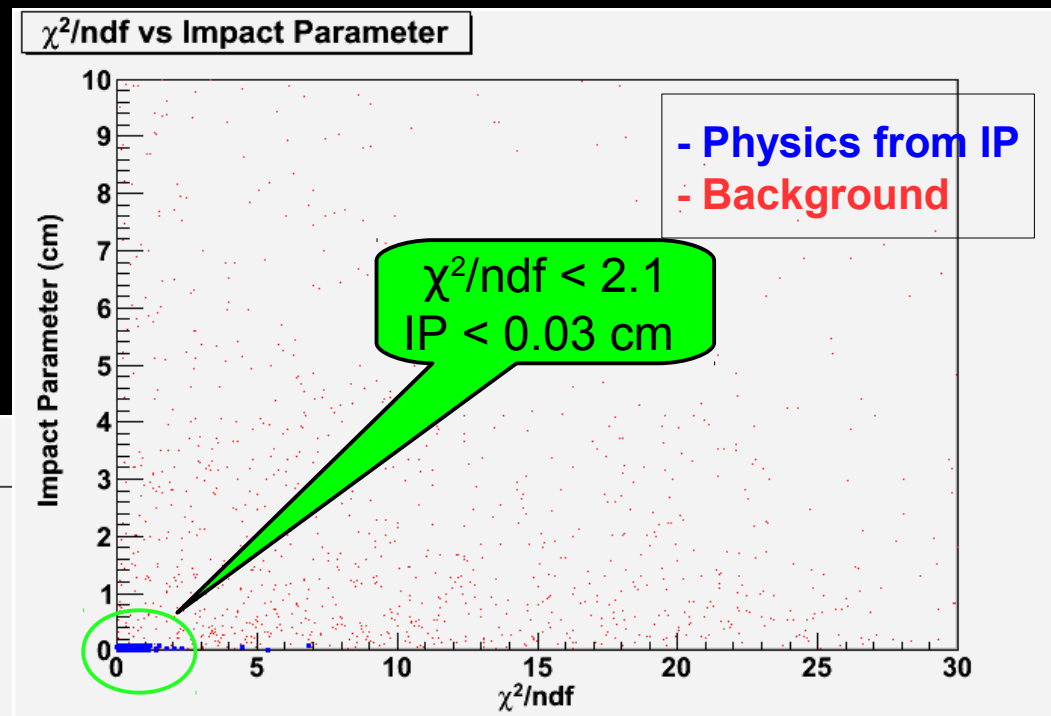
hP



Det. B = Acquires data in a fixed 7 ns time gate

Physics vs Background in Det. D: A strategy to disentangle reconstructed tracks from IP

Full simulation of
physics + bkg



Det. B = Acquires data in variable 1 ns time gate

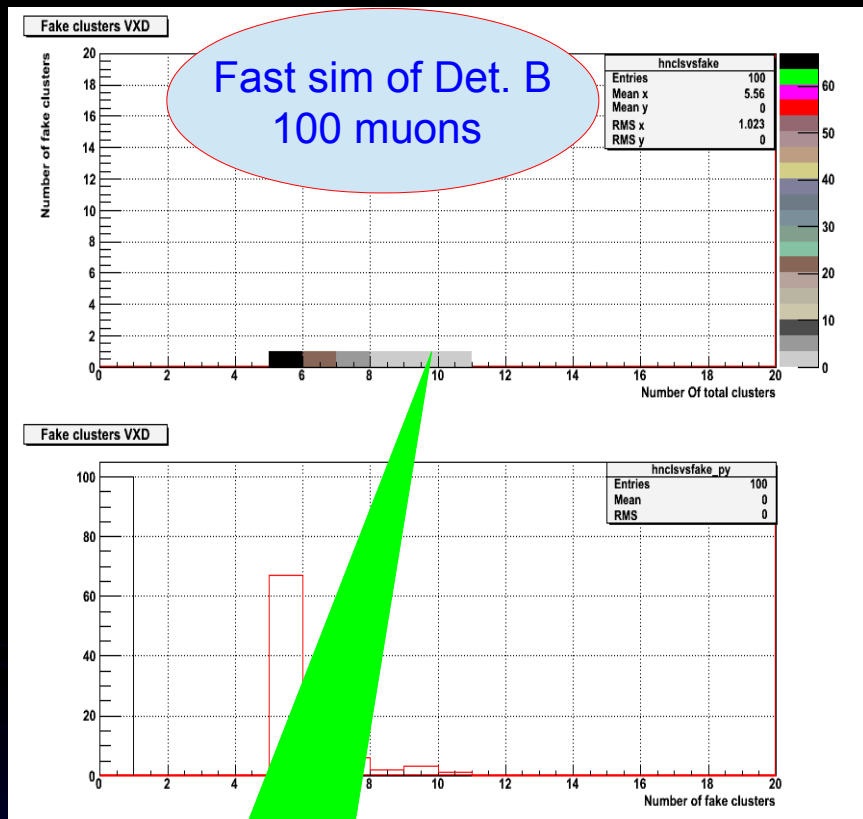
Reconstructed Background Tracks (from Kalman filter) after χ^2 and IP cuts

Full vs Fast simulation
of the bkg

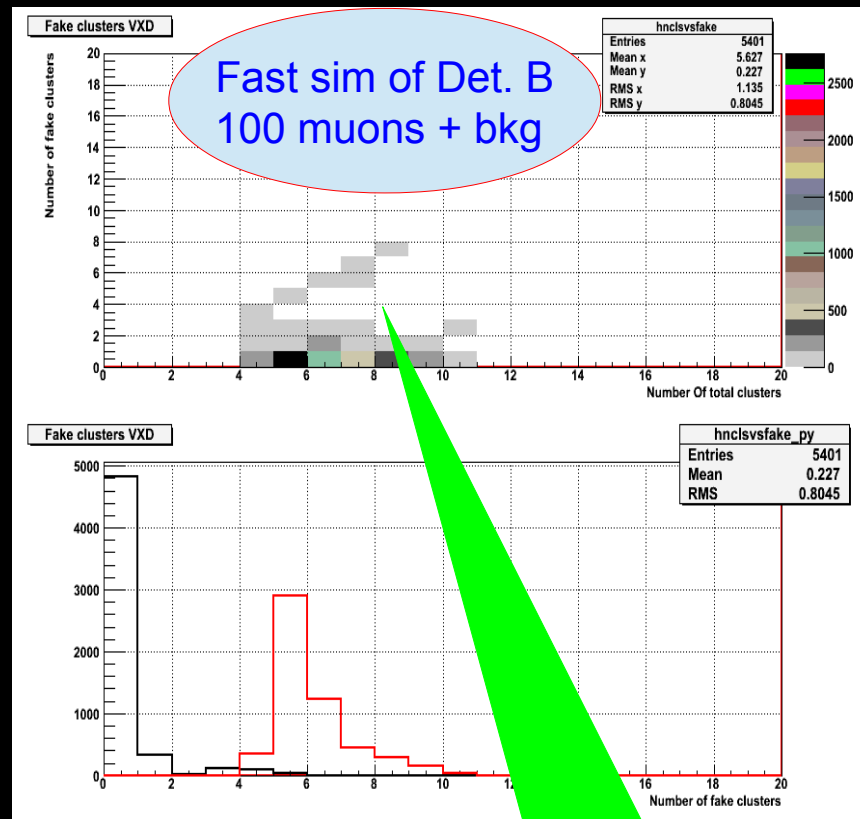
Detector type	Reconstructed Tracks (full simu)	Reconstructed Tracks (fast simu)
Det. A (no timing)	Cannot calculate	Cannot calculate
Det. B (7 ns fixed gate)	475	405
Det. C (3 ns adjustable gate)	11	8
Det. D (1 ns adjustable gate)	3	1

Full reconstruction is
paramount when combinatorics
is relevant

Effects of background Hits on Physics



no fake cluster



< 5% of tracks
have > 1 fake cluster

Effects on track parameter resolution are unaffected by background

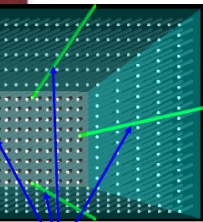
Beam Background Studies in Calorimeter System

Dual Readout
Calorimeter

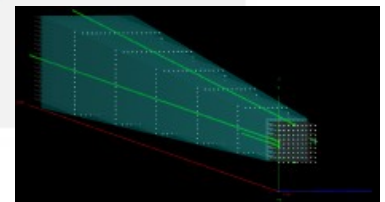
- Lead glass + scintillating fibers
- $\sim 1.4^\circ$ tower aperture angle
- 180 cm depth
- $\sim 7.5 \lambda_{\text{int}}$ depth
- $>100 X_0$ depth
- Fully projective geometry
- Azimuth coverage down to $\sim 8.4^\circ$ (Nozzle)
- Barrel: 16384 towers
- Endcaps: 7222 towers

Tracker

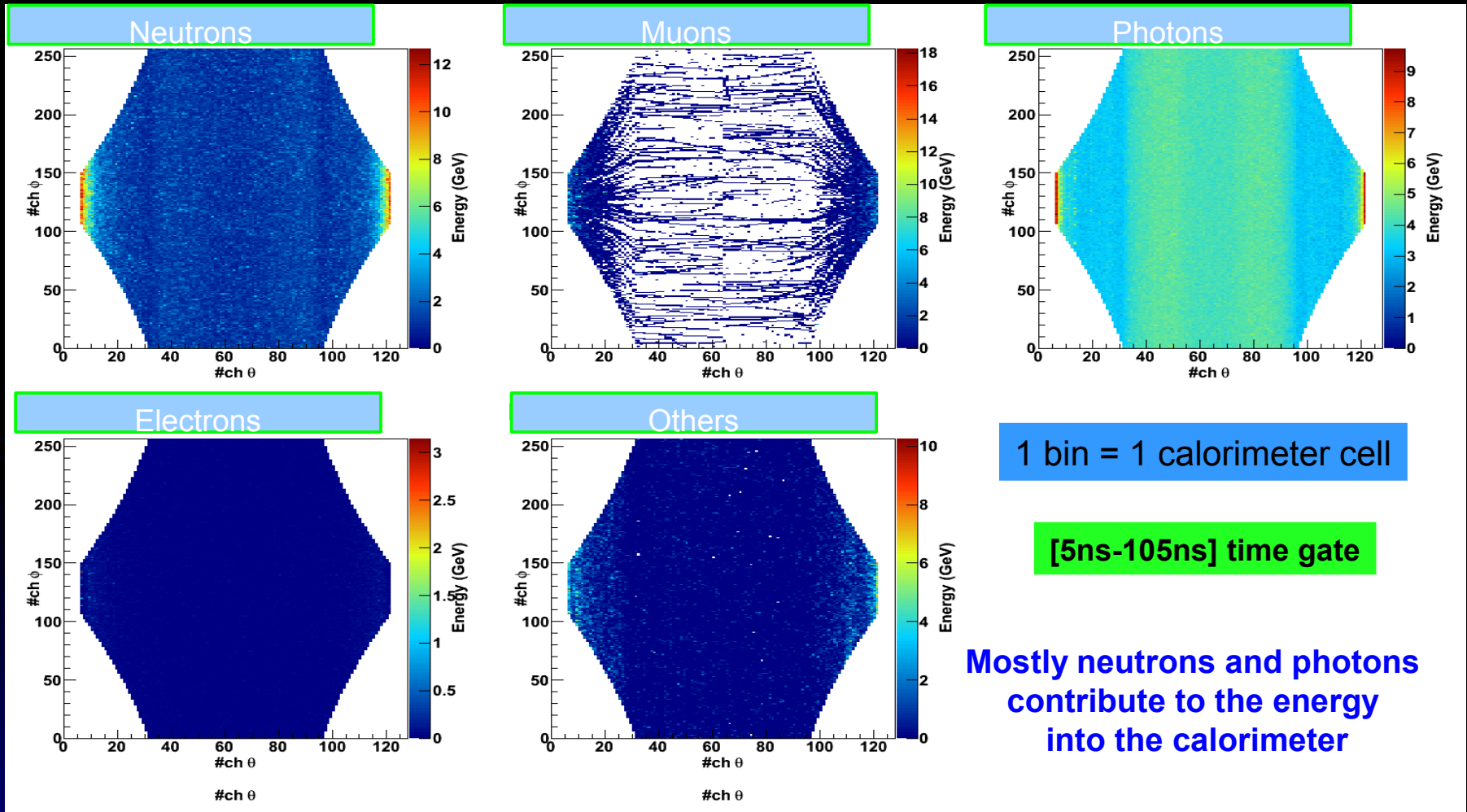
10° nozzle



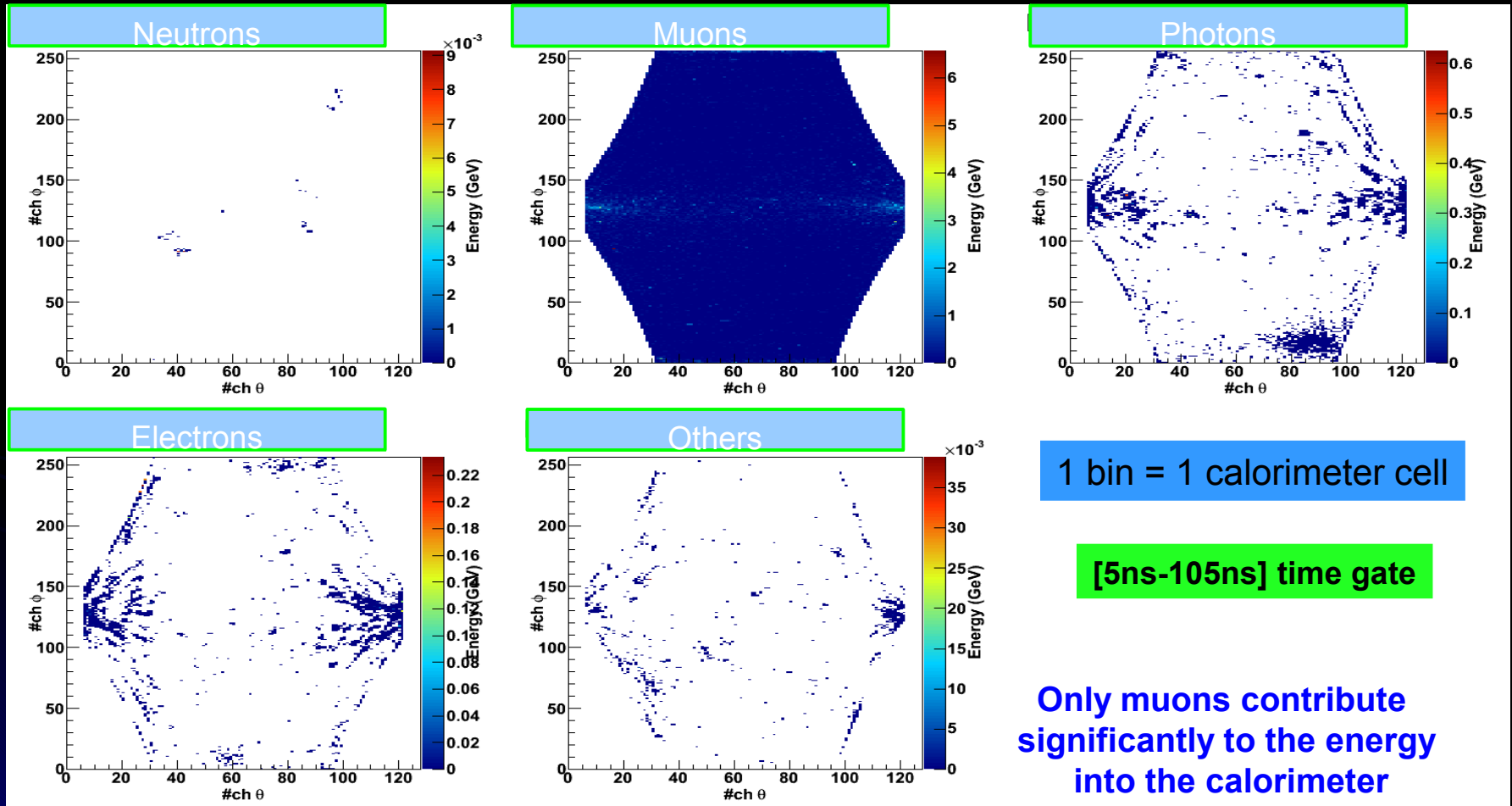
WLS



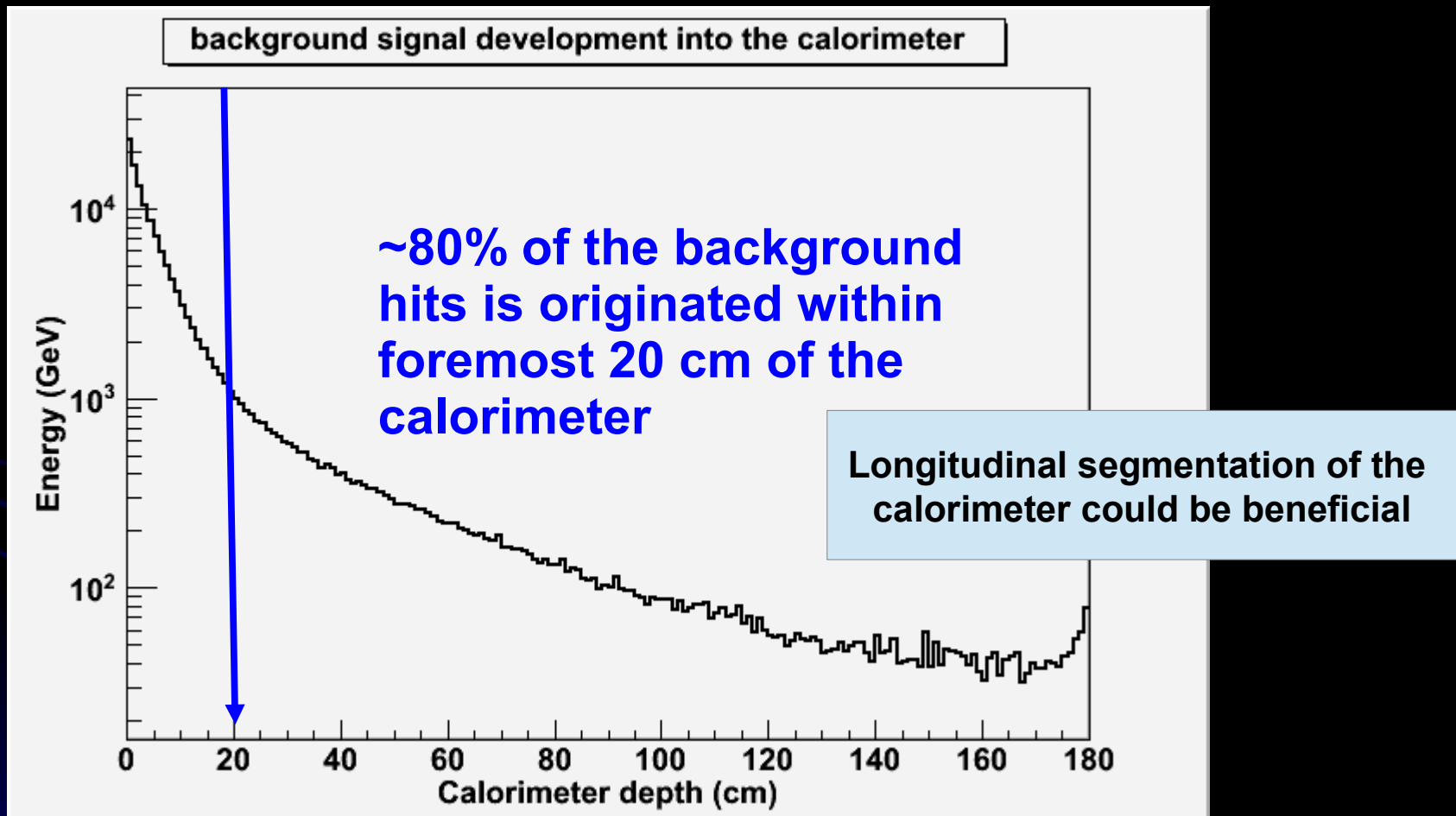
Background in the calorimeter for different particle species originating within 25 m from IP



Background in the calorimeter for different particle species originating beyond 25 m from IP



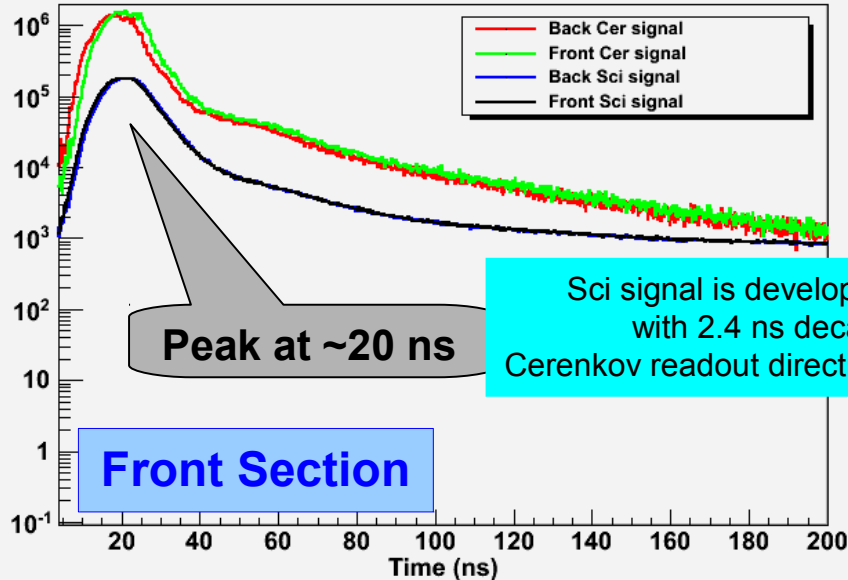
Longitudinal energy deposition produced by full background event in the calorimeter



Time Distribution of MuonCollider background energy in Calorimeter

Calorimeter is now split in a front (20cm) and rear (160 cm) section

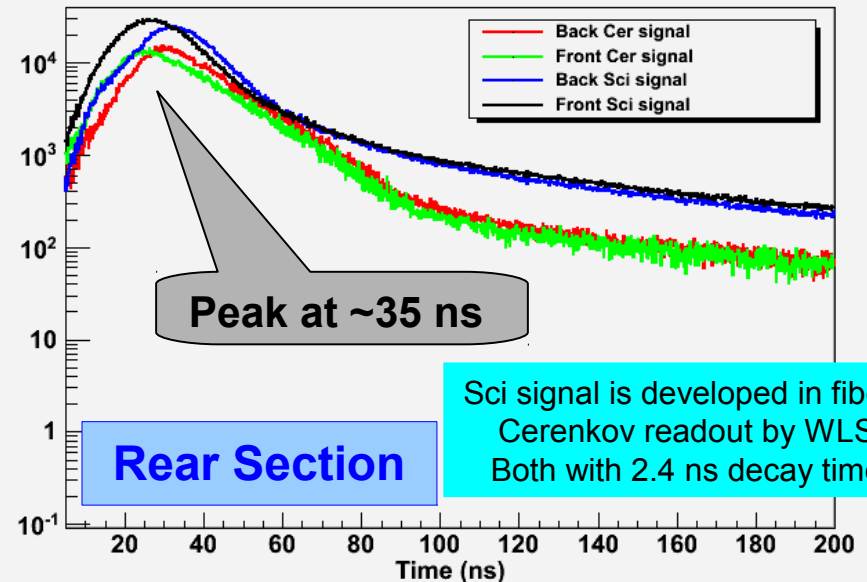
Average time distribution for μ C bkg (Front Calorimeter Section)



Sci signal is developed in fibers with 2.4 ns decay time
Cerenkov readout directly on LeadGlass

Light propagation in fibers and lead glass is implemented in ILCroot

Average time distribution for μ C bkg (Rear Calorimeter Section)



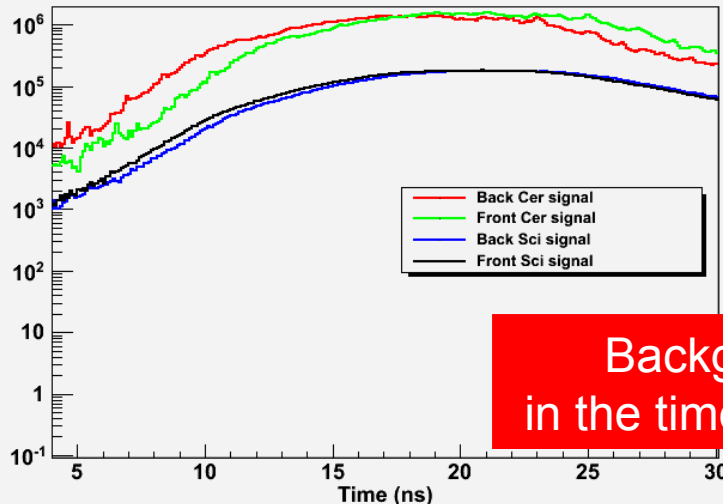
Sci signal is developed in fibers
Cerenkov readout by WLS
Both with 2.4 ns decay time

Time Distribution of MuonCollider background and IP particles energy in Calorimeter

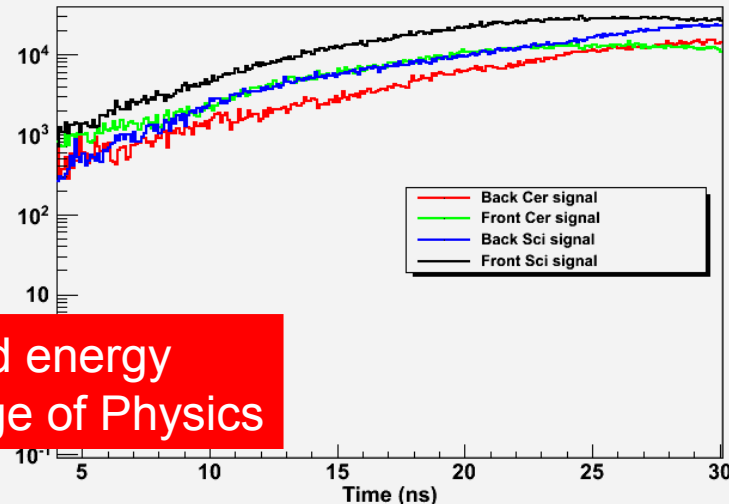
Front Section

Rear Section

Average time distribution for μC bkg (Front Calorimeter Section)

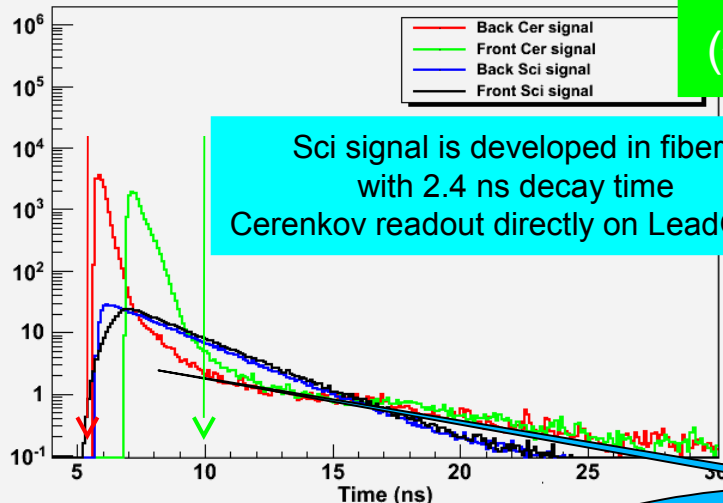


Average time distribution for μC bkg (Rear Calorimeter Section)



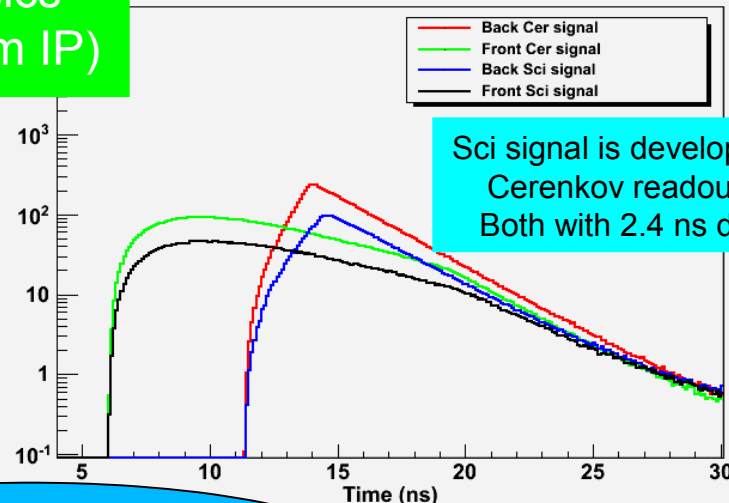
Background energy
in the time range of Physics

Average time distribution for π^- @ 40 GeV (Front Calorimeter Section)



Sci signal is developed in fibers
with 2.4 ns decay time
Cerenkov readout directly on LeadGlass

Average time distribution for π^- @ 40 GeV (Rear Calorimeter Section)



Sci signal is developed in fibers
Cerenkov readout by WLS
Both with 2.4 ns decay time

Physics
(π^- from IP)

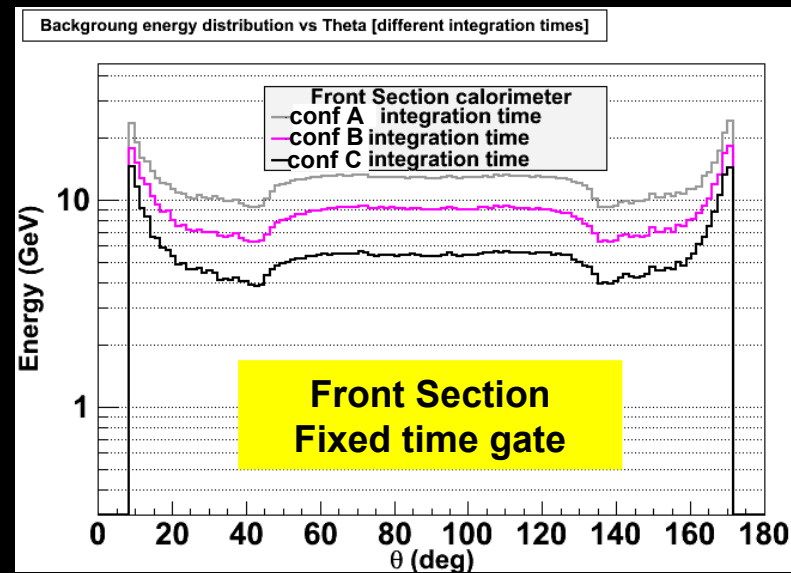
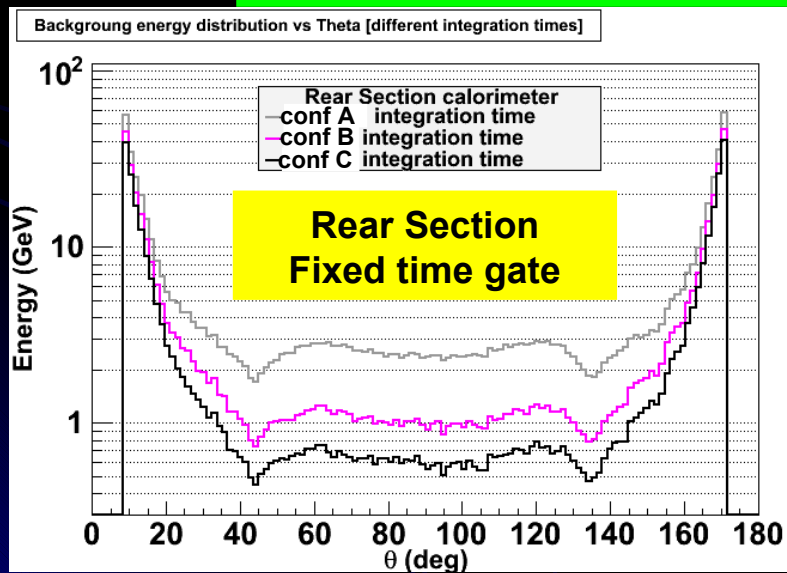
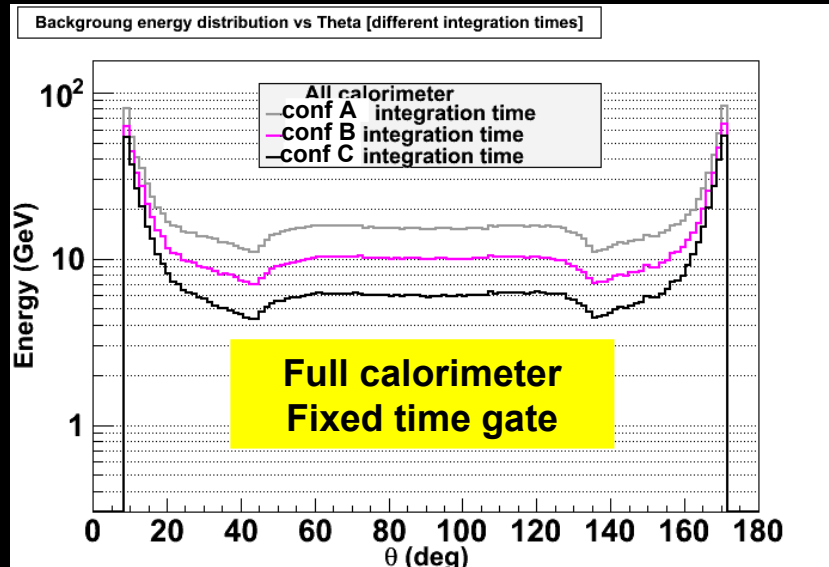
Most of physics occurs
between 5 and 10 ns

Angular distribution of background in Calorimeter for different integration time gates

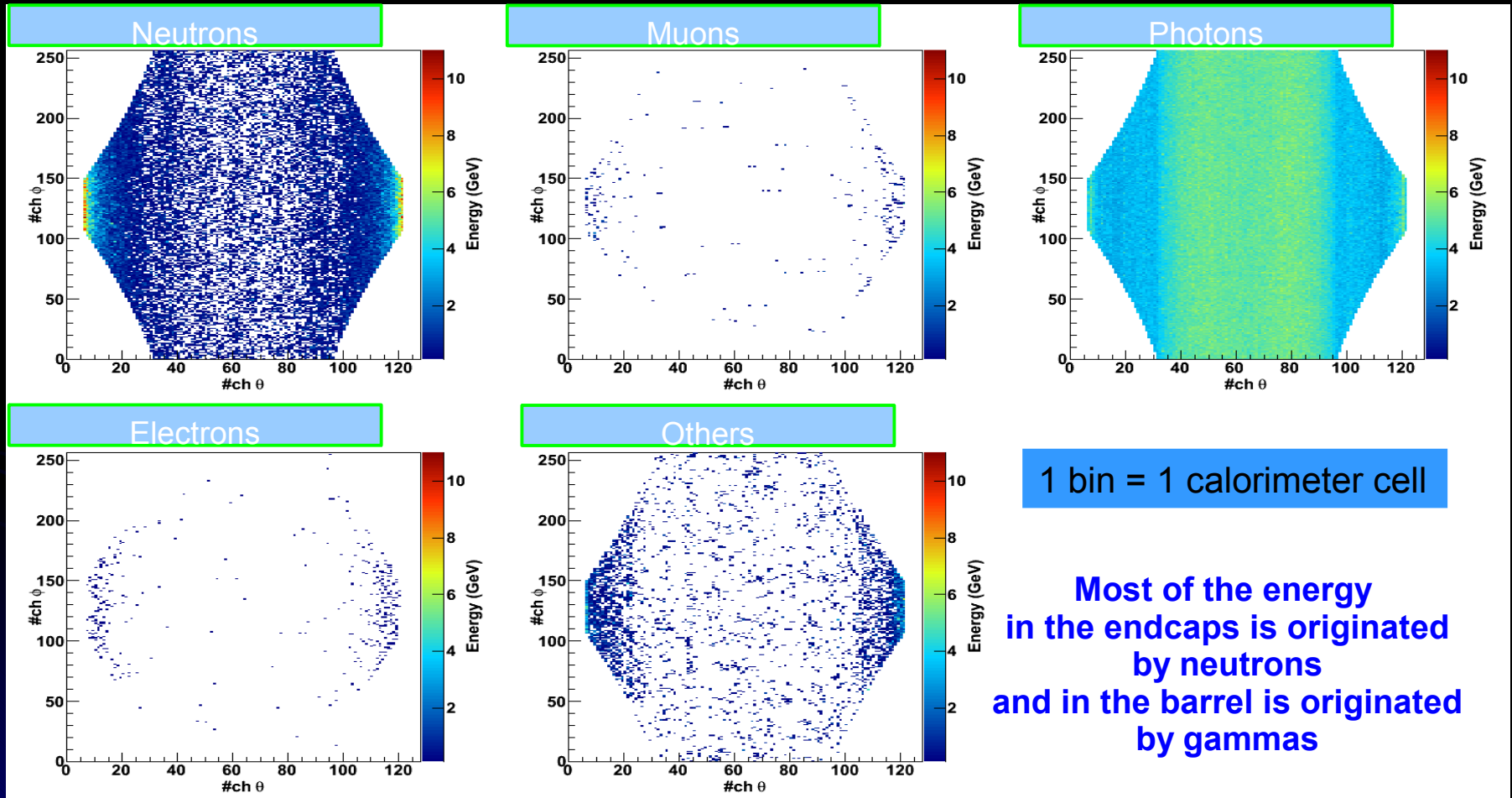
Integration time gate for each section

	Front Section		Rear Section	
	Scint	Cer	Scint	Cer
conf A	100 ns	100 ns	100 ns	100 ns
conf B	20 ns	15 ns	25 ns	25 ns
conf C	15 ns	6 ns	22 ns	22 ns

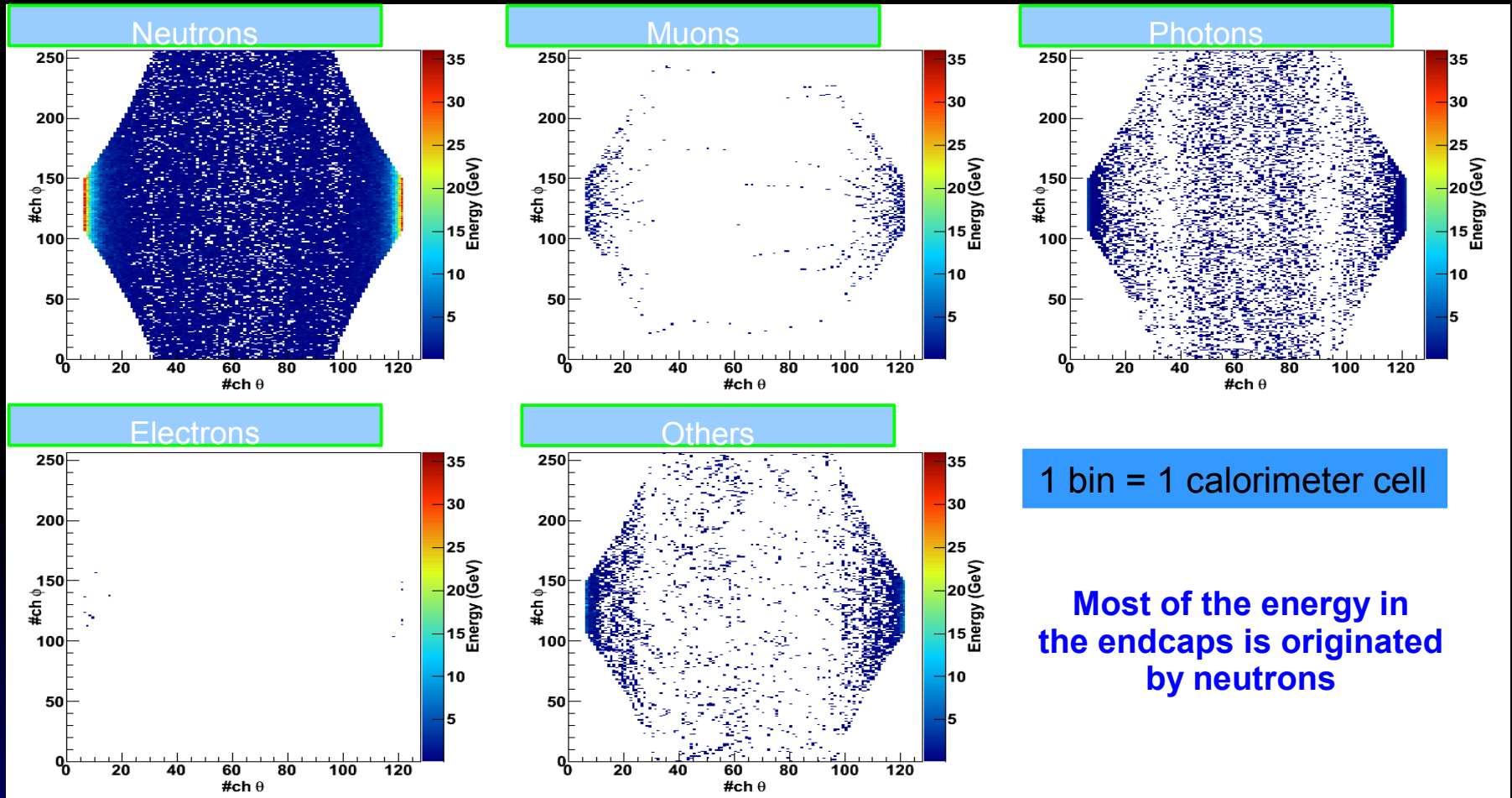
$$1 \text{ entry} = \langle 1 \text{ cell} \rangle_{|\phi}$$



Background energy distribution per tower Calorimeter Front Section “conf C”



Background energy distribution per tower Calorimeter Rear Section with “conf C”



Preliminary Physics Studies

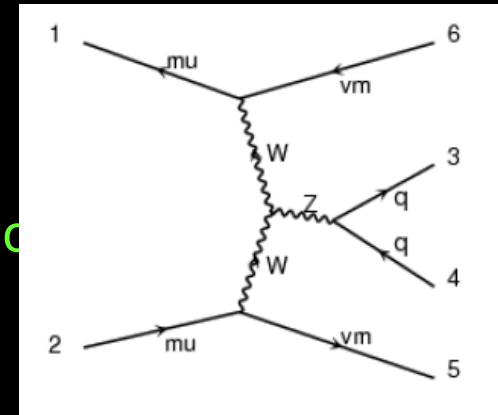
- Production of a single Z^0 in a fusion process:

$$\mu^+ \mu^- \rightarrow \nu_\mu \bar{\nu}_\mu + Z^0 \rightarrow \nu_\mu \bar{\nu}_\mu q \bar{q}$$

- How well can the invariant mass of the Z^0 be reconstructed from its decay into two jets?
- In particular, could the Z^0 be distinguished from a $W^\pm$ decaying into two jets in the process

$$\mu^+ \mu^- \rightarrow \mu^- \nu_\mu + W^+$$

- if the forward μ^- is not tagged?
- Madgraph and MARS15 as event generators (sig & bkg)
- ADRIANO calorimeter used in this study
- Recursive jet finder (from ILC studies)
- Full simulation, digitization and reconstruction

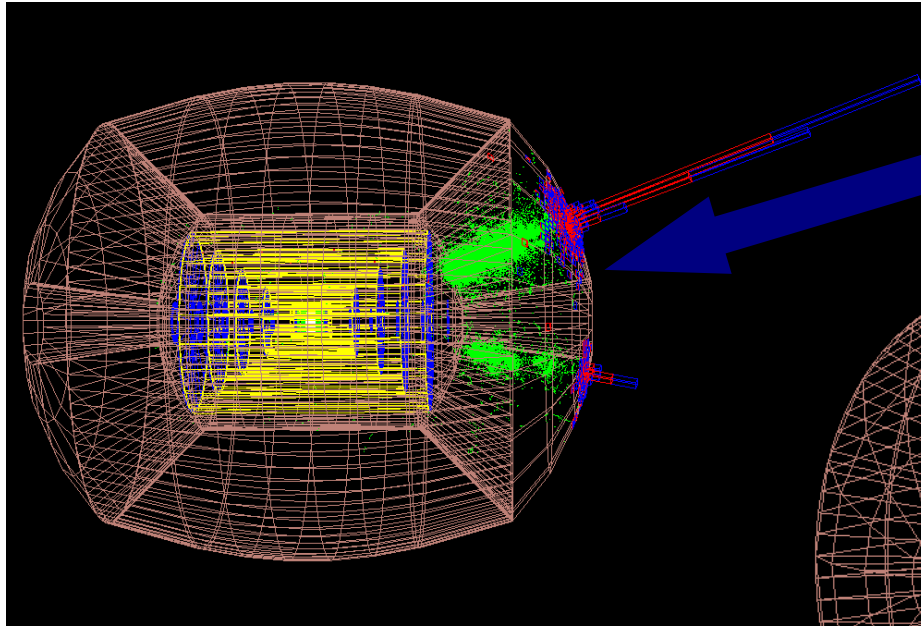


$$\mu^+ \mu^- \rightarrow \nu_\mu \bar{\nu}_\mu Z^0 @ 1.5 \text{ TeV}$$

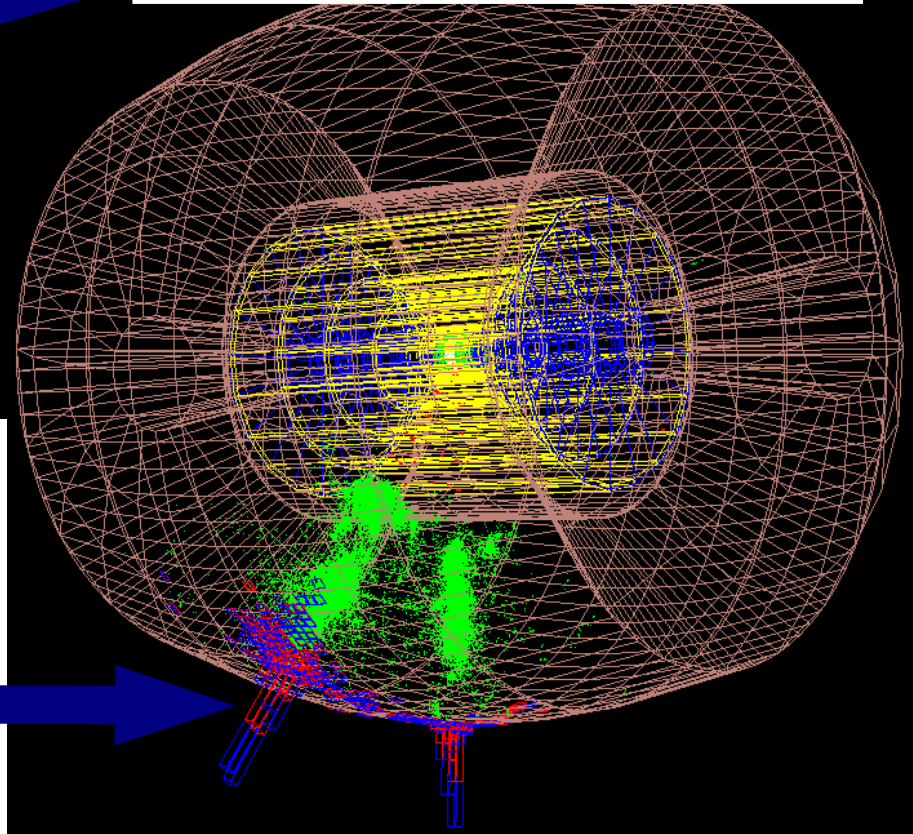
→ jet, jet

Jet's are
originated by light
quarks (u,d,s)

Same jets Event Display

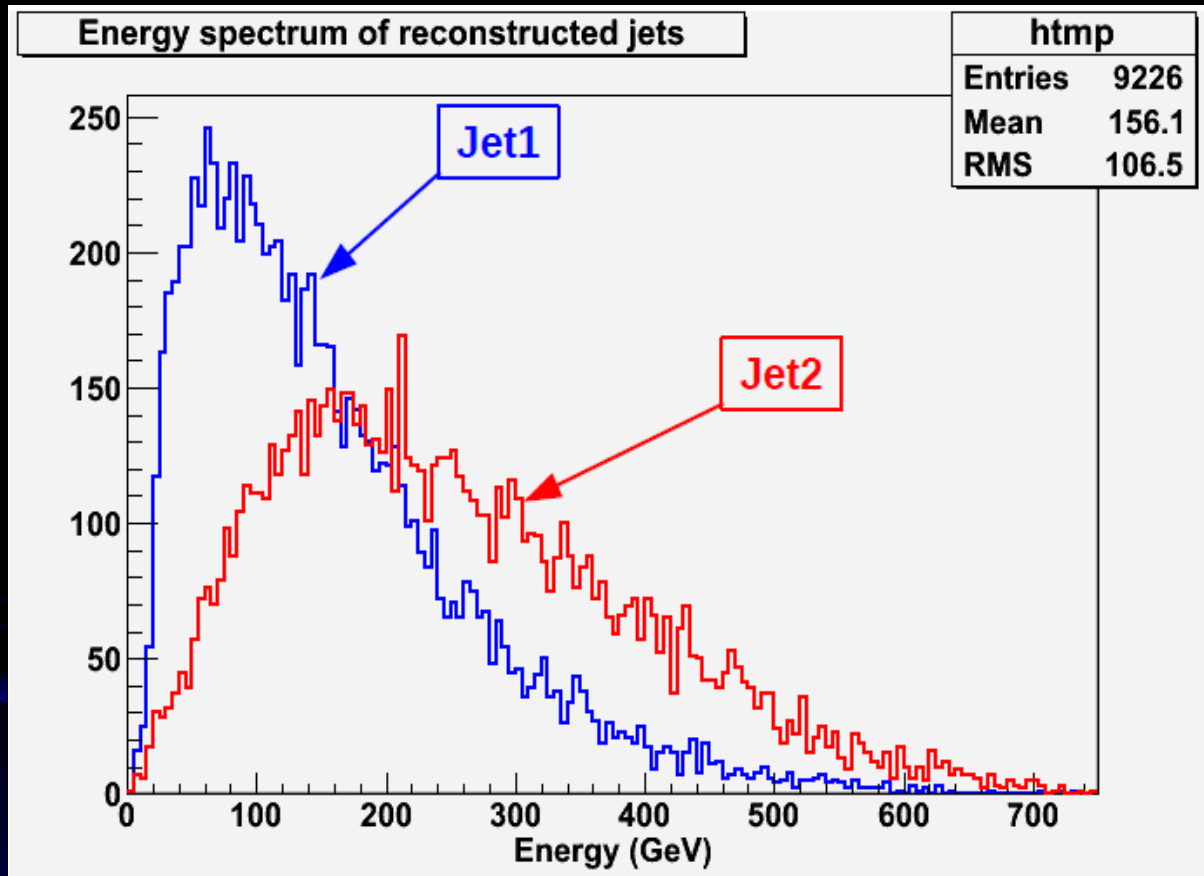


Jets with energy of
435GeV and 68GeV in
the endcap



Jets with energy of
234GeV and 117GeV in
the barrel

Jets Reconstruction

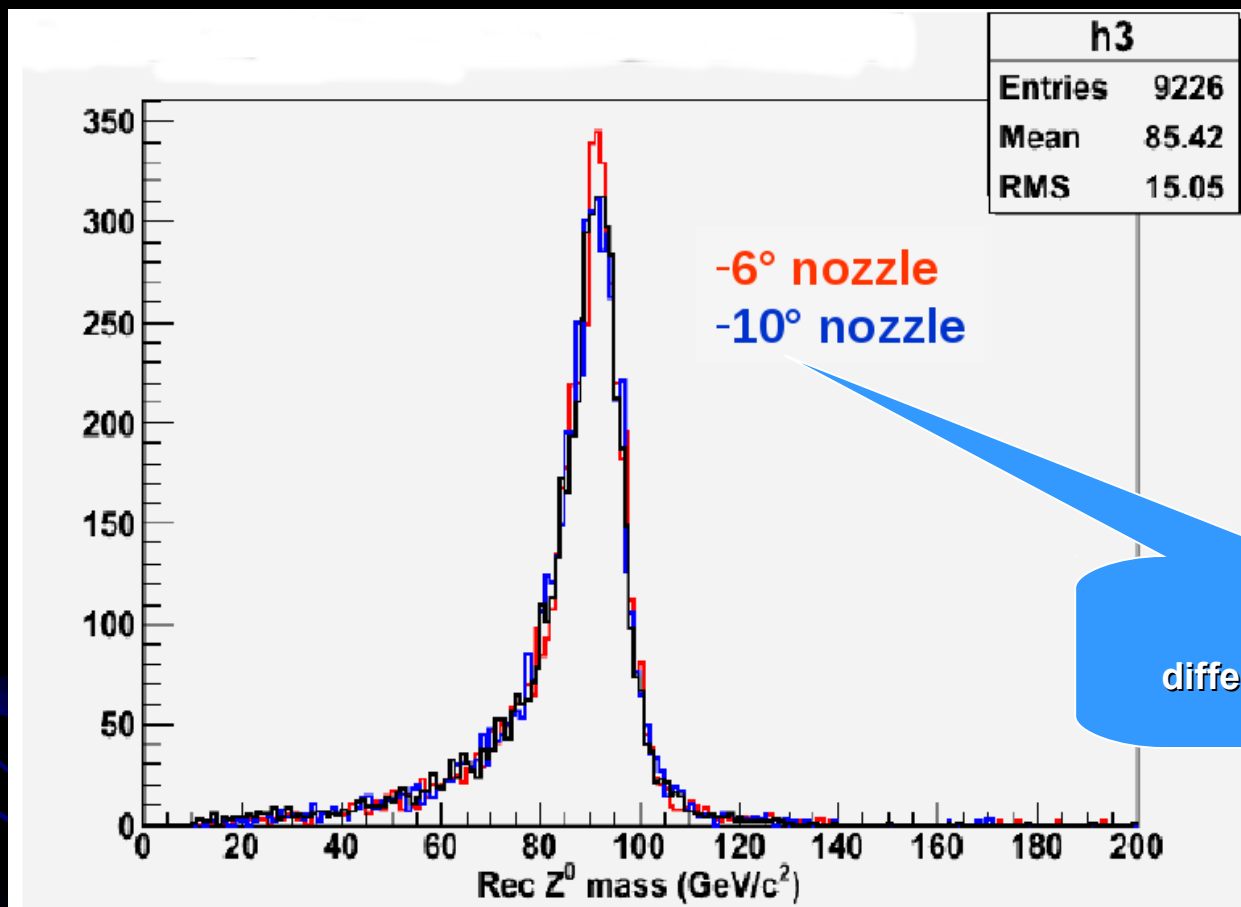


Reconstructed Jet energy spectrum
No cuts applied
1 bin = 5 GeV

Jet finder algorithm

- Divide jet in 2 non-overlapping regions:
 - **Core**: region of the calorimeter with nearby clusters
 - **Outliers**: isolated clusters
- Identify the **core energy**:
 - using calorimetric informations
- Identify the **jet axis**:
 - using infos from the tracking systems
- Reconstruct Outliers individually using:
 - trackers if calo and trackers have match clusters
 - Calo for neutral outliers
- Recursive algorithm

Z^0 Mass with Different Nozzles

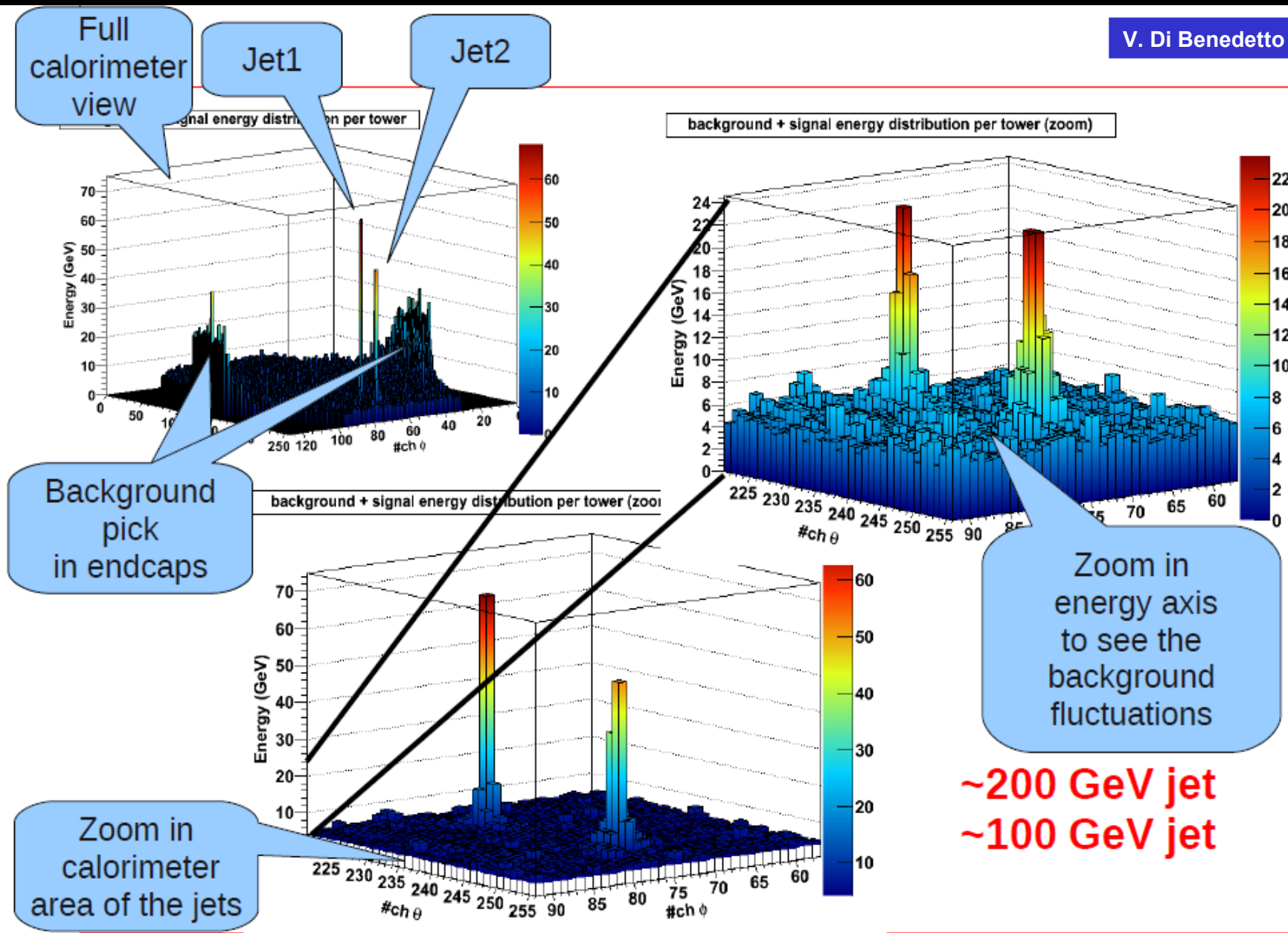


Minor
difference observed

**Fully reconstructed
 Z^0 mass (bin=1GeV)
No cuts applied
No leakage corrections**

Merging Signal + Background

V. Di Benedetto



Required Computing Resources

Time and disk space needed to simulate 1 full Muon Collider background event at hits level:

Particles with weight 1;

1 CPU $\leftrightarrow$ 2400 h

200 Gb disk space

Disk space and CPU time can be reduced by applying filter at hit level.

Future Prospects

- The machinery for full simulations is in place and working well (thanks to previous studies at ILC).
- The baseline detector configuration for Muon Collider studies performs well without background.
- Background is very nasty even with 10° tungsten nozzle, but fully understood.
- A second generation detector is being considered:
 - Two-section calorimeter with sophisticated time gate.
 - 4-D Kalman filter.
- Ready for physics studies.
- Goal is show potentialities at a Muon Collider Experiment.

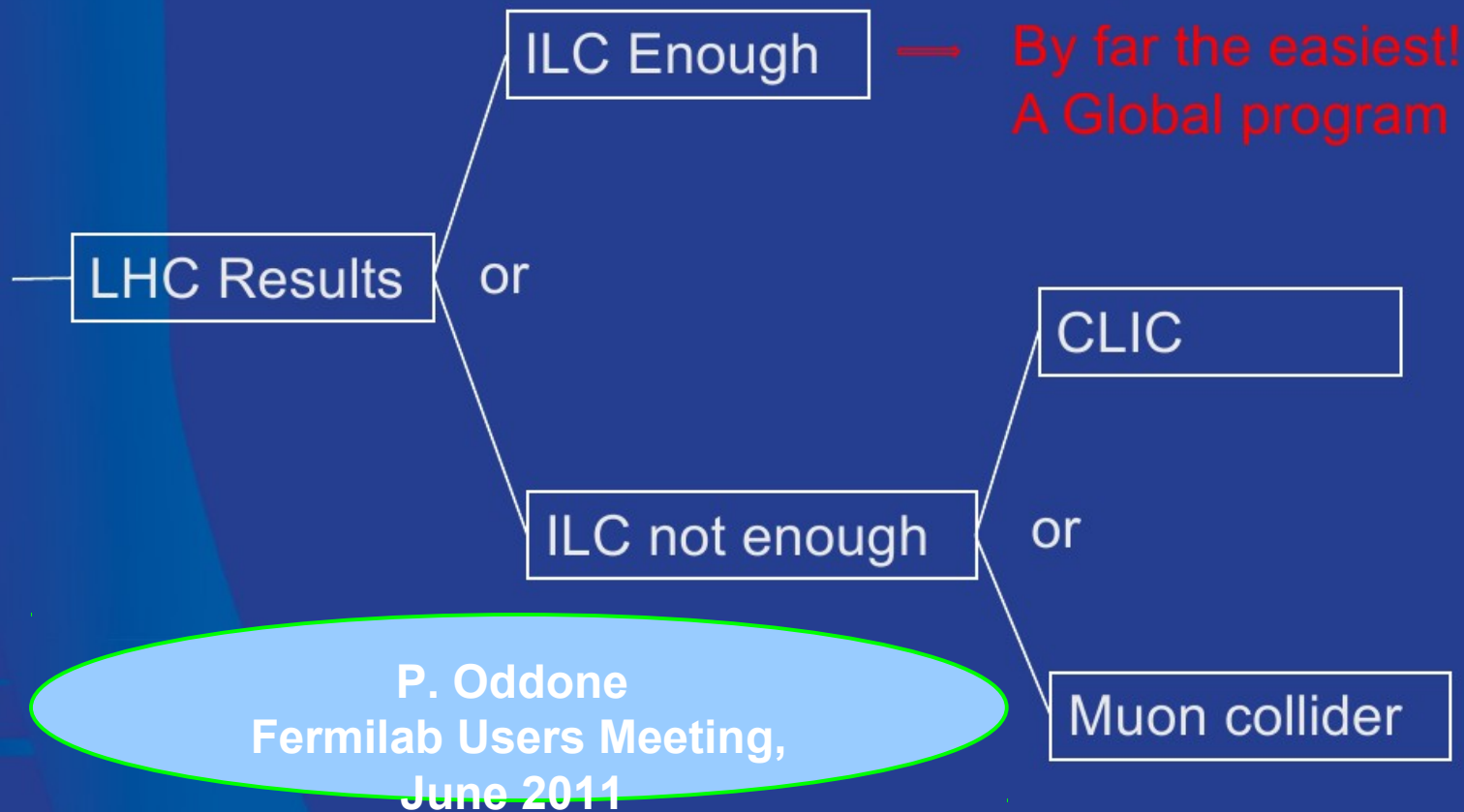
**Timing is important at a
Muon Collider!**

Conclusions

- A full simulation and reconstruction of Si-tracking detectors and a dual-readout calorimeter is implemented in ILCroot framework.
- MARS15 and ILCroot are stable and continuously improved for μ Collider physics and detector studies (and much more!).
 - Synergies between MARS and ILCroot working groups are excellent.
 - The machinery works smoothly for fast and full simulations.
- Detector performance studies with and without background are well under way.
 - Track reconstruction is expected to be only slightly affected by large background ...but, up to 10^6 real tracks from the background could be fully reconstructed.
 - Background in the calorimeter is under control for $\theta > 20^\circ$.
- Preliminary physics studies are ongoing:
 - Physics is mostly unaffected for $\theta > 20^\circ$.
 - For $\theta < 20^\circ$ jet energy uncertainties need to be improved.

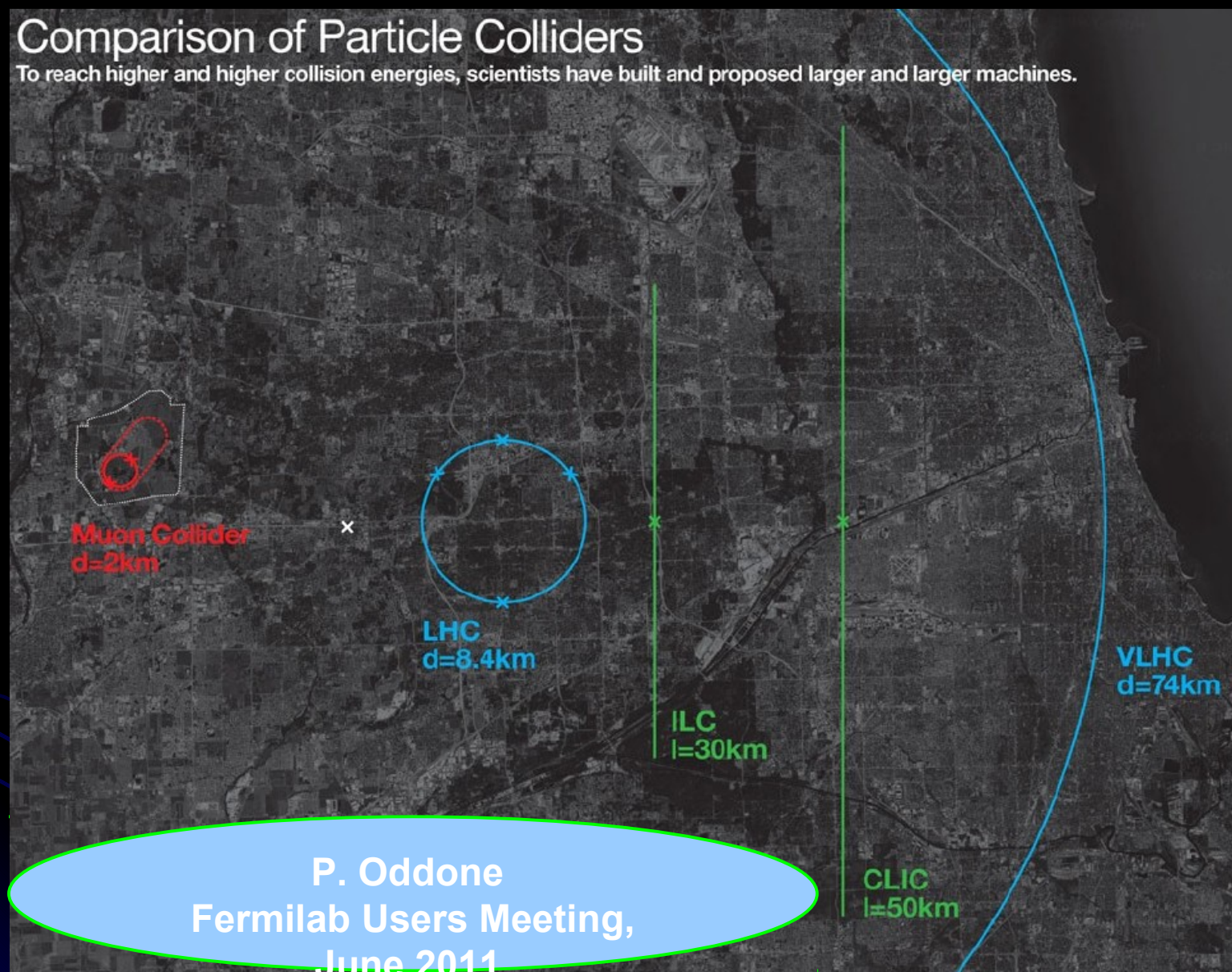
Backup slides

Biggest decision of the decade !



Comparison of Particle Colliders

To reach higher and higher collision energies, scientists have built and proposed larger and larger machines.



P. Oddone
Fermilab Users Meeting,
June 2011

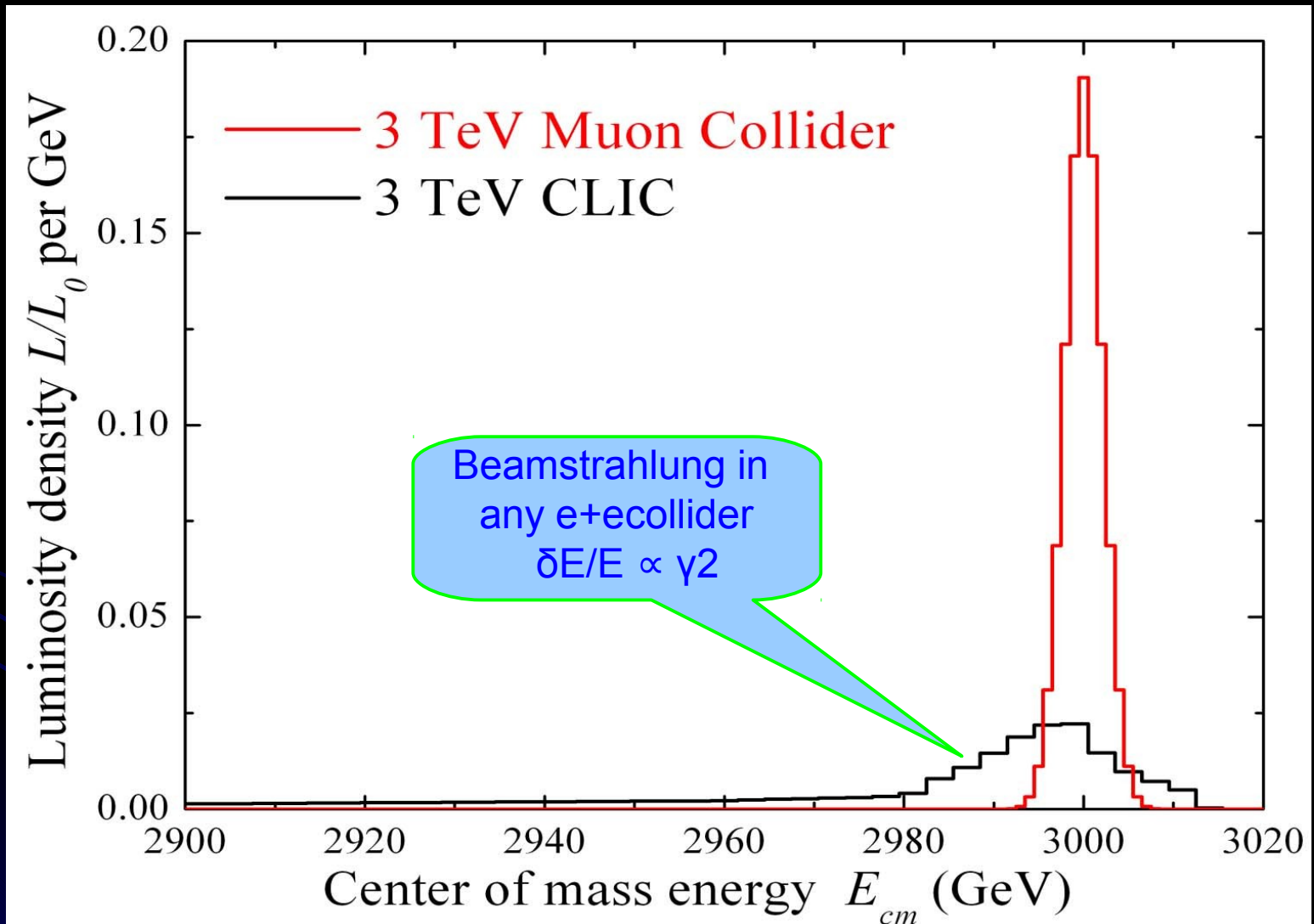
MUON COLLIDER MOTIVATION

If we can build a muon collider, it is an attractive multi-TeV lepton collider option because muons don't radiate as readily as electrons ($m_\mu / m_e \sim 207$):

- COMPACT
Fits on laboratory site
- MULTI-PASS ACC
Cost Effective operation & construction
- MULTIPASS COLLISIONS IN A RING (~1000 turns)
Relaxed emittance requirements & hence relaxed tolerances
- NARROW ENERGY SPREAD
 - Precision scans, kinematic constraints
- TWO DETECTORS (2 IPs)
- $\Delta T_{\text{bunch}} \sim 10 \mu\text{s}$... (e.g. 4 TeV collider)
Lots of time for readout
Backgrounds don't pile up
- $(m_\mu/m_e)^2 = \sim 40000$
Enhanced s-channel rates for Higgs-like particles

S. Geer- Accelerator
Seminar
SLAC 2011

Energy Spread



Challenges

- Muons are produced as tertiary particles

To make enough of them we must start with a MW scale proton source & target facility.

- Muons decay

Everything must be done fast and we must deal with the decay electrons (& neutrinos for CM energies above ~ 3 TeV).

- Muons are born within a large 6D phase-space

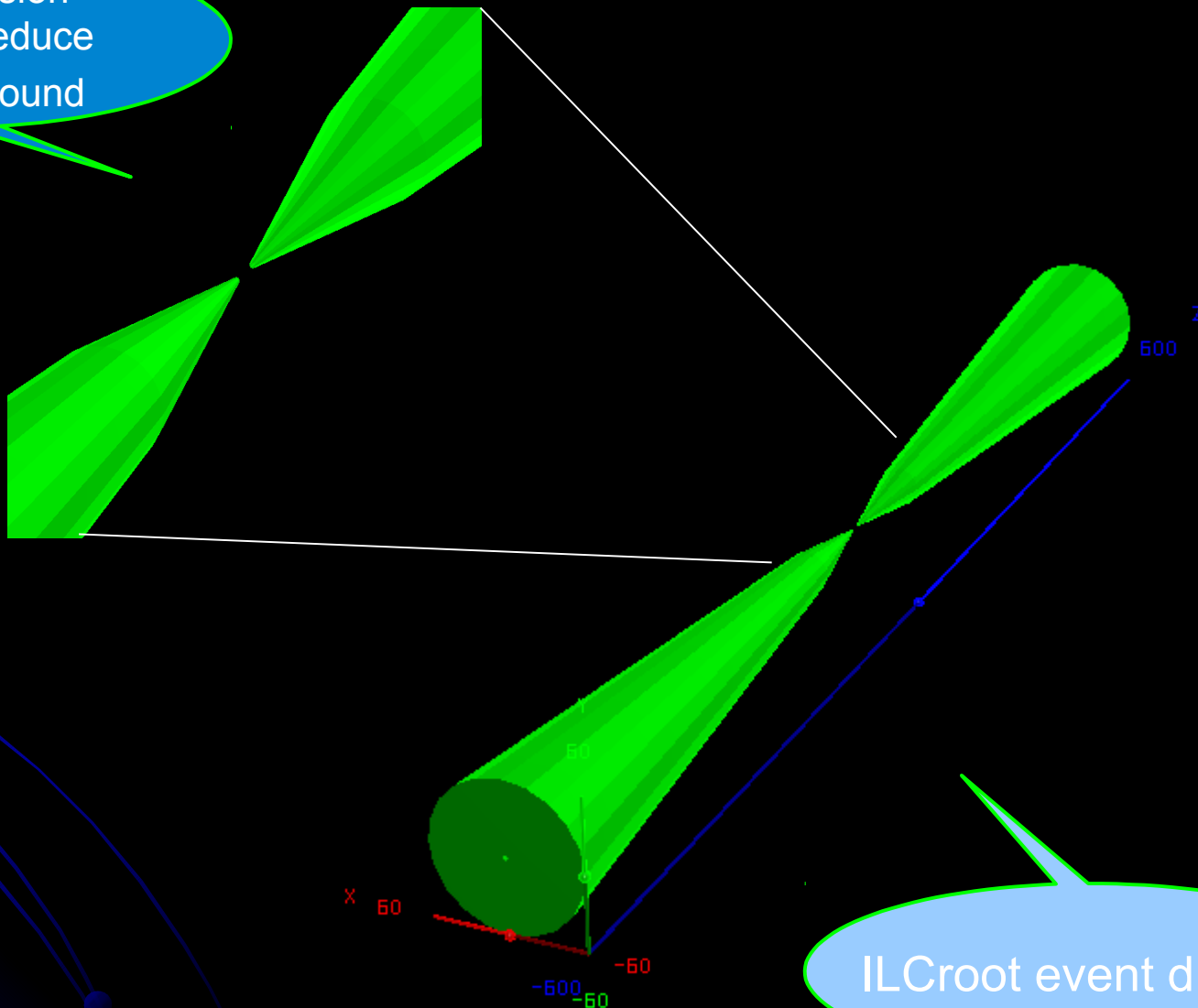
For a MC we must cool them by $O(10^6)$ before they decay

New cooling technique (ionization cooling) must be demonstrated, and it requires components with demanding performance (NCRF in magnetic channel, high field solenoids.)

- After cooling, beams still have relatively large emittance

10° Nozzle

Newer version
To further reduce
MuX background

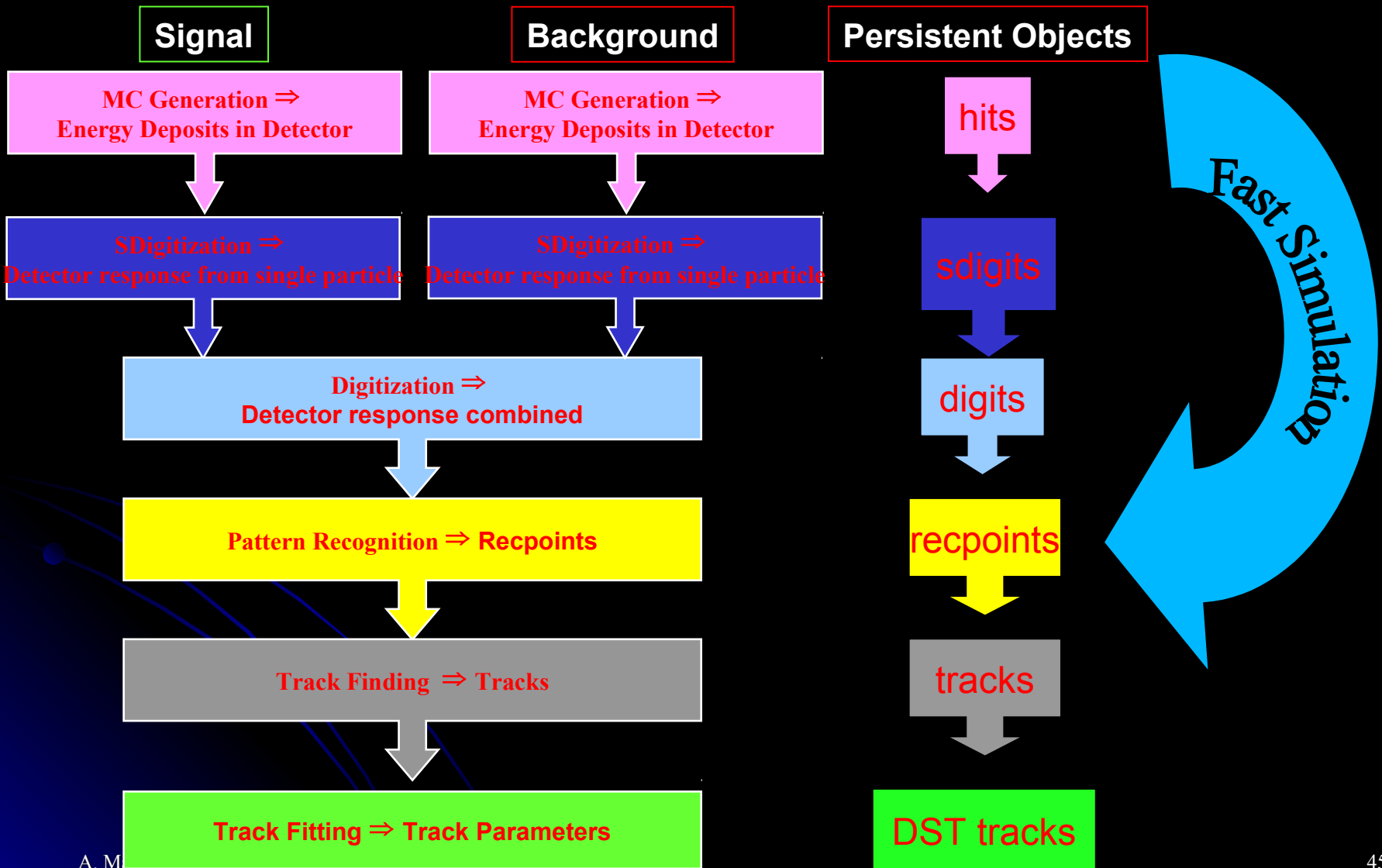


ILCrooT event display

ILCroot: root Infrastructure for Large Colliders

- **Software architecture based on root, VMC & Aliroot**
 - All ROOT tools are available (I/O, graphics, PROOF, data structure, etc)
 - Extremely large community of users/developers
- **Re-alignment with latest Aliroot version every 1-2 years (v4.17 release)**
- **It is a simulation framework and an Offline Systems:**
 - **Single framework, from generation to reconstruction through simulation. Don't forget analysis!!!**
 - It is immediately usable for test beams
 - Six MDC have proven robustness, reliability and portability
- **Main add-ons Aliroot:**
 - Interface to external files in various format (STDHEP, text, etc.)
 - Standalone VTX track fitter
 - Pattern recognition from VTX (for si central trackers)
 - Parametric beam background (# integrated bunch crossing chosen at run time)
- Growing number of experiments have adopted it: Alice (LHC), Opera (LNGS), (Meg), CMB (GSI), Panda(GSI), 4th Concept, (SiLC ?) and **LHeC**
- **It is Publicly available at FNAL on ILCSIM since 2006**
- **Used for ILC, CLIC and Muon Collider studies**

Simulation steps in ILCroot: Tracking system



Fast simulation and/or fast digitization also available in ILCroot for tracking system

- Fast Simulation = hit smearing
- Fast Digitization = full digitization with fast algorithms
- Do we need fast simulation in tracking studies?

Yes!

- Calorimetry related studies do not need full simulation/digitization for tracking
- Faster computation for quick answer to response of several detector layouts/shielding

- Do we need full simulation in tracking studies?

Yes!

- Fancy detector and reconstruction needed to be able to separate hits from signal and background

Digitization and Clusterization of Si Detectors in Ilcroot: a description of the algorithms available for detailed tracking simulation and studies

Technologies Implemented

- 3 detector species:
 - Silicon pixels
 - Silicon Strips
 - Silicon Drift
- Pixel can have non constant size in different layers
- Strips can also be stereo and on both sides
- Dead regions are taken into account
- Algorithms are parametric: almost all available technologies are easily accomodated (MAPS, 3D, DEPFET, etc.)

Used for VXD SiT and
FTD
in present studies

SDigitization in Pixel Detector (production of summable digits)

- Summable digit = signal produced by each individual track in a pixel
- Loop over the hits produced in the layer and create a segment in Si in 3D
 - Step (from MC) along the line $>1 \mu\text{m}$ increments
 - Convert GeV to charge and get bias voltage:
 $q = dE \cdot dt / 3.6e-9$ $dV = \text{thick} / \text{bias voltage}$
 - Compute charge spreading:
 $\sigma_{xy} = \sqrt{2k/e \cdot T^\circ \cdot dV \cdot L}$, $\sigma_z = fda \cdot \sigma_{xy}$
 - Spread charge across pixels using $\text{Erfc}(xy, z, \sigma_{xy}, \sigma_z)$
 - Charge pile-up is automatically taken into account

SDigitization in Pixels (2)

- Add couplig effect between nearby pixels row-wise and column-wise (constant probability)
- Remove dead pixels (use signal map)

Digitization in Pixels

Digit = sum of all sdigit corresponding to the same pixel

- Load SDigits from several files (signal or multiple background)
- Merge signals belonging to the same pixel
 - Non-linearity effects
 - Saturation
- Add electronic noise
- Save Digits over threshold

Clusterization in Pixel Detector

Cluster = a collection of nearby digit

Create a initial cluster from adjacent pixels (no for diagonal)

Subdivide the previous cluster in smaller $N \times N$ clusters

Reconstruct cluster and error matrix from coordinate average of the cluster

Kalman filter picks up the best cluster

Parameters used for the pixel tracking detectors in current MuX studies

Size Pixel X = 20 μm (VXD and FTD), 50 μm (SiT)

Size Pixel Z = 20 μm (VXD and FTD), 50 μm (SiT)

Eccentricity = 0.85 (fda)

Bias voltage = 18 V

cr = 0% (coupling probability for row)

cc = 4.7% (coupling probability for column)

threshold = 3000 electrons

electronics noise = 0 electrons

T° = 300 °K

Clusterization in Strip Detector

- Create a initial cluster from adjacent strips (no for diagonal)
- Separate into Overlapped Clusters
 - Look for through in the analog signal shape
 - Split signal of parent clusters among daughter clusters
- Intersect stereo strips to get Recpoints from CoG of signals (and error matrix)
- Kalman filter picks up the best Clusters

SDigitization in Strips Detector

- Get the Segmentation Model for each detector (from IlcVXDSegmentationSSD class)
- Get Calibration parameters (from IlcVXDCalibrationSSD class)
- Load background hits from file (if any)
- Loop on the hits and create a segment in Si in 3D

Step along the line in equal size increments

- Compute Drift time to p-side and n-side:

```
tdrift[0] = (y+(seg->Dy()*1.0E-4)/2)/GetDriftVelocity(0);
```

```
tdrift[1] = ((seg->Dy()*1.0E-4)/2-y)/GetDriftVelocity(1);
```

- Compute diffusion constant:

```
sigma[k] = TMath::Sqrt(2*GetDiffConst(k)*tdrift[k]);
```

- integrate the diffusion gaussian from -3σ to 3σ

– Charge pile-up is automatically taken into account

SDigitization in Strips (2)

- Add electronic noise per each side separately

```
// noise is gaussian
```

```
noise = (Double_t) gRandom->Gaus(0,res->GetNoiseP().At(ix));
```

```
// need to calibrate noise
```

```
noise *= (Double_t) res->GetGainP(ix);
```

```
// noise comes in ADC channels from the calibration database
```

```
// It needs to be converted back to electronVolts
```

```
noise /= res->GetDEvToADC(1.);
```

- Add coupling effect between nearby strips
 - different contribution from left and right neighbours
 - Proportional to nearby signals

- Remove dead pixels (use signal map)

- Convert total charge into signal (ADC count)

```
if(k==0) signal /= res->GetGainP(ix);
```

```
else signal /= res->GetGainN(ix);
```

```
// signal is converted in unit of ADC
```

```
signal = res->GetDEvToADC(fMapA2->GetSignal(k,ix));
```

The Parameters for the Strips

- Strip size (p, n)
- Stereo angle (p-> 7.5 mrad, n->25.5 mrad)
- Ionization Energy in Si = 3.62E-09
- Hole diffusion constant (= 11 cm²/sec)
- Electron diffusion constant (= 30 cm²/sec)
- $v_{\text{drift}}^{\text{p}}$ (=0.86E+06 cm/sec) , $v_{\text{drift}}^{\text{n}}$ (=2.28E+06 cm/sec)
- Calibration constants
 - Gain
 - ADC conversion (1 ADC unit = 2.16 KeV)
- Coupling probabilities between strips (p and n)
- σ of gaussian noise (p AND n)
- threshold

Track Fitting in ILCRoot

Track finding and fitting is a global task: individual detector collaborate

It is performed after each detector has completed its local tasks (simulation, digitization, clusterization)

It occurs in three phases:

- Seeding in SiT and fitting in VXD+SiT+MUD
- Standalone seeding and fitting in VXD
- Standalone seeding and fitting in MUD

Two different seedings:

- Primary seeding with vertex constraint
- Secondary seeding without vertex constraint

Not yet implemented

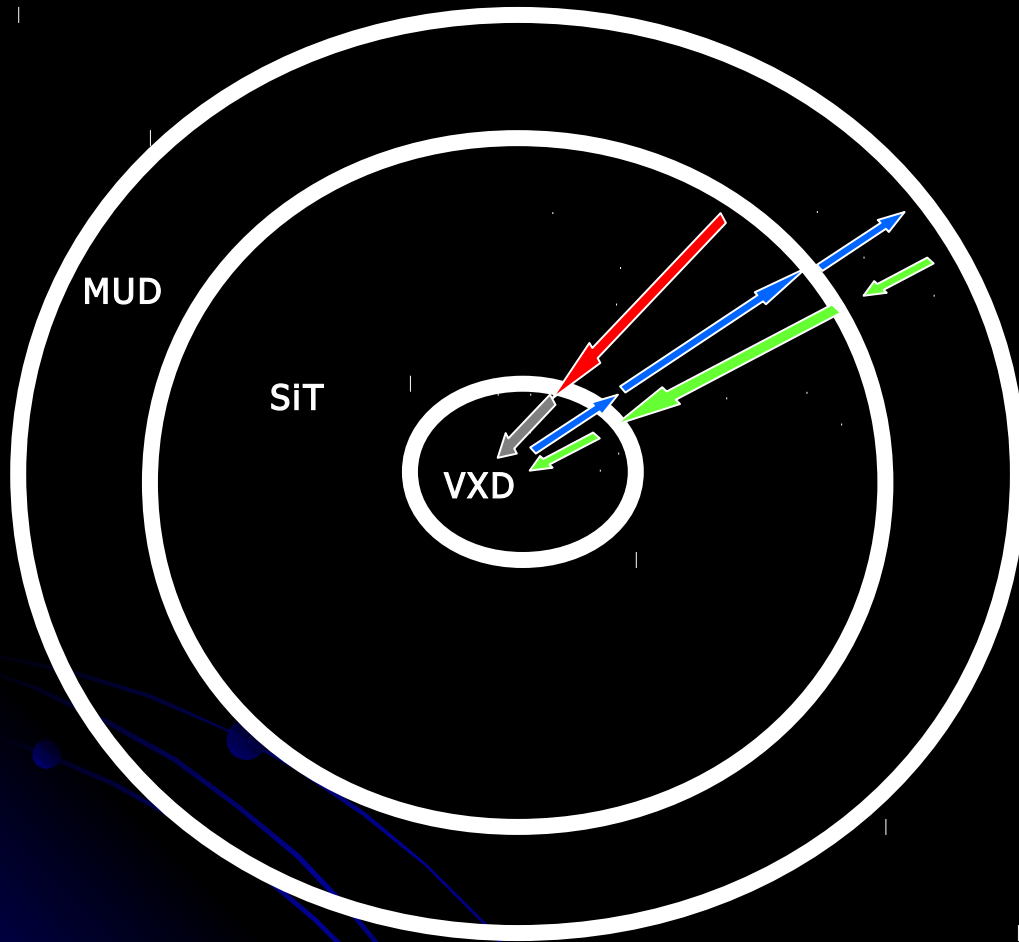
Kalman Filter (classic)

- Recursive least-squares estimation.
- Equivalent to global least-squares method including all correlations between measurements due to multiple scattering.
- Suitable for combined track finding and fitting
- Provides a natural way:
 - to take into account multiple scattering, magnetic field inhomogeneity
 - possibility to take into account mean energy losses
 - to extrapolate tracks from one sub-detector to another

Parallel Kalman Filter

- Seedings with constraint + seedings without constraint at different radii (necessary for kinks and V0) from outer to inner
- Tracking
 - Find for each track the prolongation to the next layer
 - Estimate the errors
 - Update track according current cluster parameters
 - (Possible refine clusters parameters with current track)
- Track several track-hypothesis in parallel
 - Allow cluster sharing between different track
- Remove-Overlap
- **Kinks and V0** fitted during the Kalman filtering

Tracking Strategy – Primary Tracks



- Iterative process
 - Seeding in SiT
 - Forward propagation towards to the vertex
 $\text{SiT} \rightarrow \text{VXD}$
 - Back propagation towards to the MUD
 $\text{VXD} \rightarrow \text{SiT} \rightarrow \text{MUD}$
 - Refit inward
 $\text{MUD} \rightarrow \text{SiT} \rightarrow \text{VXD}$
- Continuous seeding –track segment finding in all detectors

VXD Standalone Tracking

- Uses Clusters leftover in the VXD by Parallel Kalman Filter
- **Requires at least 4 hits to build a track**
- Seeding in VXD in two steps
 - Step 1: look for 3 Clusters in a narrow row or 2 Clusters + IP constraint
 - Step 2: prolongate to next layers each helix constructed from a seed
- After finding Clusters, all different combination of clusters are refitted with the Kalman Filter and the tracks with lowest χ^2 are selected
- Finally, the process is repeated attempting to find tracks on an enlarged row constructed looping on the first point on different layers and all the subsequent layers
- In 3.5 Tesla B-field $P_t > 20$ MeV tracks reconstructable

Event Display

ILCroot event display
for 10 muons up to 200 GeV

green - hits

purple - reconstructed tracks

red - MC particle

10 generated muons
9 reconstructed tracks

Effects on Track Resolution

Background in the calorimeter for different particle species originating within 25 m from IP

Background in the calorimeter for different particle species originating in [25-200] m from IP

Future Prospects

Conclusions

Backup slides

MUON COLLIDER MOTIVATION

Energy Spread

Challenges

10° Nozzle

ILCroot: root Infrastructure for Large Colliders

A. Mazzacane (Fermilab)

Simulation steps in ILCroot:

Tracking system

Effects of background Hits on Physics

Background in the calorimeter for different particle species originating within 25 m from IP

Background in the calorimeter for different particle species originating beyond 25 m from IP

Future Prospects

Conclusions

Backup slides

MUON COLLIDER MOTIVATION

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(production of summable digits)

SDigitization in Pixels (2)

Digitization in Pixels

Clusterization in Pixel Detector

Parameters used for the pixel tracking detectors in current MuX studies

Clusterization in Strip Detector

SDigitization in Strips Detector

SDigitization in Strips (2)

The Parameters for the Strips

Track Fitting in ILCRoot

Kalman Filter (classic)

Parallel Kalman Filter

VXD Standalone Tracking

Event Display