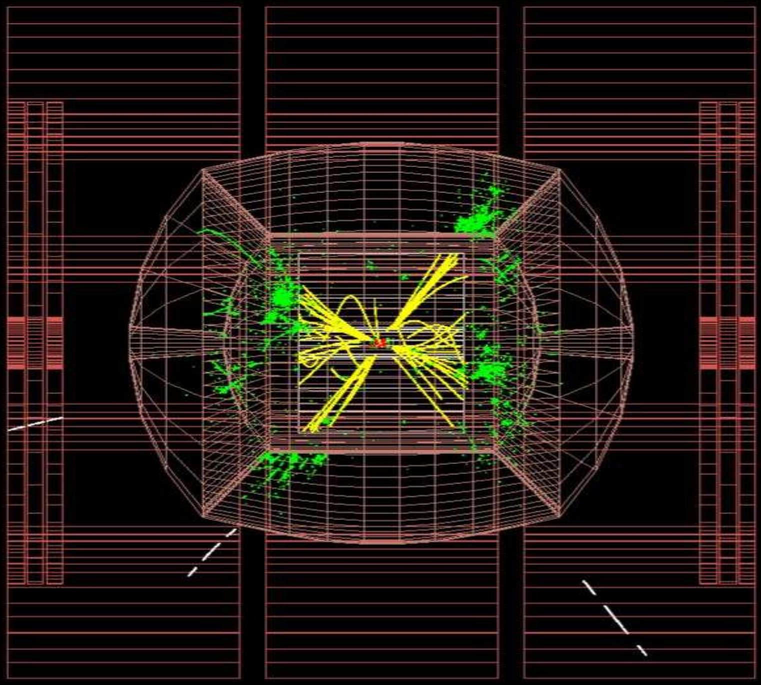
The 4th Concept Detector: Performance and Physics Capabilities



Corrado Gatto
INFN Napoli/Lecce
On behalf of the
4th Concept Collaboration

The simulations in the *4th Concept*

See also the following talk:

C. Gatto on Sunday morning on Software of the *4th Concept*
Complete description in:
http://www.fisica.unisalento.it/~vitomeg/allow_listing/LoiDraft/B.ILCroot-Gatto-simulations-a.pdf

4th Concept Software Framework: ILCroot

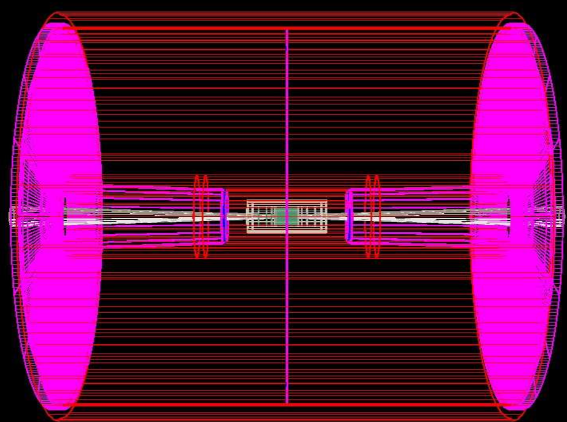
- Growing number of experiments have adopted it: Alice (LHC), Opera (LNGS), (Meg), CMB (GSI), Panda(GSI), 4th Concept, **LHeC and the forthcoming International Dual Readout Collaboration**
- Modularity allows to reuse subdetector modules developed by other collaborations
- Observation: it is a simulation framework and an Offline Systems:
  - It naturally evolves into the offline systems of your experiment
  - It is immediatly usable for test beams
  - Six MDC have proven robustness, reliability and portability
- **Introduced at ACFA06 (Bangalore) after Aliroot and MEGroot**
- **Only three additions ever since:**
  1. Interface to external files in various format (STDHEP, text, etc.)
  2. Standalone VTX track fitter
  3. Pattern recognition from VTX (for si central trackers)

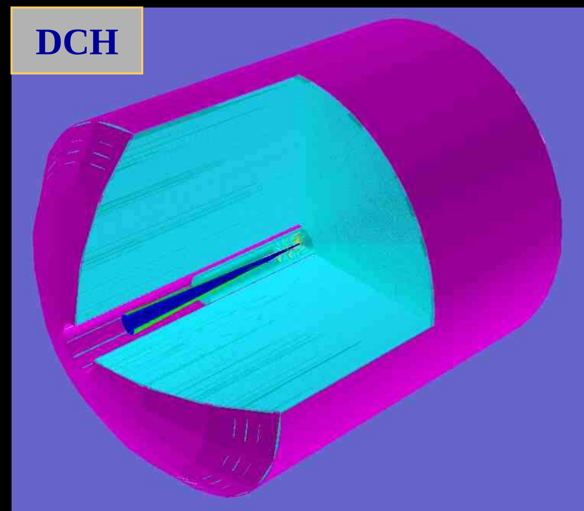
Do not Reinvent the wheel
Concentrate on Detector studies and Physics

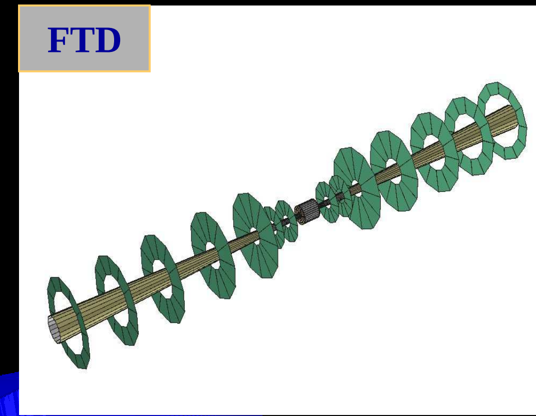
From Bangalore to Now: Detectors in ILCroot

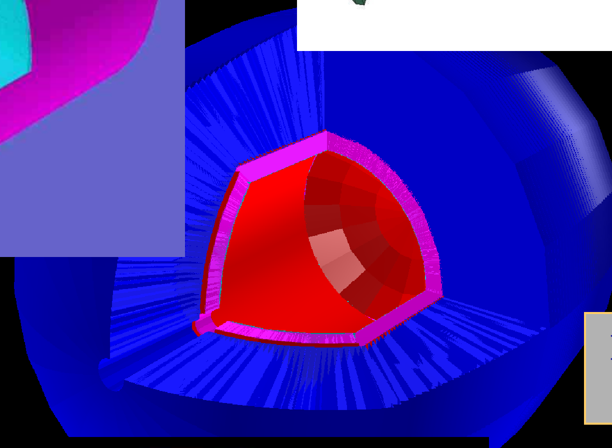
- 4th Concept Baseline
  - VTX: from SiD scaled to 3.5 Tesla (original version)
  - Drift Chamber: 2nd version
  - Fiber Triple Readout Calorimeter: 3rd version
  - Muon Spectrometer: Original version
- New additions:
  - Crystal Triple Readout Calorimeter ← Included into the LoI
  - FTD (from SiLC) ← Did not make it into the LoI
- Also available
  - VTX Detectors: Original SiD
  - Central Trackers: TPC, Si-Strips (SID01), SPT (Pixel Tracker)
- **Total: 10 subdetectors (16 versions), most of them with full simulation**
  - Detector response
  - Digitization
  - Noise/treashold
  - Clusterization
  - Patter recognition
  - Parallel Kalman filter

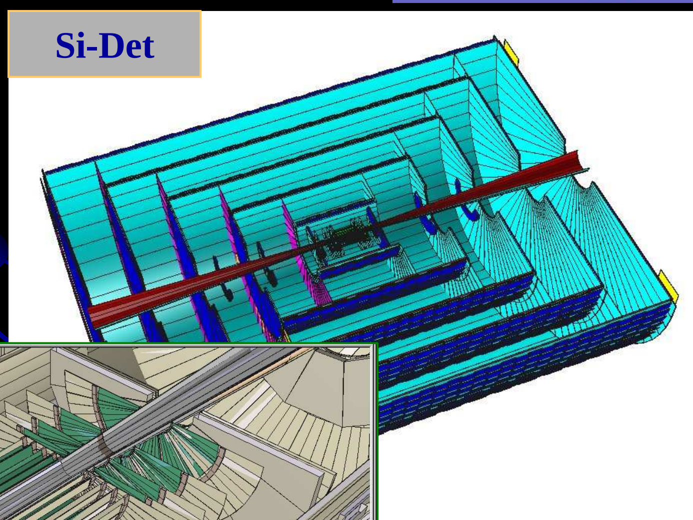
Detectors Galore

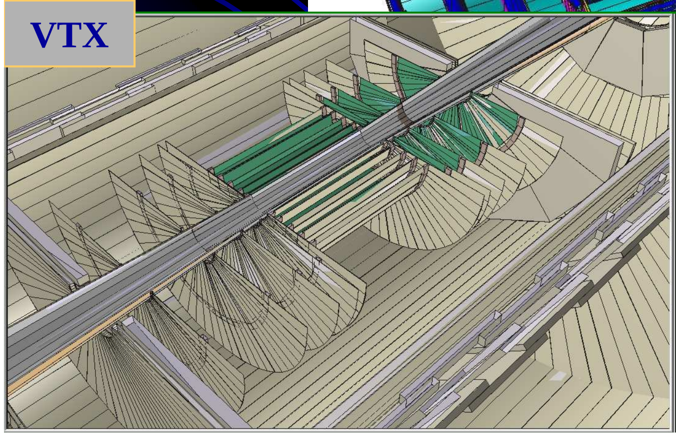


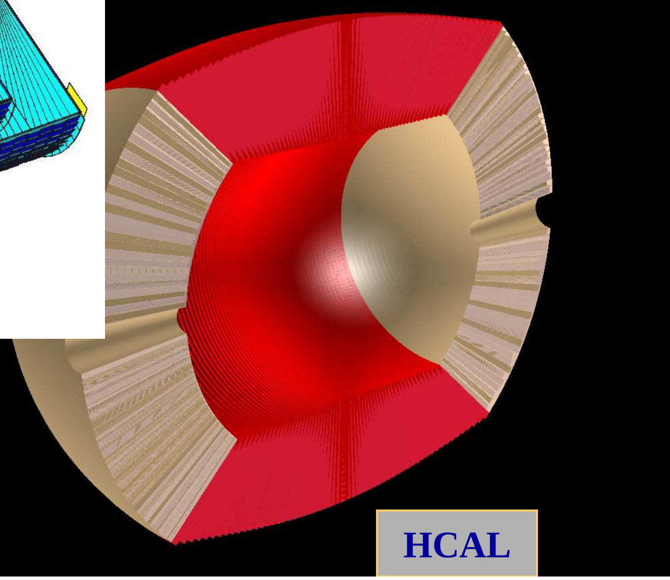


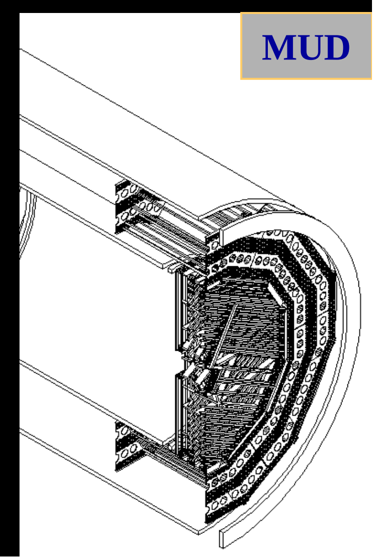












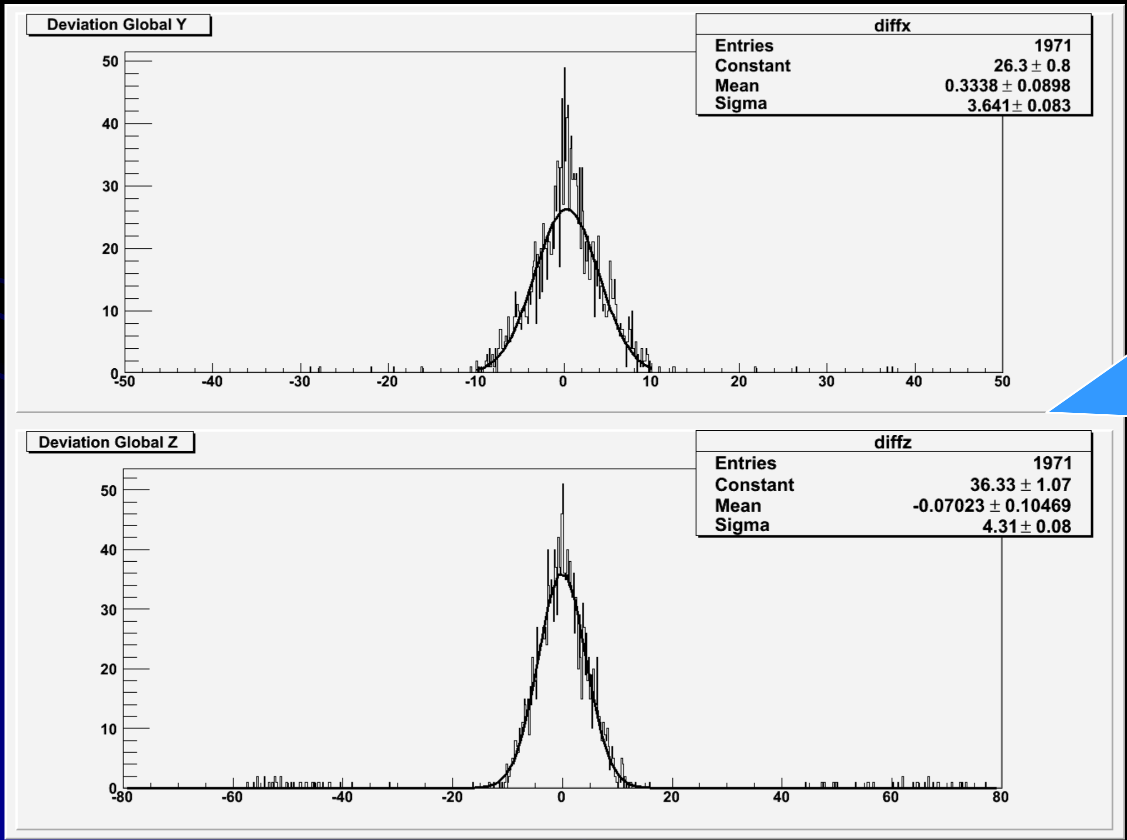
Performance Studies

See also the following talks:

J. Hauptman on Saturday
F. Grancagnolo on Saturday

VXD Single Cluster Residual (single track)

- FNAL/SLAC layout more than adequate for current requirements at ILC
- Main Issue is choice of technology
- Mostly driven by Montecarlo studies on beam background



Includes:

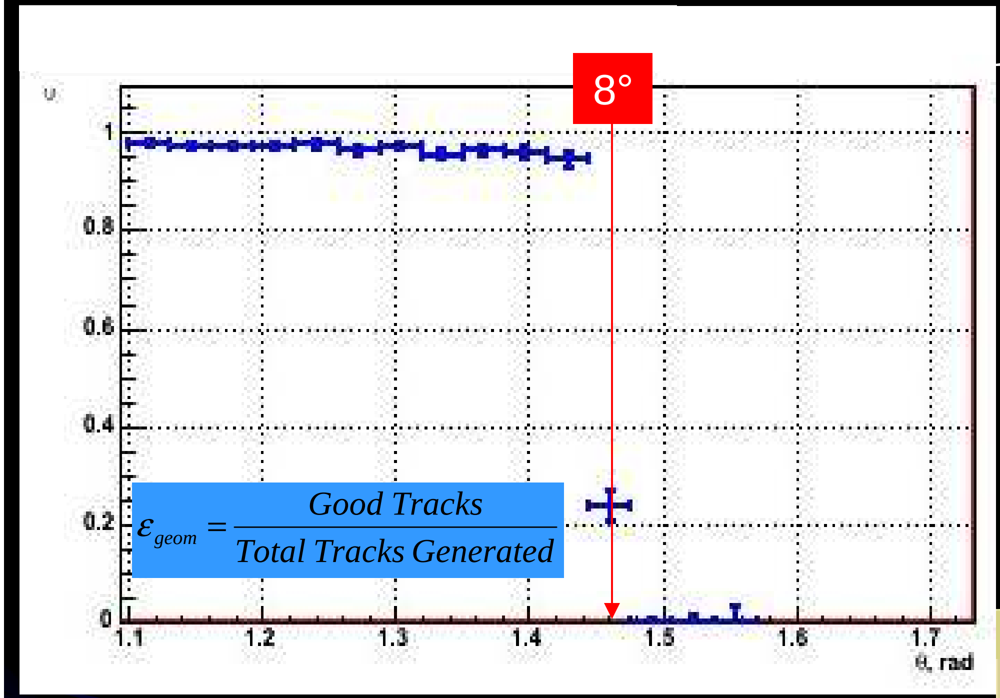
1. Diffusion in Si
2. Cross talk
3. Gaussian noise
4. Electronic thresholds
5. Clusterization

ILCRoot simulation

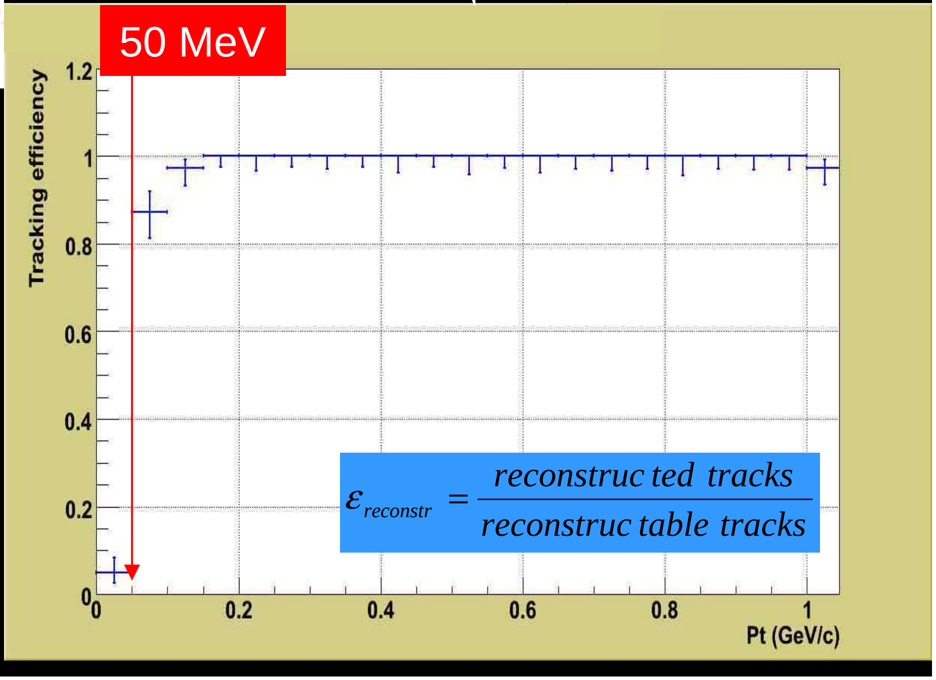
Single muons
No beam bkg

Tracking Performance

Geometrical efficiency



Tracking efficiency



Defining "reconstructable tracks"

I. DCA(true) < 3.5 cm

AND

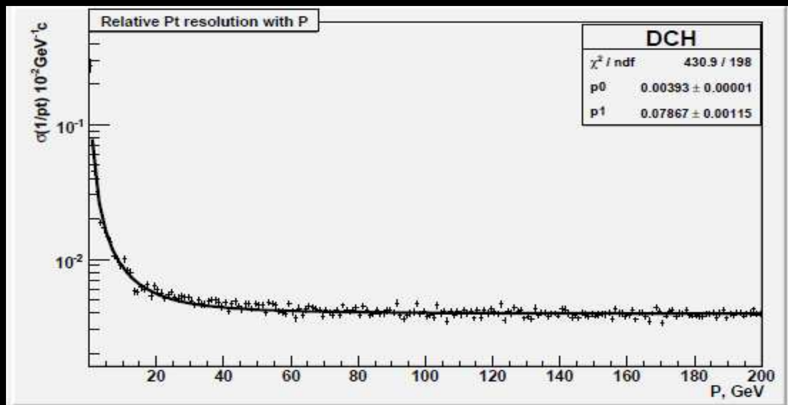
II. (At least 10 hits in DCH

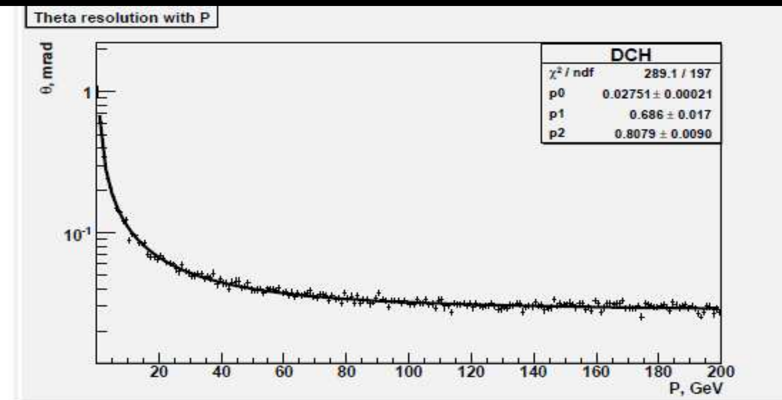
OR

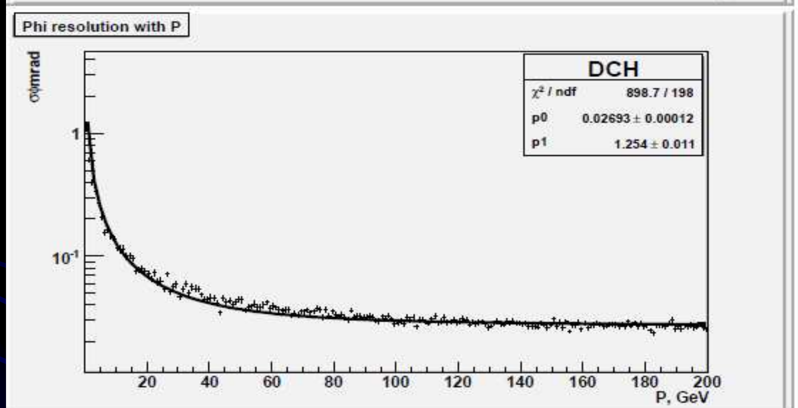
III. At least 4 hits in VTX)

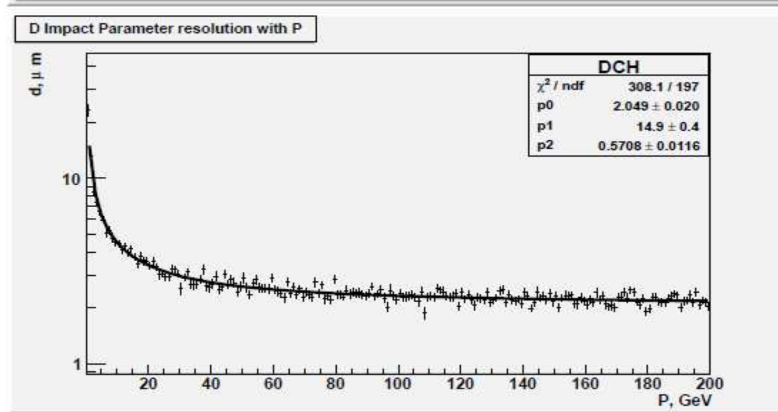
Single muons
No beam bkg

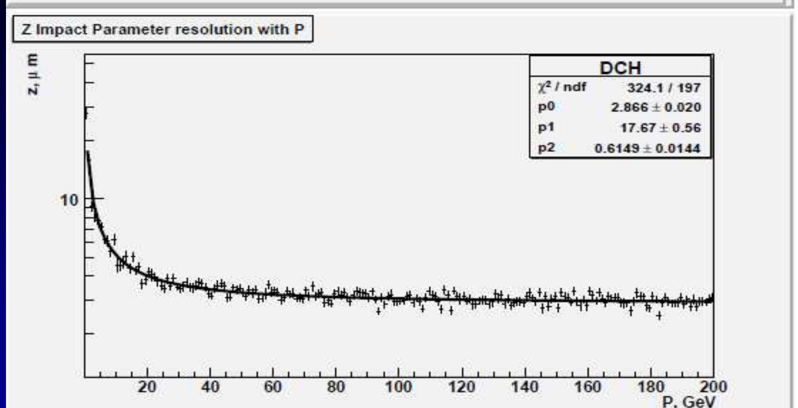
Tracking resolution vs P







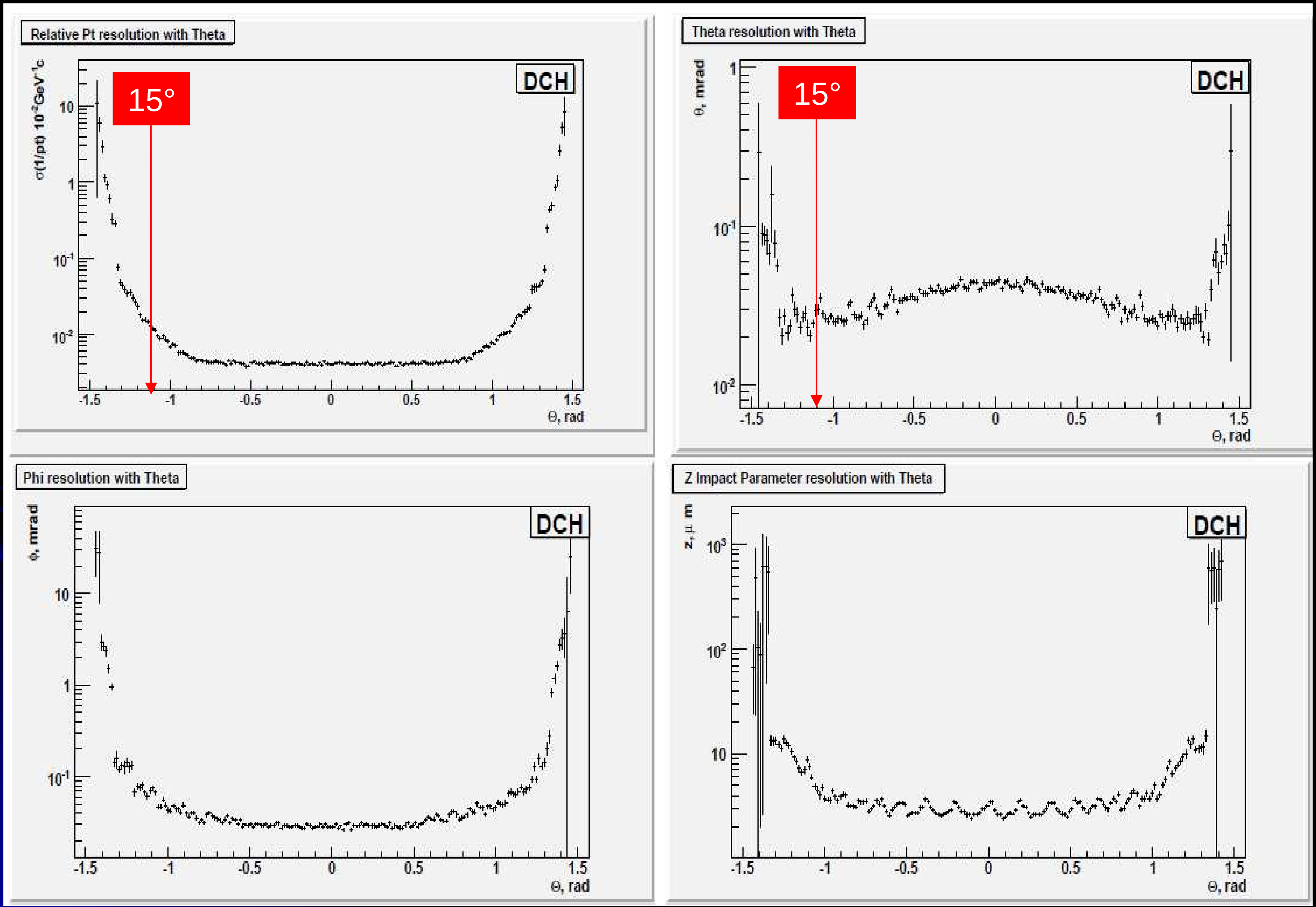




track parameter	fit results stochastic term	multiple scattering term
$\sigma(1/p_T)$	3.9×10^{-5} (GeV/c)$^{-1}$	$\oplus\ 7.9 \times 10^{-3}/p_T$
σ_θ	0.69 mrad$/p_T^{0.80}$	$\oplus$ 0.027 mrad
σ_ϕ	1.25 mrad$/p_T$	$\oplus$ 0.027 mrad
σ_d	$14.9\ \mu$m$/p_T^{0.57}$	$\oplus\ 2.0\mu$m
σ_z	$17.7\ \mu$m$/p_T^{0.58}$	$\oplus\ 2.9\mu$m

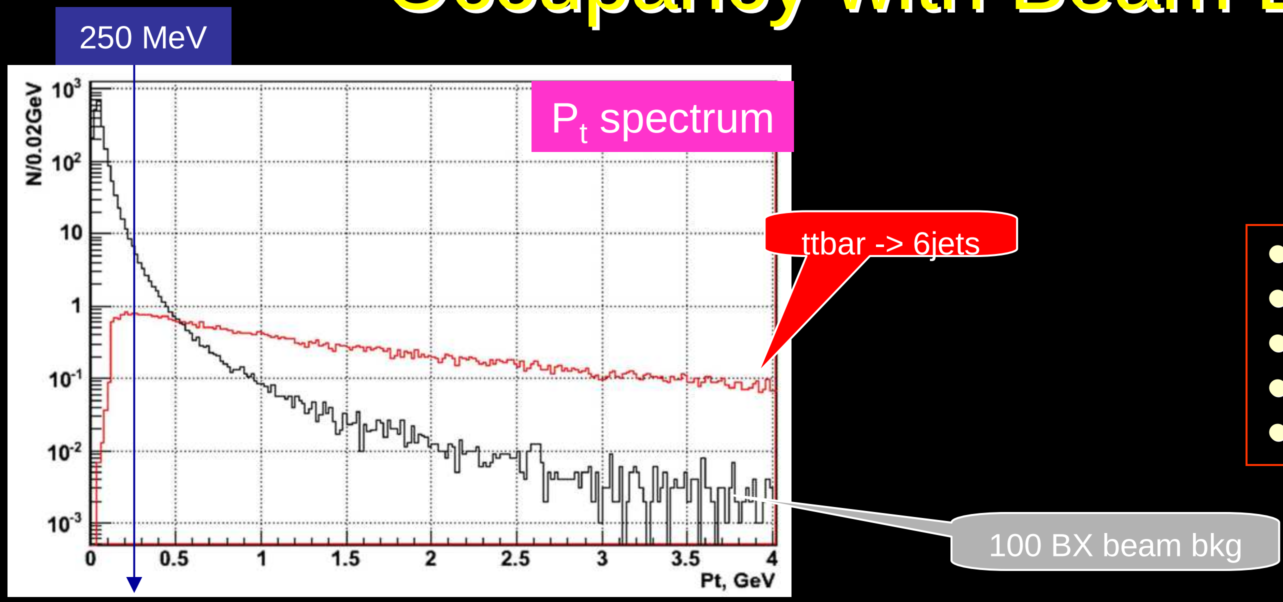
Single muons
No beam bkg

Tracking resolution vs θ

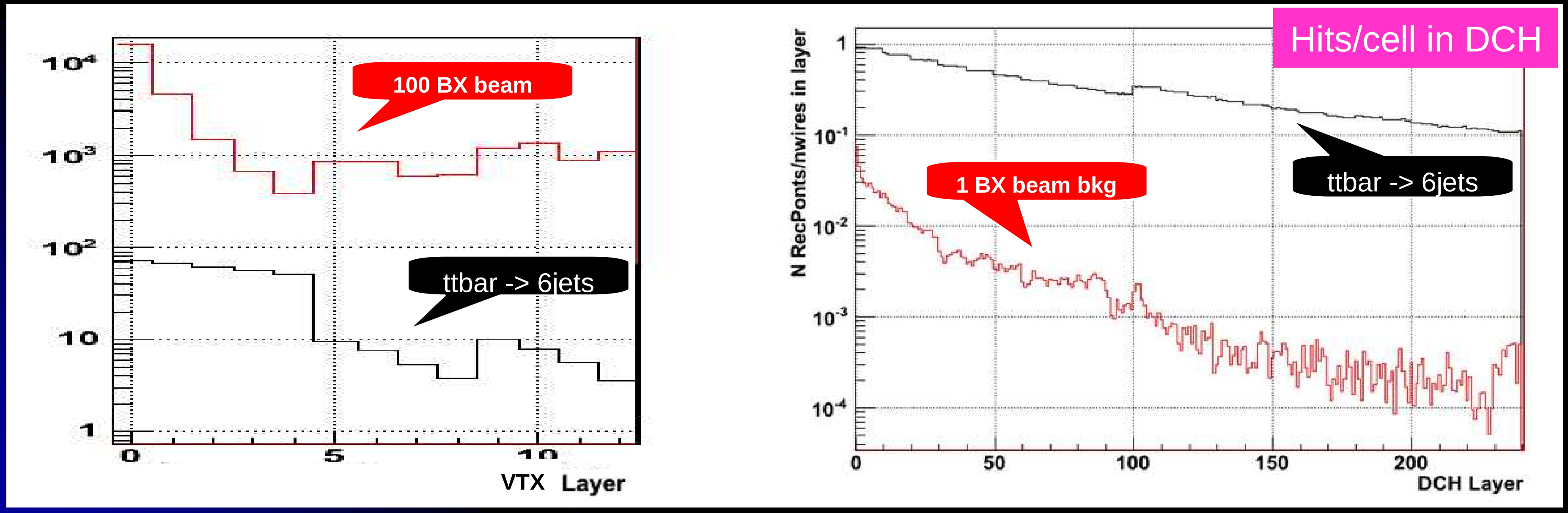


ttbar –> 6 jets
100 BX beam bkg

Occupancy with Beam Background

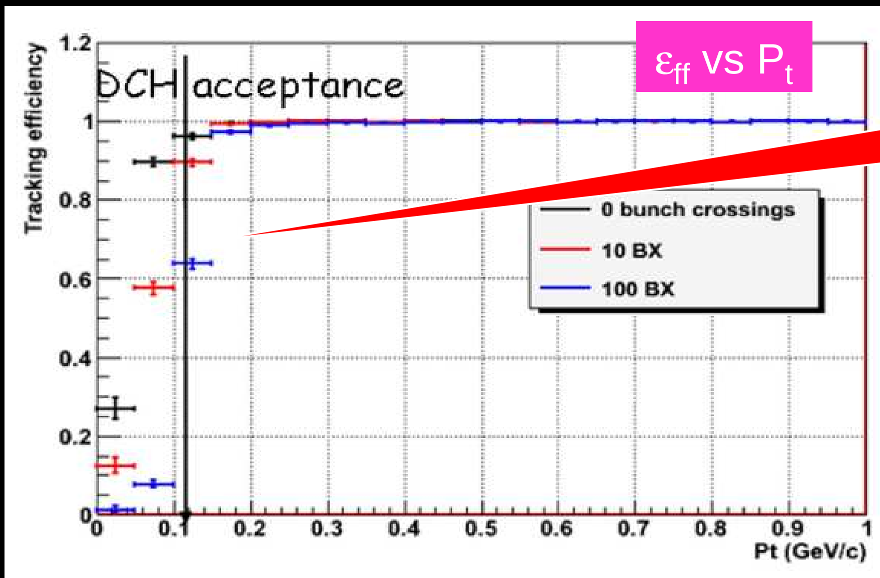


- ttbar->6jets
- Drift chamber + VTX
- Full simulation/reconstruction
- 3.5 Tesla B-field
- 0.02 hits/mm^2/BX in VTX



ttbar –> 6 jets
10-100 BX beam bkg

Tracking Efficiency with Beam Background



90% Acceptance With BX

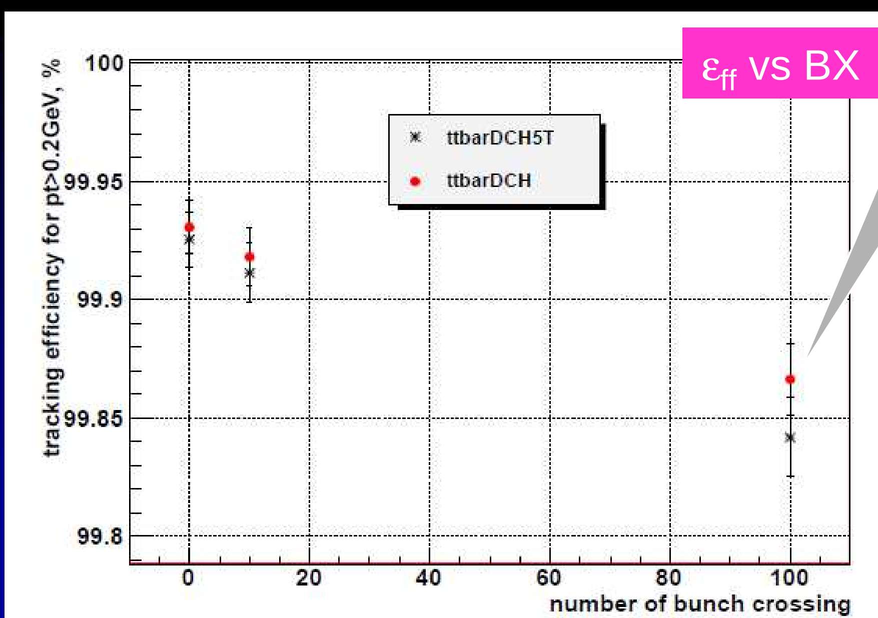
Fake track definition

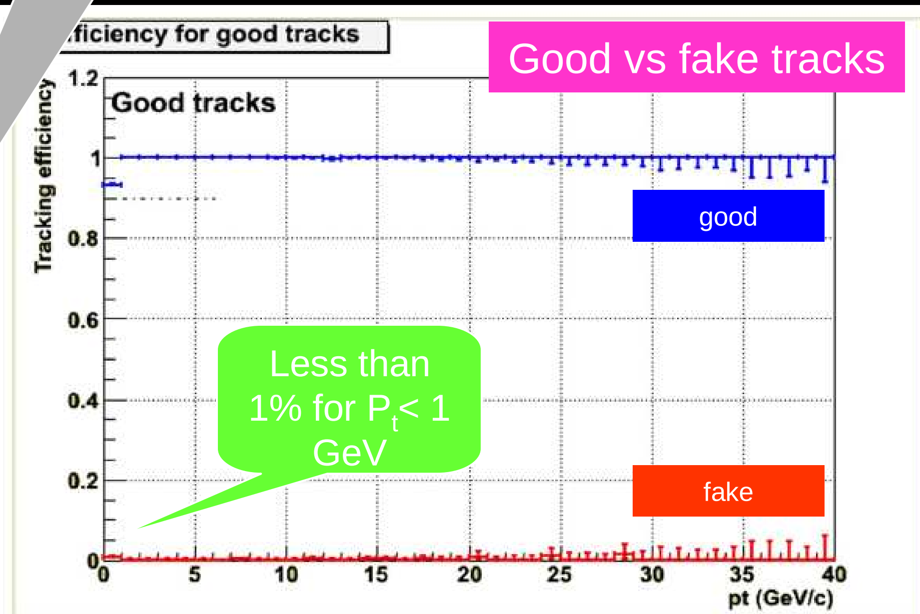
- 1 misassigned cluster in VTX
- 10% misassigned clusters in DCH

Sources of inefficiencies

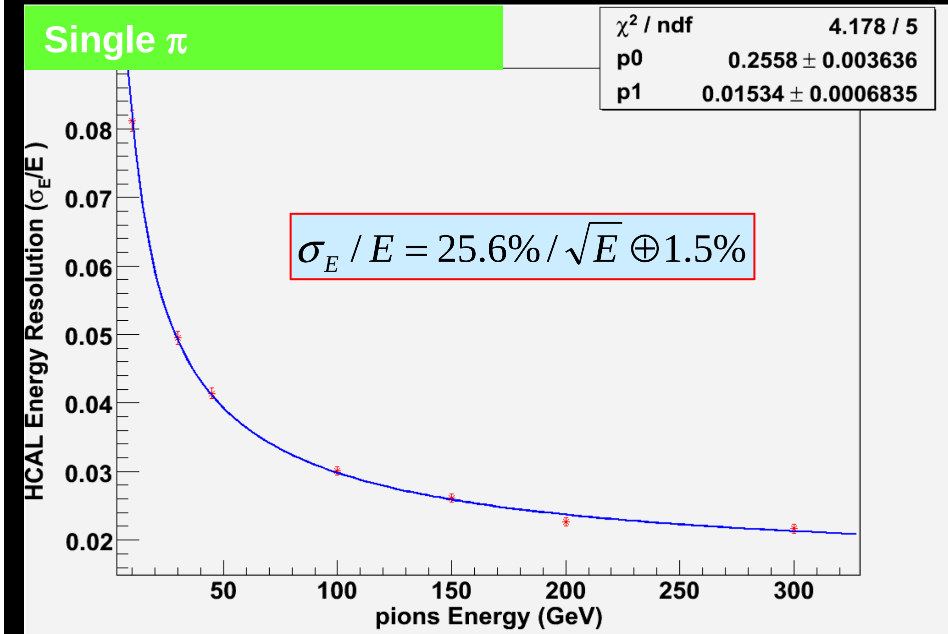
- seeding for low Pt & Kalman filter with fake clusters

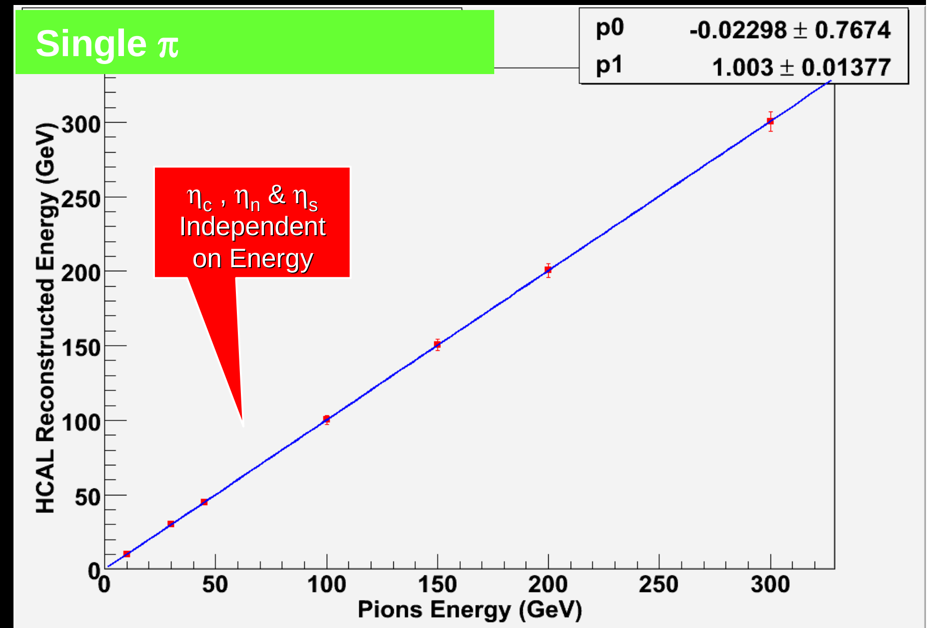
3.5 T vs 5 T

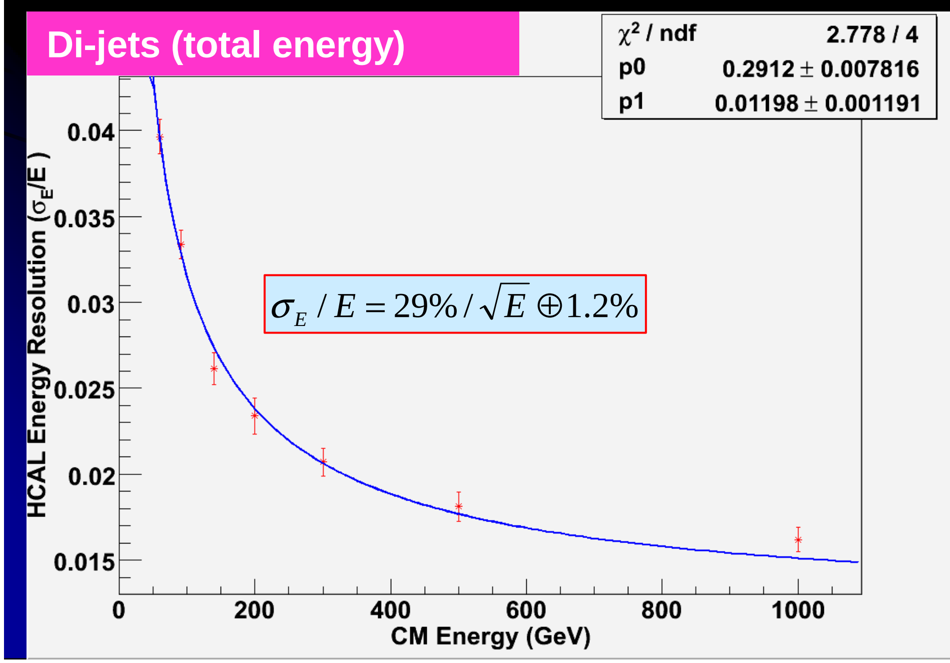


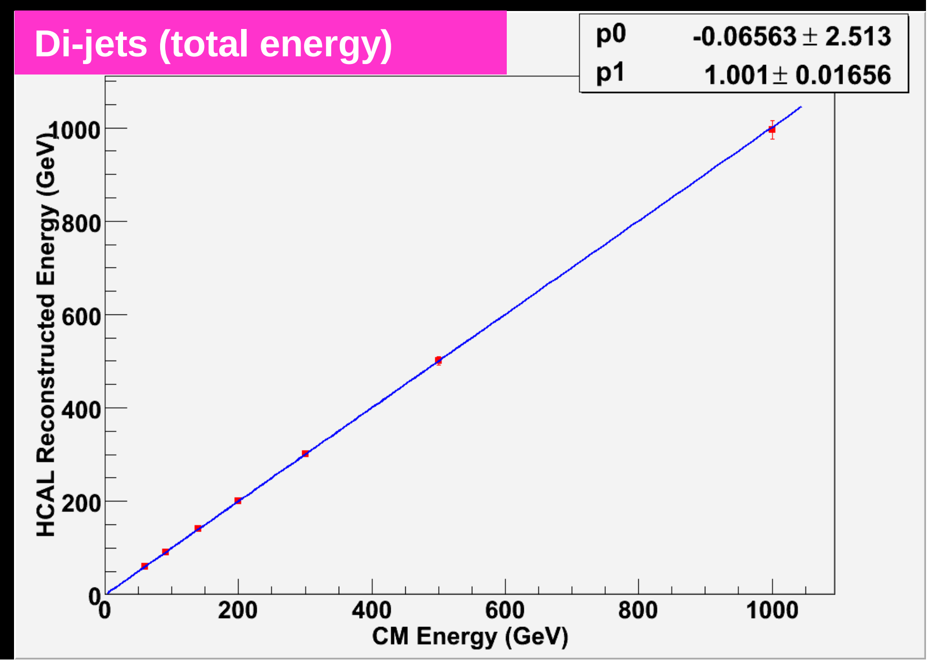


Fiber Calorimeter Performance (Triple Readout)

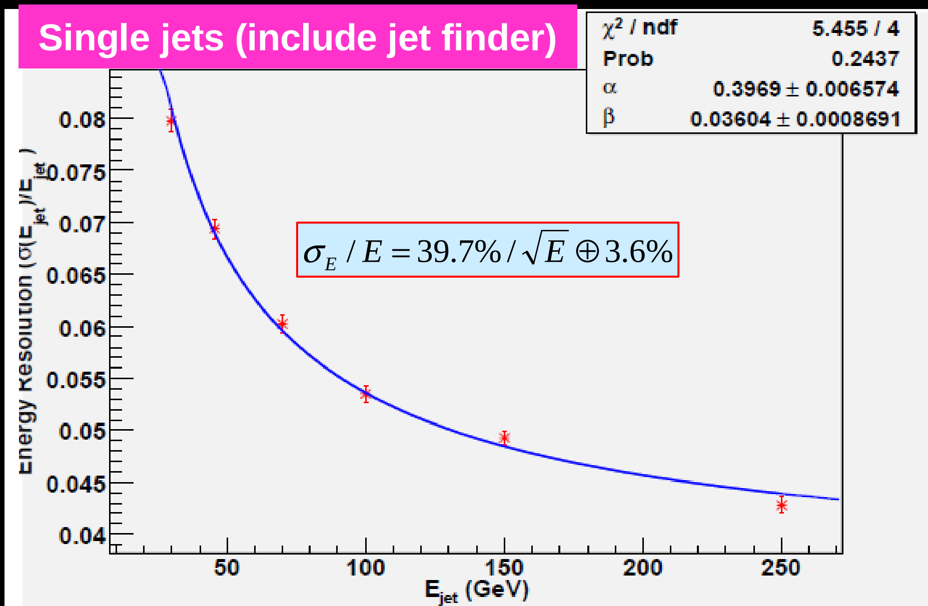


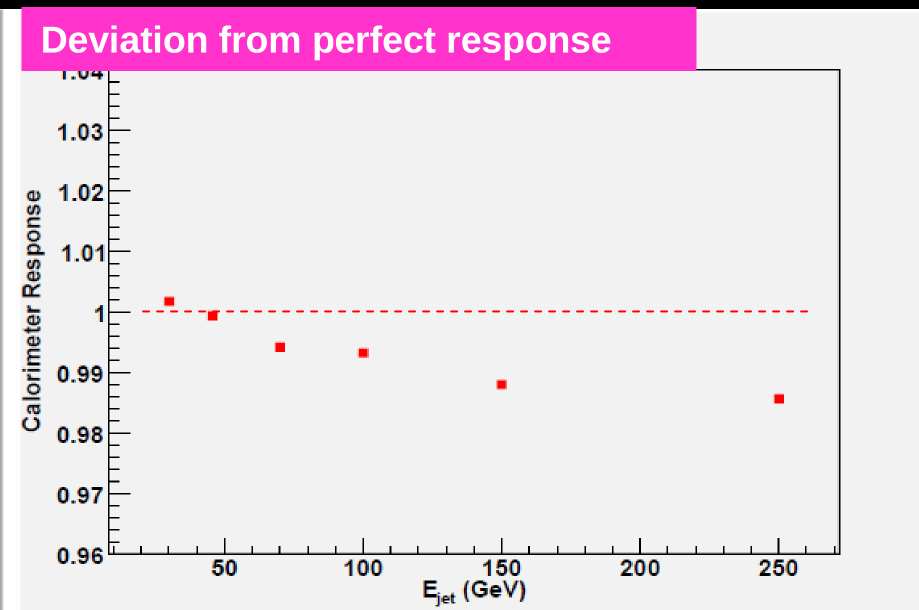


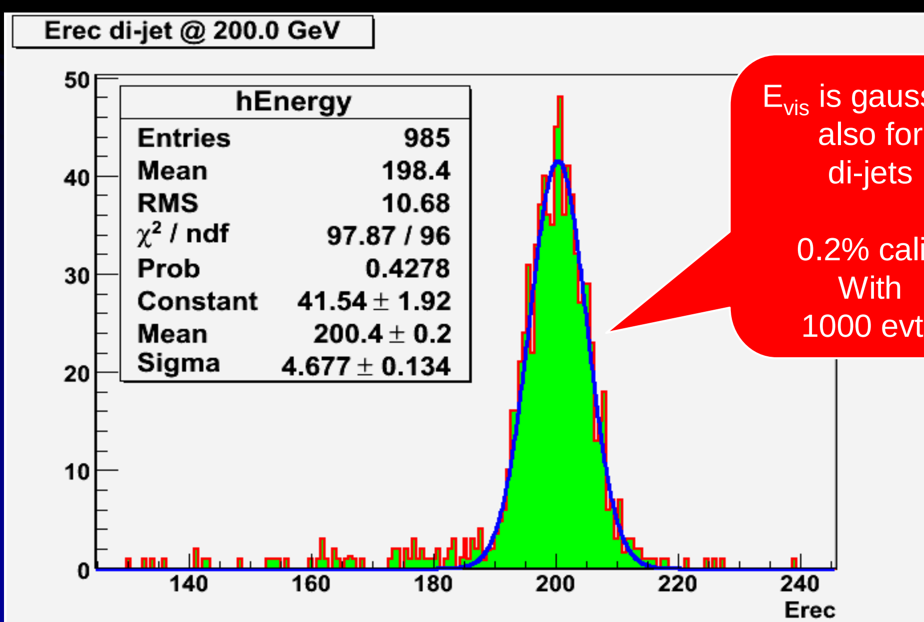




Calorimeter + Jet Finder Performance







E_{vis} is gaussian also for di-jets

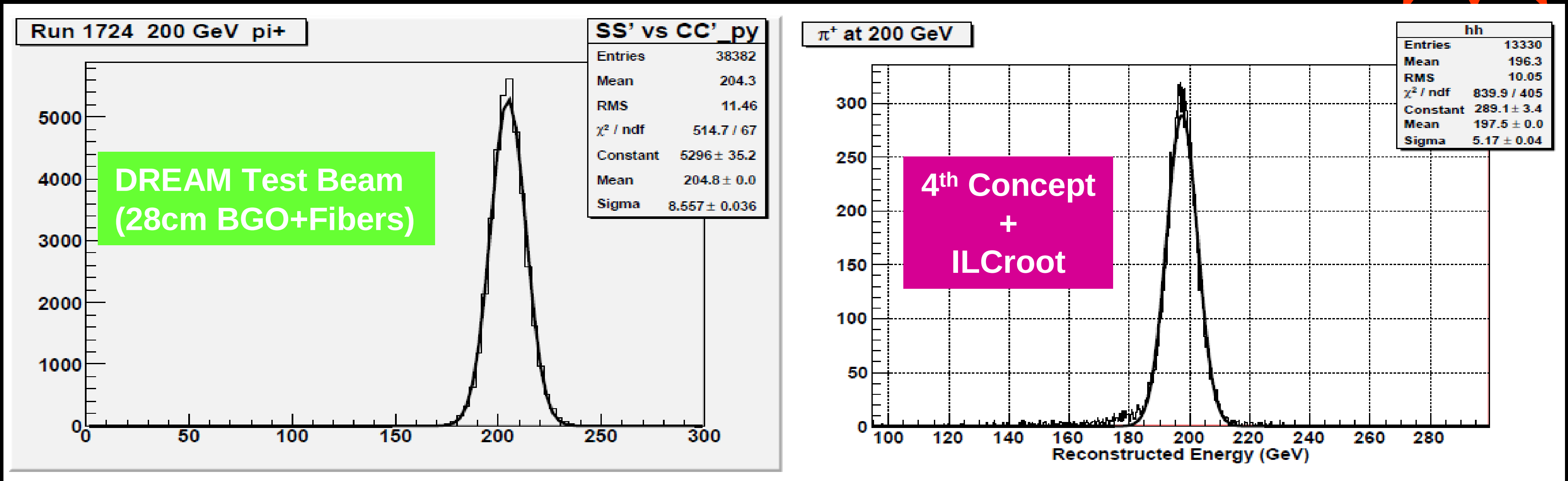
0.2% calib With 1000 evts

Jet finder algorithm still in progress

Must understand loss of resolution

Crystal + Fiber Calorimeter

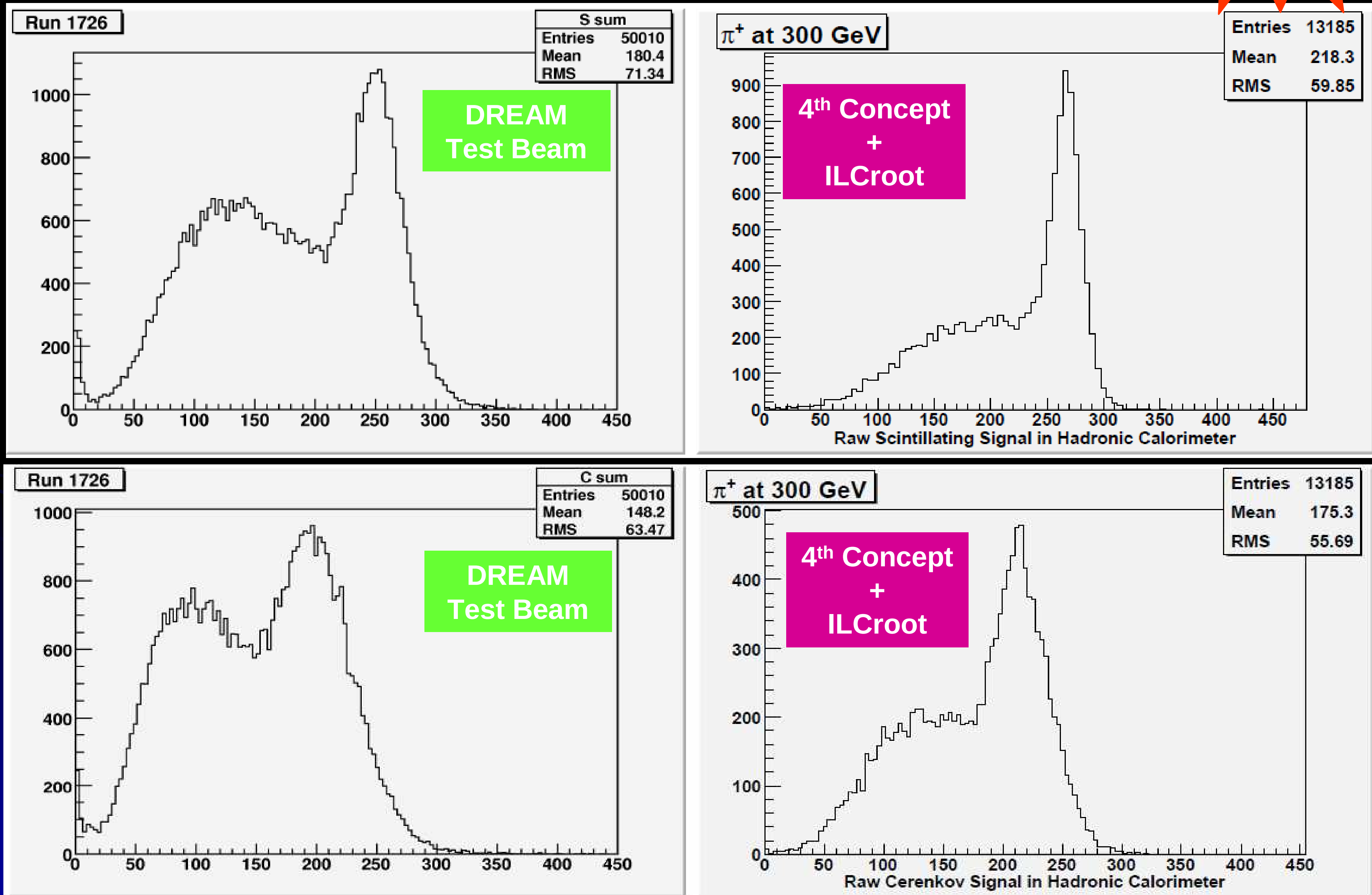
New



- Finally, we found the correct algorithm!
- Works for DREAM test beam as well
- Excellent agreement (taking into account the geometric differences)
- **Implications are very important**

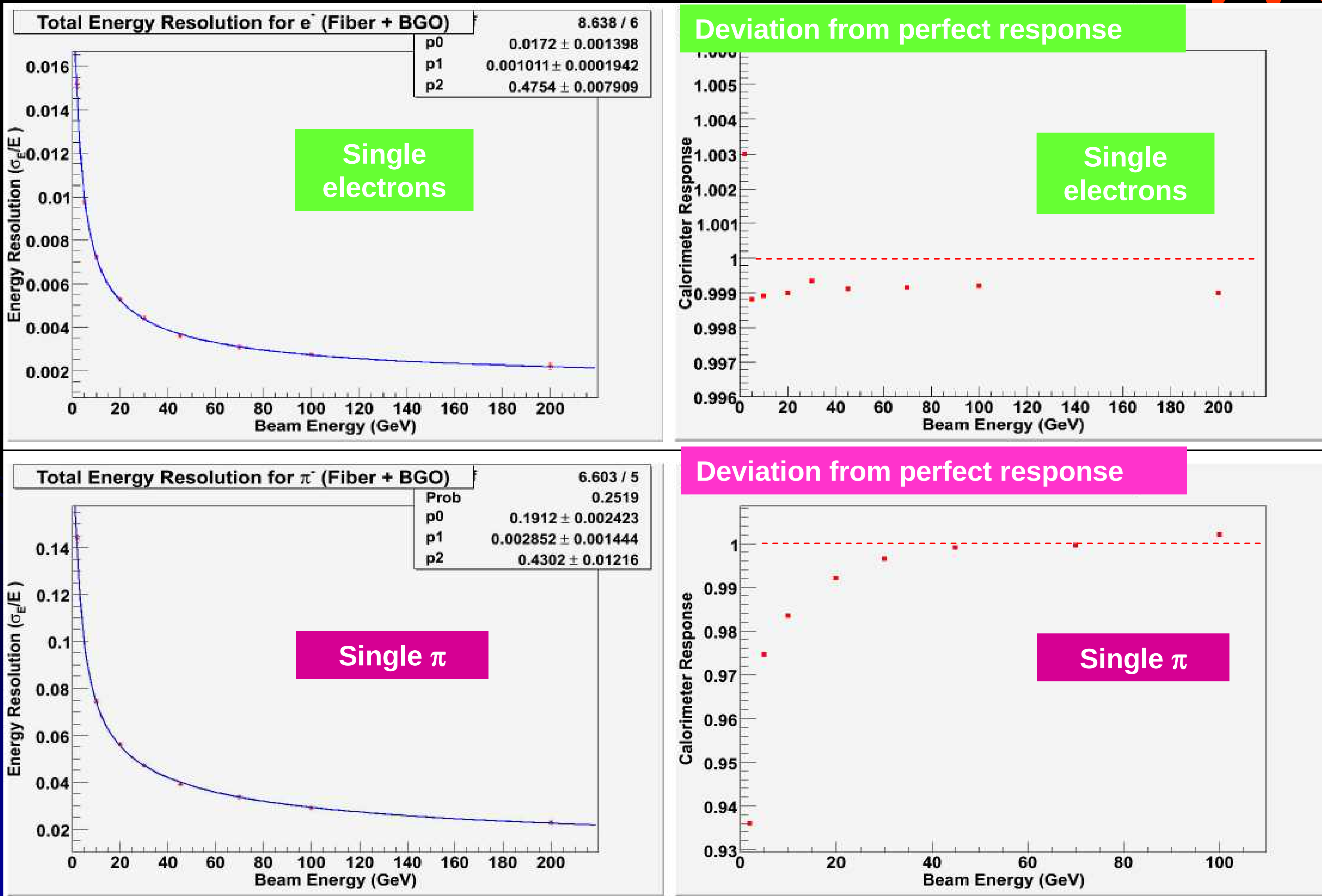
DREAM vs *4th Concept*

New



Crystal + Fiber Calorimeter Performance

New



Crystal + Fiber Calorimeter Performance

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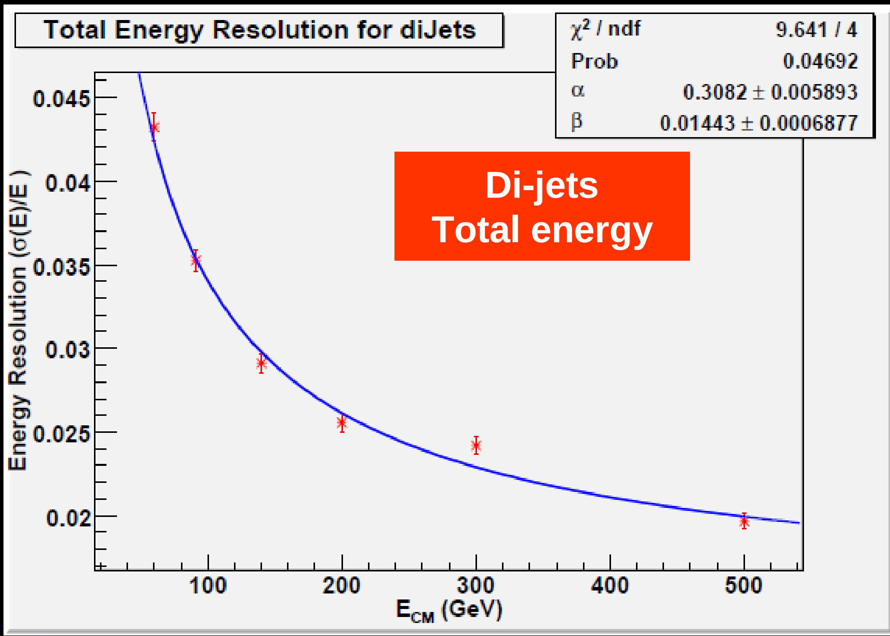
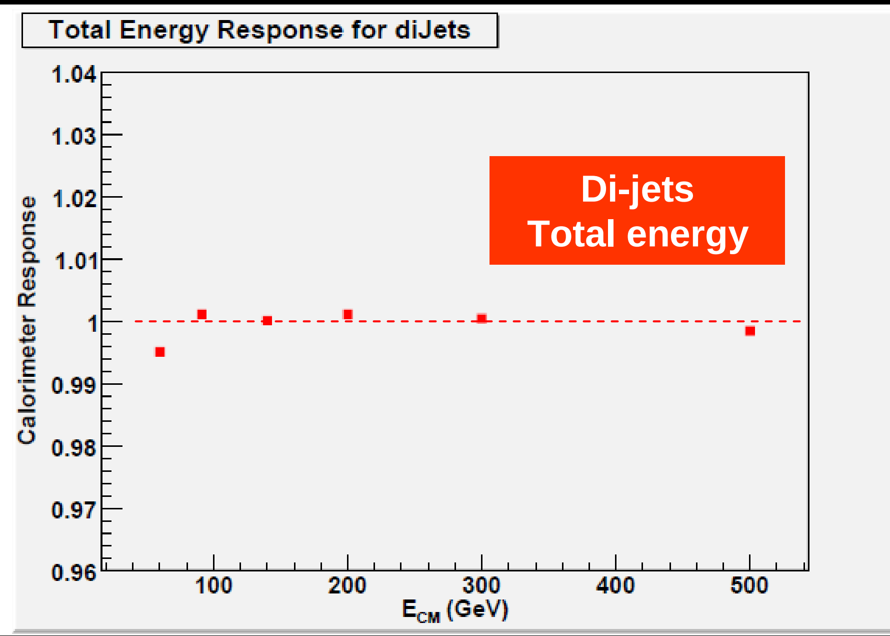




Particle species	Gaussian resolution stochastic term	σ_E/E constant term
electrons	$1.7\%/E^{0.48}$	$\oplus\ 0.1\%$
pions	$19.1\%/E^{0.43}$	$\oplus\ 0.3\%$
jets	$30.8\%/\sqrt{E}$	$\oplus\ 1.4\%$

Constant term Dominated by Simulation in the Crystals

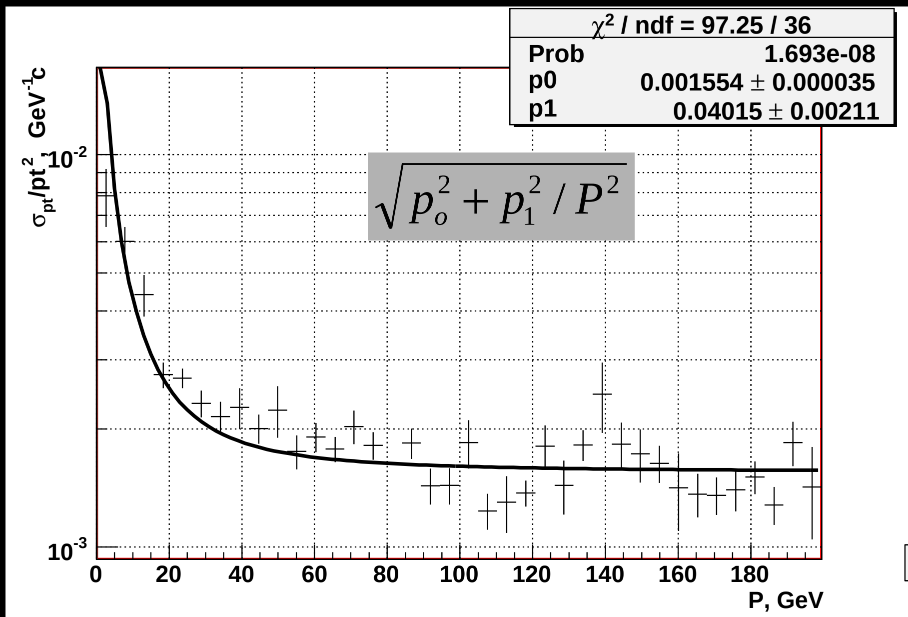
Still too naive

Summary of Calorimetry Performance

Particle type	Calorimeter	Stochastic term	Constant term
e^-	ECAL + HCAL	1.7% *	0.1%*
π^-	ECAL + HCAL	19.1%*	0.3%*
di-jet	ECAL + HCAL	30.8%*	1.4%*
π^-	HCAL	25.6%	1.5%
di-jet	HCAL	29.1%	1.2%

*** Non $E^{-½}$ behaviour**

Muon Spectrometer Performance

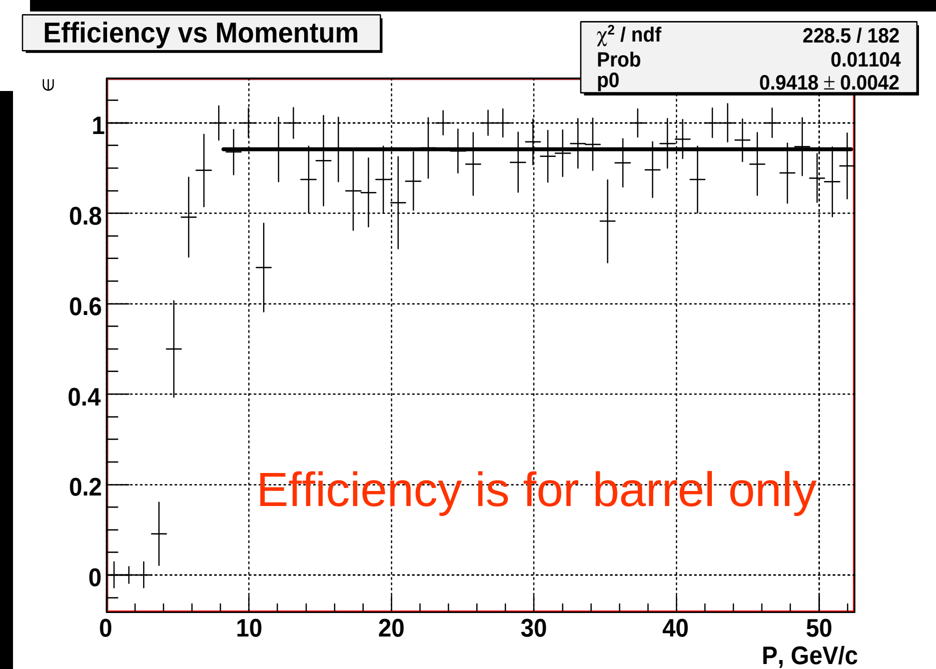


Cracks excluded

Requires tracks already reconstructed in DCH

$$\sigma(P_t^{-1}) = 0.04 / P \oplus 1.5 \times 10^{-3} GeV^{-1} c$$

vs 10% for a range based detector



Optimization Studies

Tracking vs Calorimetry

Compare 100 GeV π in tracking and calorimeter

Tracking resolution

track parameter	fit results stochastic term	multiple scattering term
$\sigma(1/p_T)$	3.9×10^{-5} (GeV/c)$^{-1}$	$\oplus$ $7.9 \times 10^{-3}/p_T$
σ_θ	0.69 mrad$/p_T^{0.80}$	$\oplus$ 0.027 mrad
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Calorimeter resolution

Particle species	Gaussian resolution stochastic term	σ_E/E constant term
electrons	$1.7\%/E^{0.48}$	$\oplus\, 0.1\%$
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jets	$30.8\%/\sqrt{E}$	$\oplus\, 1.4\%$

MS term is dominant already at 100 GeV

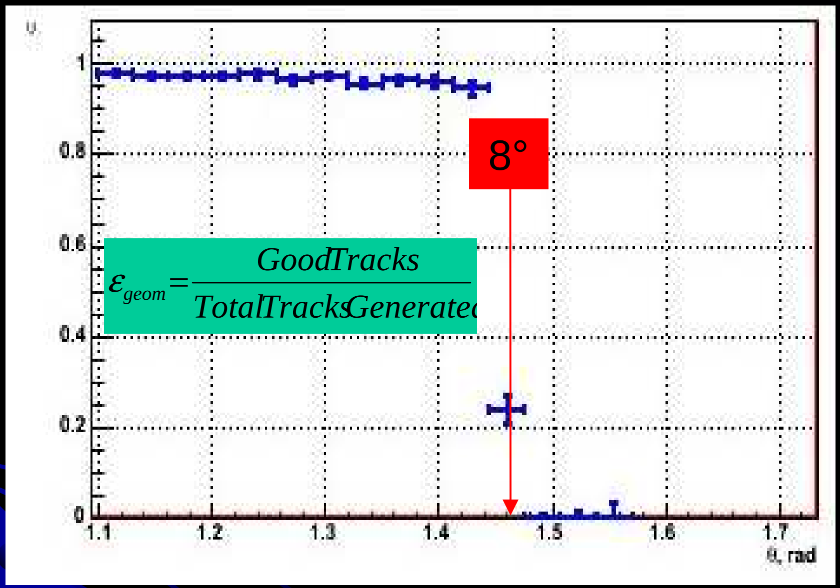
Constant term likely underestimated

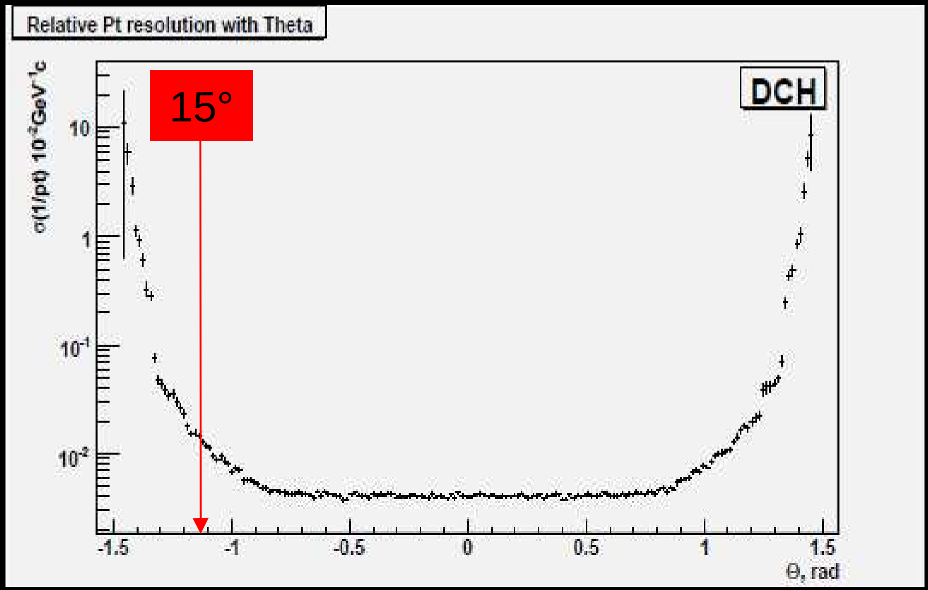
$$\sigma_P(100\,GeV) = 0.39 \oplus 0.79 \quad GeV$$

$$\sigma_E(100\,GeV) = 1.9 \oplus 0.3 \quad GeV$$

Tracking and Calorimeters are well matched
No need of gross optimization in terms of resolution

Tracking: Geometric Coverage



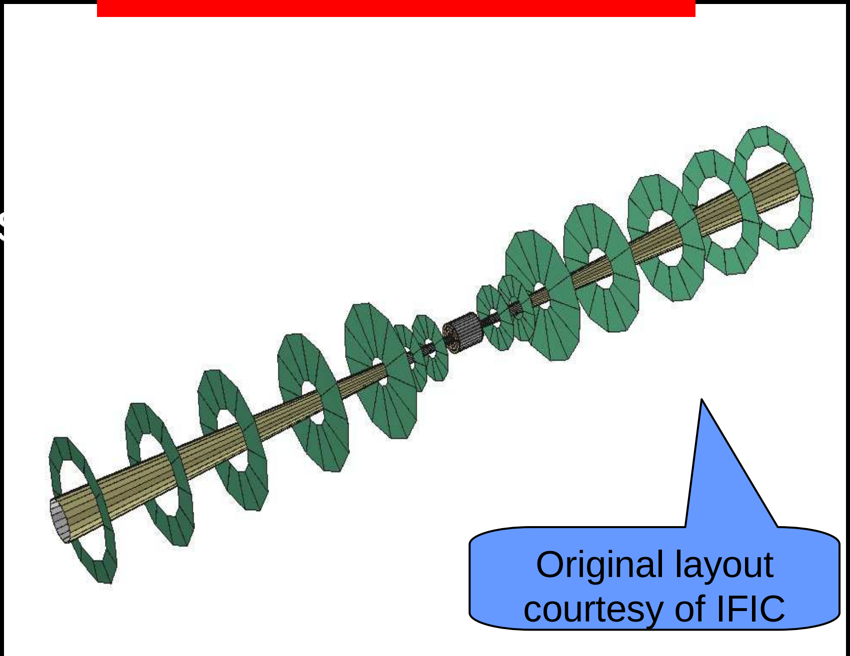


Compare with under 3° coverage of calorimeter

CluCou +SiLC

- Late December 2009 agreement (not in LoI)
- Two options considered:
  1. FTD detector à-là IFIC
  2. Silicon detectors
     - surronding the DCH endplates
- Simulations will help

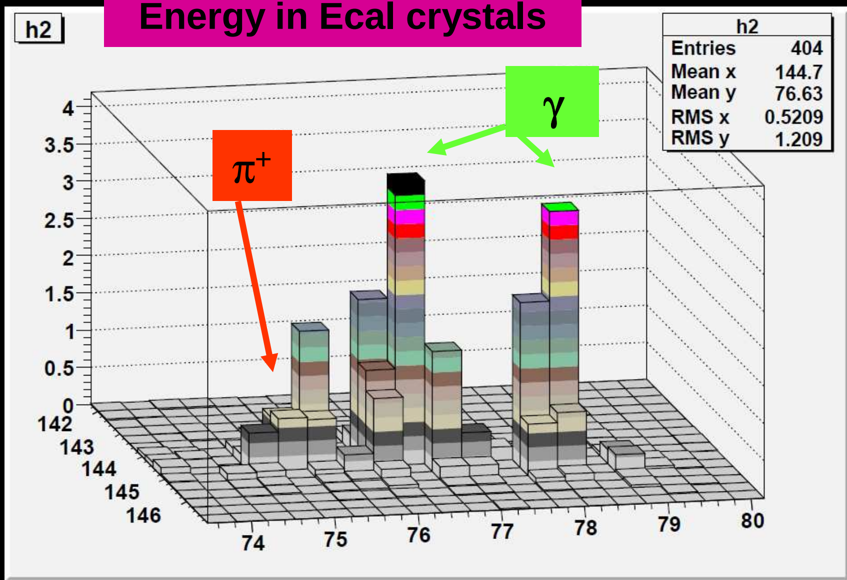
FTD internal to Drift Chamber

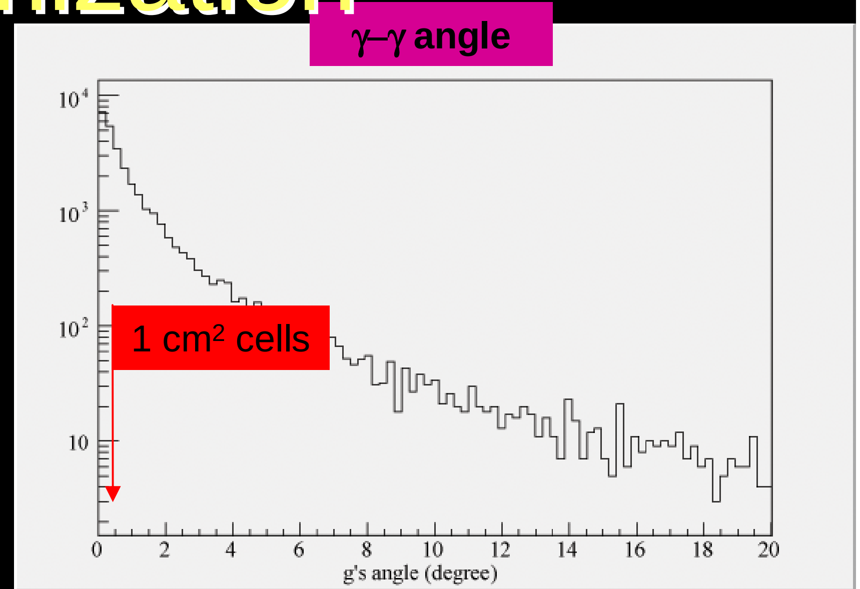


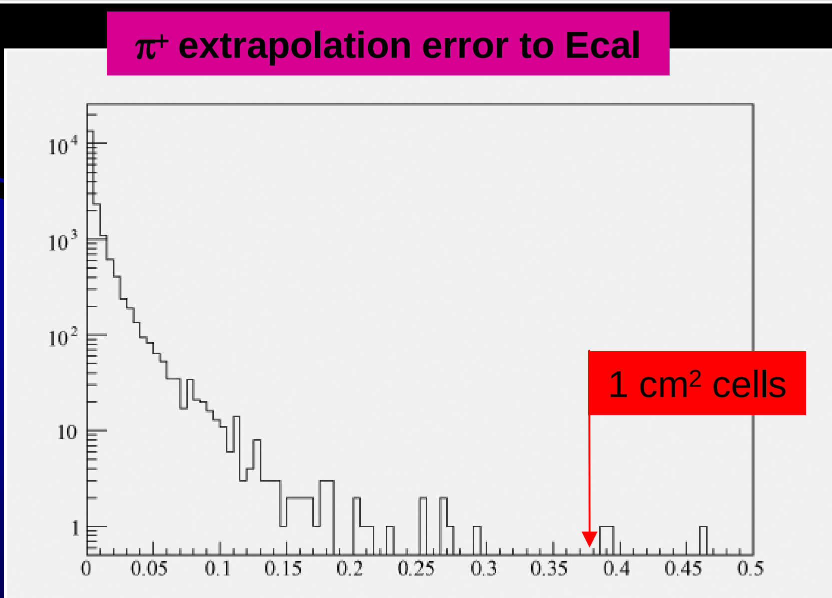
A. Savoy-Navarro, A. Charpy

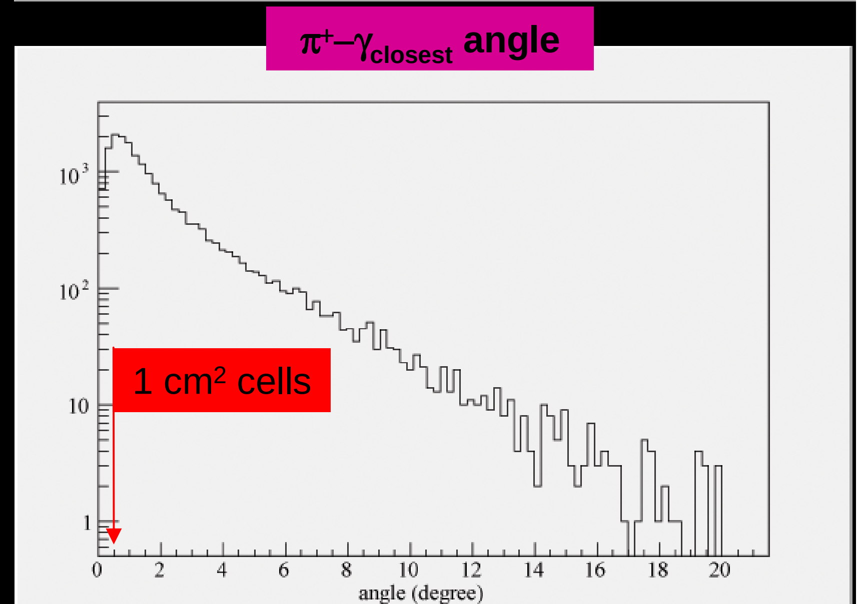
ECAL Optimization

$\tau\tau$, $\tau \rightarrow \rho\nu$ @ 500 GeV

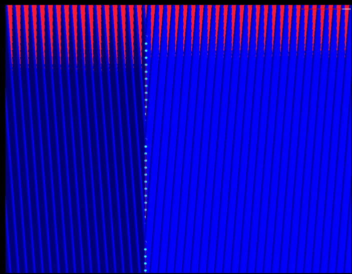






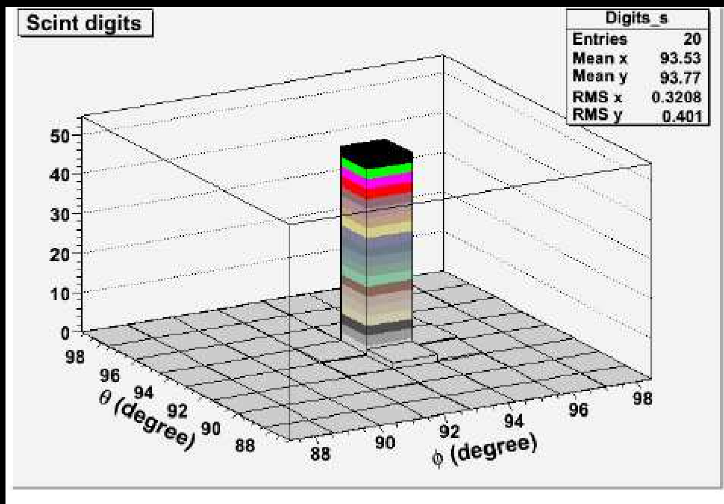


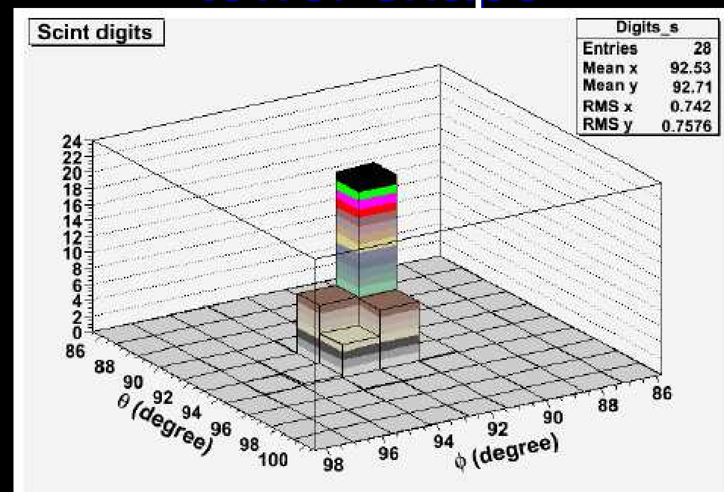
Clear indication that 1 cm² cells is overkilling

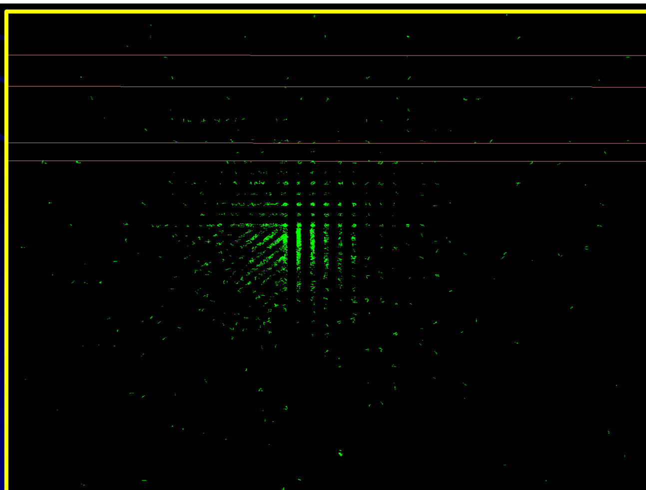


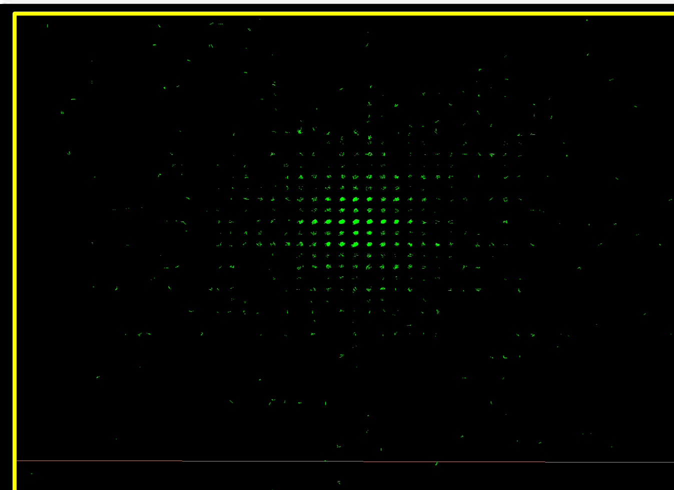
HCAL Optimization

Main Source of Constant Term:
tower shape









boundary | Top view of the shower of a 45 GeV e^- | **core**

Physics Studies

See also the following talks:

J. Hauptman on Saturday
C. Gatto on Saturday

Physics Studies for LoI

- Detector simulation frozen in July 2008 (except Ecal). Simu & Reco started August 2008 (expect some discrepancy with LOI)
- Not a smooth ride: event generations started before creation of the software panel
- Initial agreement to use a common event sample had no followthrough
- 4th Concept used ILD sample (many thanks to Frank and Akiya)
- Too many issues encountered: no QC
- Not only ILCroot: MarlinKinFit & Rave
- 99% computing resources are from Fermilab
- ILCroot is freely available at Fermilab

http://ilc.fnal.gov/detector/rd/physics/technical/resources/ilcroot.shtml

Summary

Process	e^- polar.	e^+ polar.	Ecal	Beam bkgnd	MC
$Z^oH^o \rightarrow \mu^+ \mu^- X$	+100%	-100%	yes	yes	Fluka
$Z^oH^o \rightarrow e^+ e^- X$	+100%	-100%	yes	yes	Fluka
$Z^oH \rightarrow$ 4 jets	+100%	-100%	no	no	Fluka
$Z^oH^o \rightarrow \nu\underline{\nu} X$	+100%	-100%	no	no	Fluka
$e^+e^- \rightarrow t\,\underline{t}$	+100%	-100%	no	yes	Fluka
$e^+e^- \rightarrow \tau^+\tau^-$	+100%	-100%	yes	yes	Fluka

Worst case polarization scenario considered: largest WW background

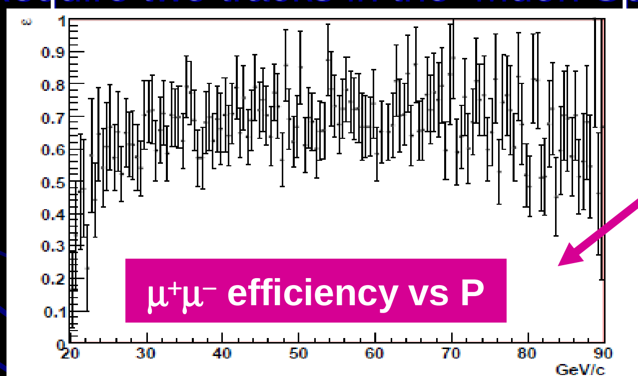
$e^+e^- \rightarrow Z^oH^o \rightarrow \mu^+ \mu^- X$ $\sqrt{s}$=250 GeV

Analysis strategy

1. Initial cuts to reduce background

   1. $|cos\theta_\mu| < 0.98$
   2. $P_t(\mu^\pm) > 9$ GeV
   3. $72 < M(\mu^+\mu^-) < 110$ GeV
   4. $102 < M_{recoil}(\mu^+\mu^-) < 168$ GeV
   5. At least 4 charged tracks for the

2. Require two tracks in the Muon Spectrometer



3. Final cuts for S/N enjhancement

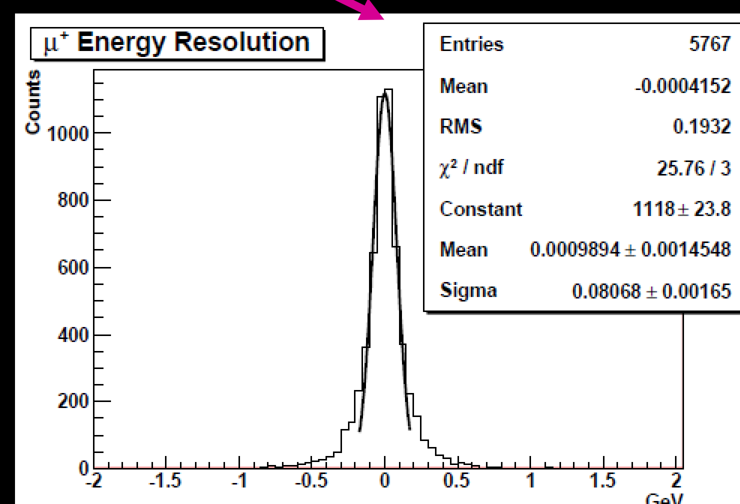
   1. largest $P_\mu > 20$ GeV
   2. At least 5 charged tracks successfully reconstructed (including the muons)
   3. Distance of closest approach to the origin for the candidate muon tracks < 6 mm

signal

bkgnd

Final state
$e^+e^- \rightarrow Z^0H^0 \rightarrow \mu^+\mu^- + X$
$e^+e^- \rightarrow \mu^+\mu^-$
$e^+e^- \rightarrow \mu^+\mu^-\mu^+\mu^-$
$e^+e^- \rightarrow \mu^+\mu^-\tau^+\tau^-$
$e^+e^- \rightarrow \mu^+\mu^-e^+e^-$
$e^+e^- \rightarrow \mu^+\mu^-\nu\overline{\nu}$
$e^+e^- \rightarrow \mu^+\mu^-u\overline{u}$
$e^+e^- \rightarrow \mu^+\mu^-d\overline{d}$
$e^+e^- \rightarrow \mu^+\mu^-s\overline{s}$
$e^+e^- \rightarrow \mu^+\mu^-c\overline{c}$
$e^+e^- \rightarrow \mu^+\mu^-b\overline{b}$

$\varepsilon_{\mu\mu}$ = 80.5%
Purity= 99.9%



G. Tassielli, G. Terracciano, M. Peccarisi

$e^+e^- \to Z^oH^o \to \mu^+ \mu^- X$ $\sqrt{s}$=250 GeV

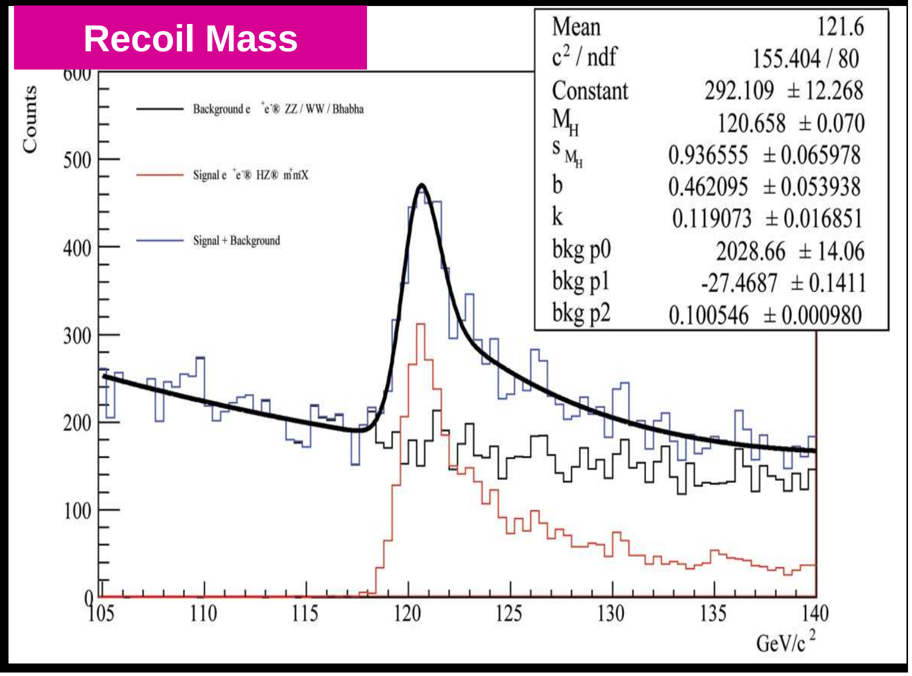
Results

$\Delta M^{stat}_{Higgs} = 296\ MeV/c^2 \quad \Delta M^{syst}_{Higgs} = 31\ MeV/c^2$

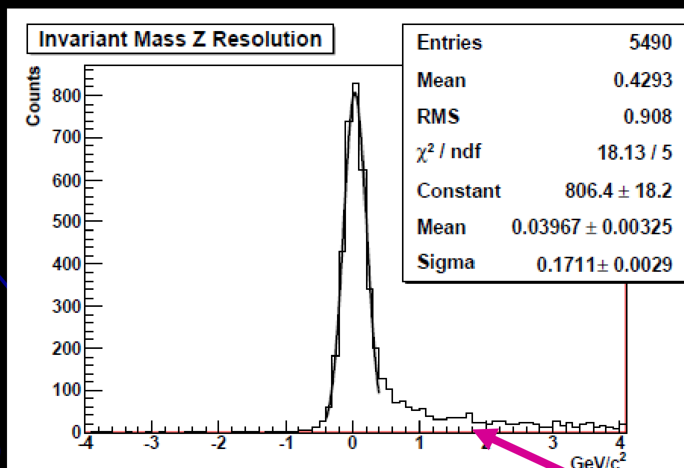
$\Delta M^{stat}_{Z^o} = 171\ MeV/c^2 \quad \Delta M^{syst}_{Z^o} = 40\ MeV/c^2$

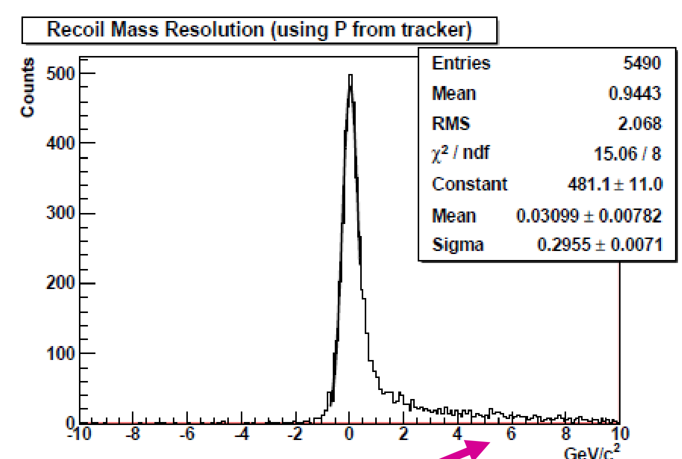
$\sigma_{e^+e^- \to Z^oH^o} = 13.62 \pm 0.77\ fb$

$\varepsilon_{reconstruction} = 64.1\%$



Results affected by M_μ=0 (and consequent μ brehemstralung)





tails should not be there

G. Tassielli, G. Terracciano, M. Peccarisi

$e^+e^- \to Z^0H^0 \to e^+e^- X$ $\sqrt{s}$=250 GeV

Analysis strategy

1. Initial cuts to reduce background

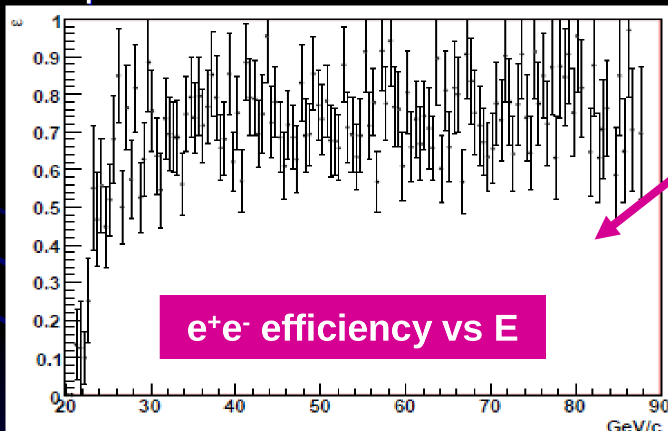
1. $|cos\theta_e| < 0.95$
2. $P_t(e^{\pm}) > 9$ GeV
3. $72 < M(e^+e^-) < 110$ GeV/c²
4. $102 < M_{recoil}(e^+e^-) < 168$ GeV/c²
5. At least 4 charged tracks for the $e^+e^- \to e^+e^-$ montecarlo sample
6. At least 6 charged tracks for the $e^+e^- \to e^+e^-\mu^+\mu^-$ montecarlo sample

signal

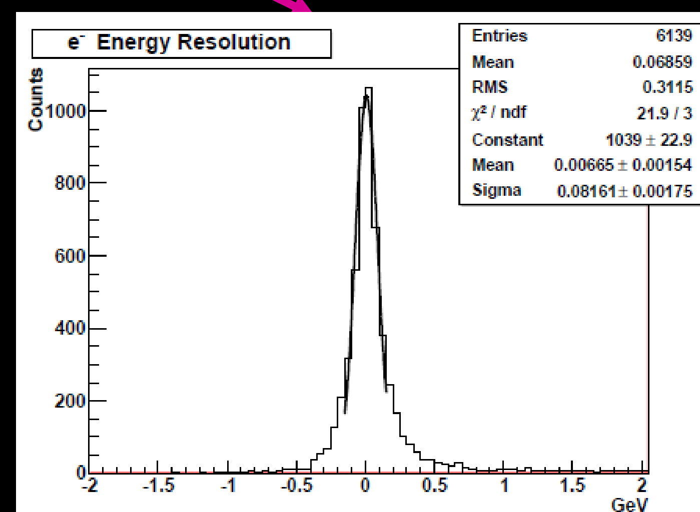
bkgnd

Final state
$e^+e^- \to Z^0H^0 \to e^+e^- + X$
$e^+e^- \to e^+e^-$
$e^+e^- \to e^+e^-e^+e^-$
$e^+e^- \to e^+e^-\tau^+\tau^-$
$e^+e^- \to e^+e^-\mu^+\mu^-$
$e^+e^- \to e^+e^-\nu\bar{\nu}$
$e^+e^- \to e^+e^-u\bar{u}$
$e^+e^- \to e^+e^-d\bar{d}$
$e^+e^- \to e^+e^-s\bar{s}$
$e^+e^- \to e^+e^-c\bar{c}$
$e^+e^- \to e^+e^-b\bar{b}$

2. Require two electrons in the ECAL/DCH



ε_{ee} = 93.4%
Purity= 98.2%



3. Final cuts for S/N enjhancement

1. largest $P_e > 20$ GeV
2. At least 5 charged tracks successfully reconstructed
3. Distance of closest approach to the origin for the candidate electron tracks < 6 mm

G. Tassielli, G. Terracciano, M. Peccarisi

$e^+e^- \rightarrow Z^oH^o \rightarrow e^+ e^- X$ $\sqrt{s}$=250 GeV

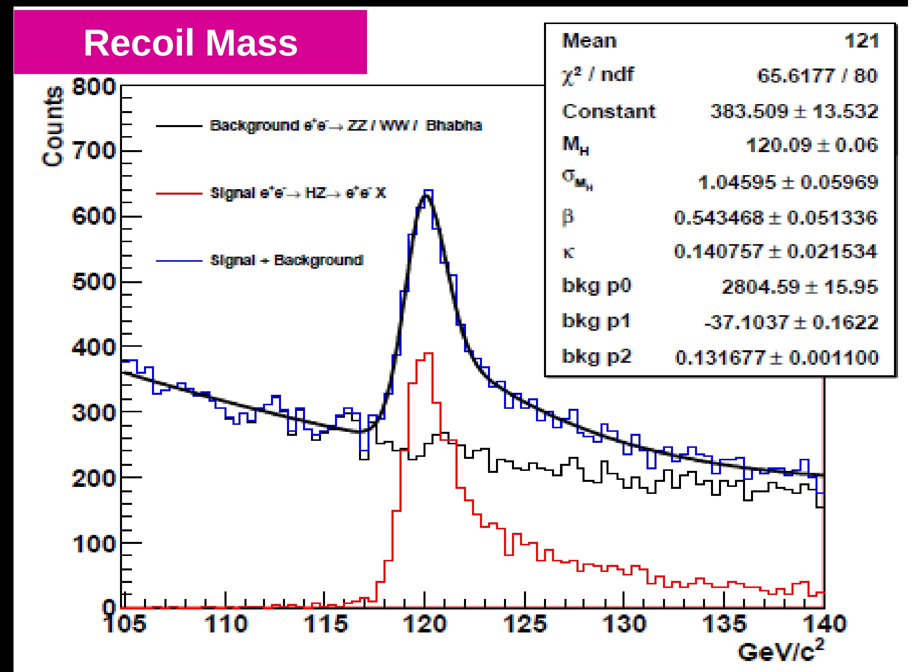
Results

$$\Delta M^{stat}_{Higgs} = 400\ MeV/c^2 \quad \Delta M^{syst}_{Higgs} = 19\ MeV/c^2$$

$$\Delta M^{stat}_{Z^o} = 149\ MeV/c^2 \quad \Delta M^{syst}_{Z^o} = 28\ MeV/c^2$$

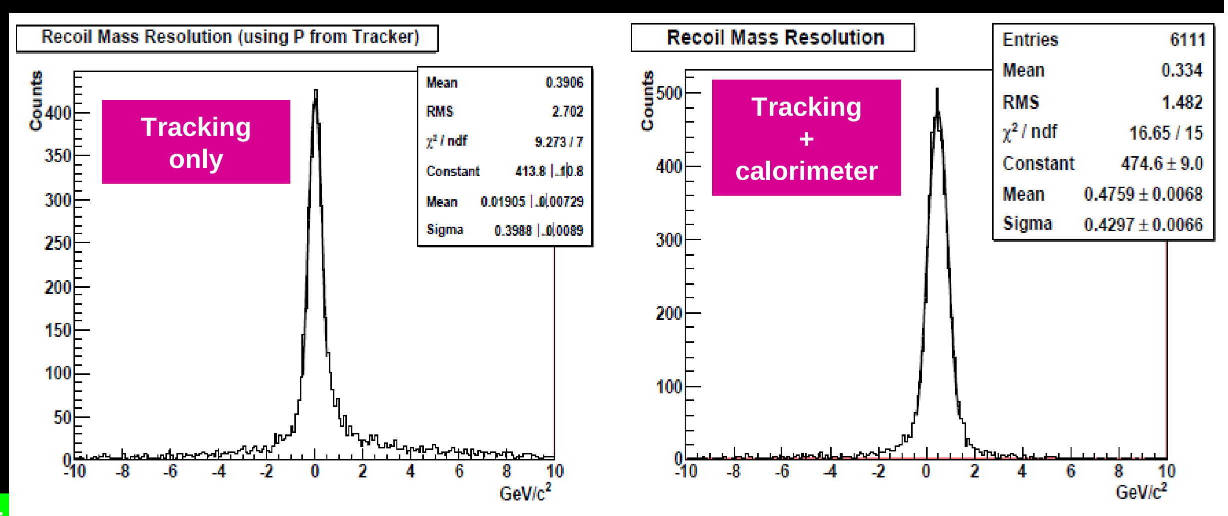
$$\sigma_{e^+e^- \rightarrow Z^oH^o} = 15.08 \pm 0.76\ fb$$

$$\varepsilon_{reconstruction} = 68.3\%$$



Two different analyses using:
1) Only the tracking system
2) Tracking systems + Calorimeter

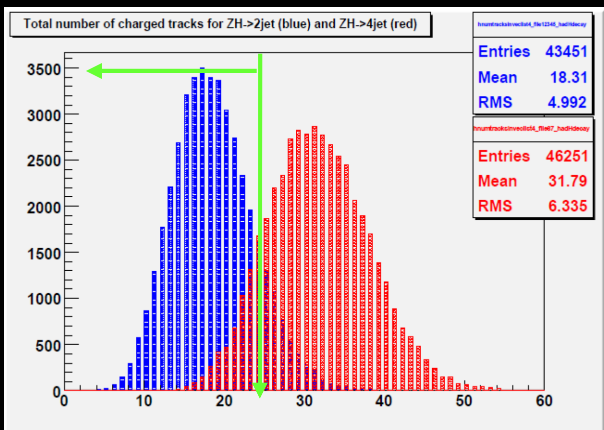
Need a better integration of the informations from the two systems

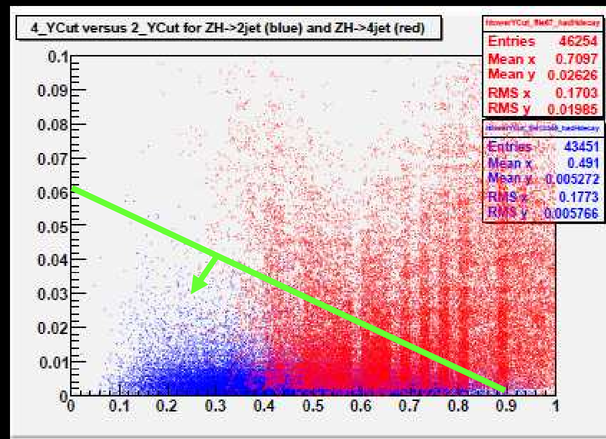


G. Tassielli, G. Terracciano, M. Peccarisi

$e^+e^- \to Z^oH^o \to \nu\underline{\nu}\ X\ \sqrt{s}=250$ GeV

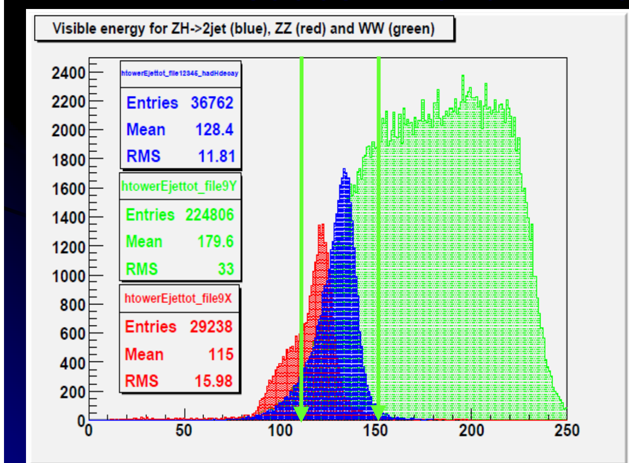
1. Disentangle 2-jets from multi-jets events

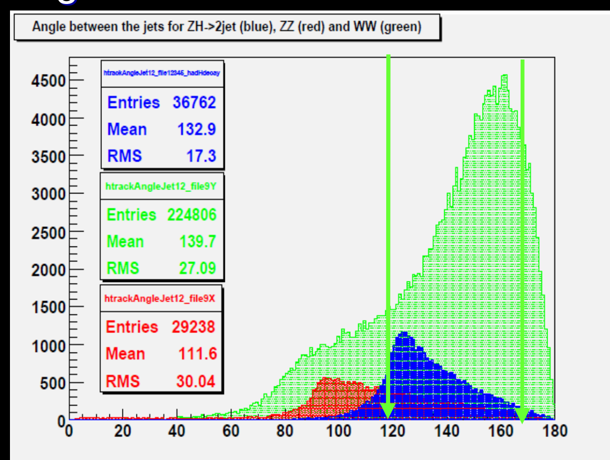




Final State	
signal	$e^+e^- \to H°Z°$; $H \to qq$, $Z \to \nu\nu$
4 jets bkgnd	$e^+e^- \to H°Z°$; $H \to qq$, $Z \to qq$
2 jets bkgnd	$e^+e^- \to W^+W^- \to qq\ l\nu$
2 jets bkgnd	$e^+e^- \to Z°Z° \to qq\ l\ l$

2. Reduce ZZ and WW background



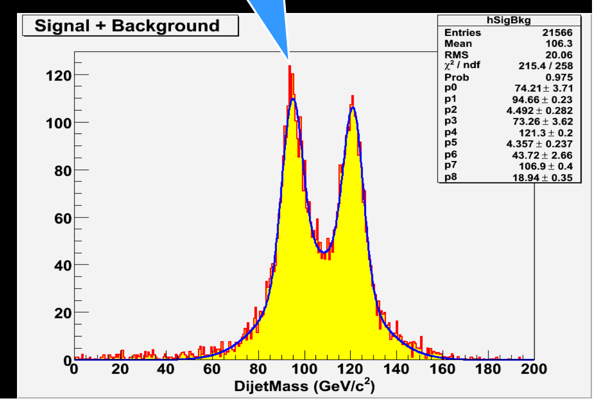


$e^+e^- \to H°Z° \to qq\ \nu\nu$

+

$e^+e^- \to Z°Z° \to qq\ \nu\nu$

Already studied



3. Reject prompt muons (via the Muon Spectrometer) from leptonic WW decay

A. Mazzacane

$e^+e^- \to Z^oH^o \to \nu\bar{\nu}\ X\ \sqrt{s}=250$ GeV

Results

$$M_{Higgs} = 119.60 \pm 0.07\ GeV/c^2$$

$$\sigma_{Higgs} = 3.83 \pm 0.07\ GeV/c^2$$

$$\sigma\ (e^+e^- \to Z^oH^o; Z \to \nu\bar{\nu}; H \to q\bar{q}) = 155.3 \pm 2.2\ fb$$

$$\varepsilon_{reconstrution} = 28.8\%$$

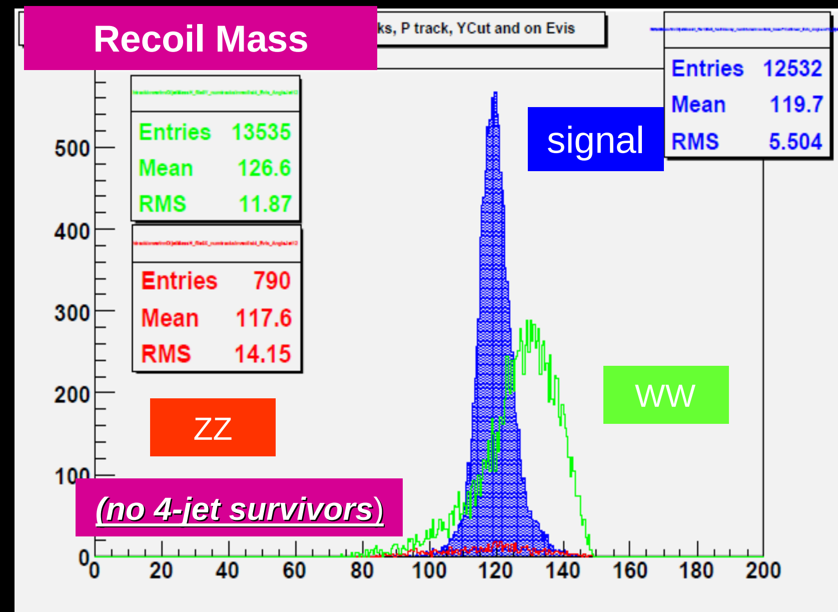
Next step is to consider

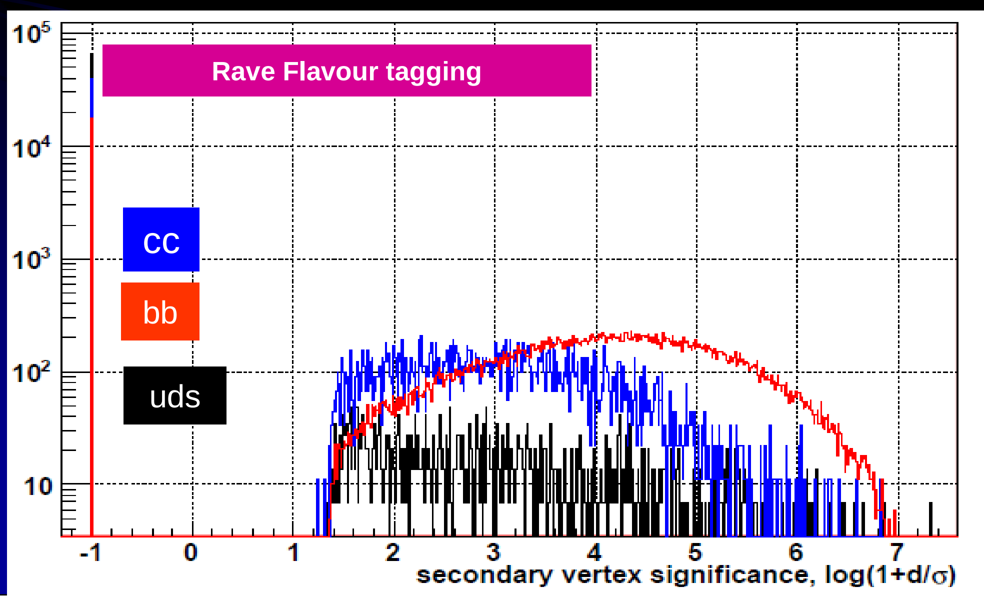
$e^+e^- \to Z°Z° \to qq\ \nu\nu$

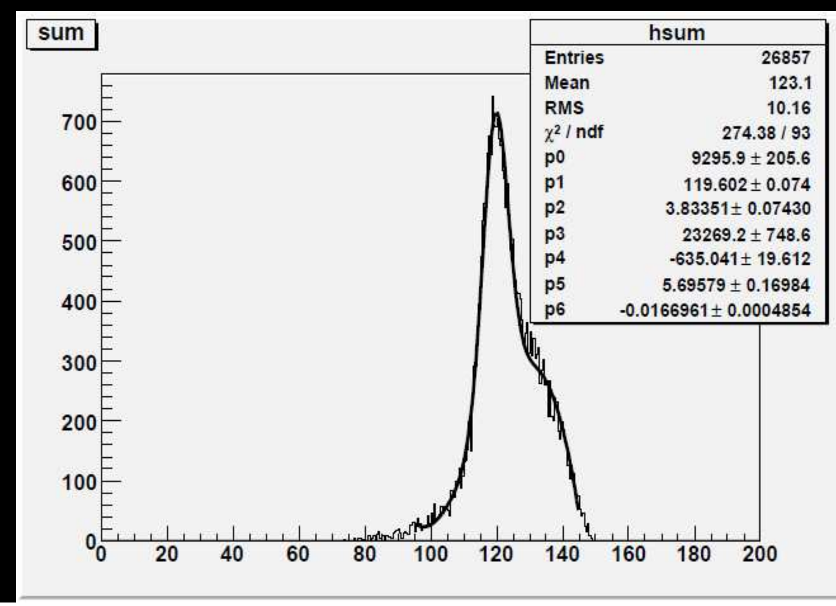
and

$e^+e^- \to Z°Z° \to qq\ qq$

$e^+e^- \to W^+W^- \to qq\ qq$







$e^+e^- \to Z^oH^o$; and $Z^o \to c\bar{c}$ $H^o \to b\bar{b}$ $\sqrt{s}=250$ GeV

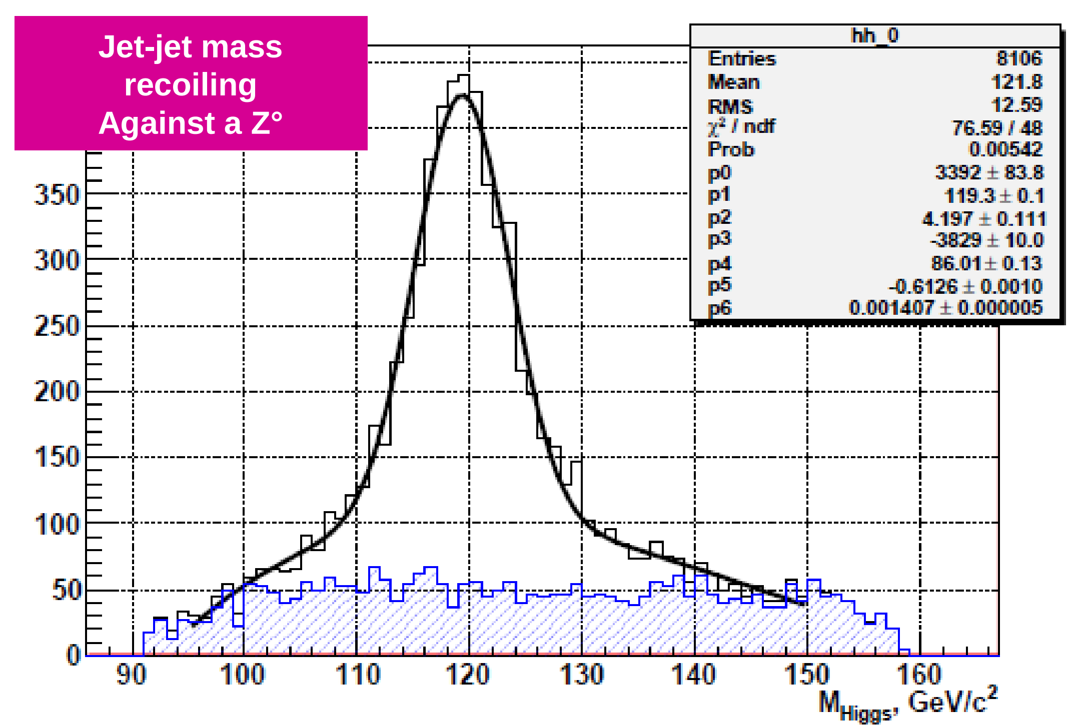
Analysis strategy

1. Select Event with 4 jets (use jet finder with recursive y_{cut})
2. E_{calo} + E_{muon} cut to reduce background (events with neutrino or ISR)
3. 5-C kinematic fit to all possible jet-jet combinations

$$1.\ \sum \vec{P}_i = 0$$
$$2.\ \sum E_i = 250\ \text{GeV}$$
$$3.\ M_Z = 91\ \text{GeV}/c^2$$

4. Pick combination with highest probability
5. Final cut: χ^2/ndf<16/5

Signal only
No Background



F. Ignatov

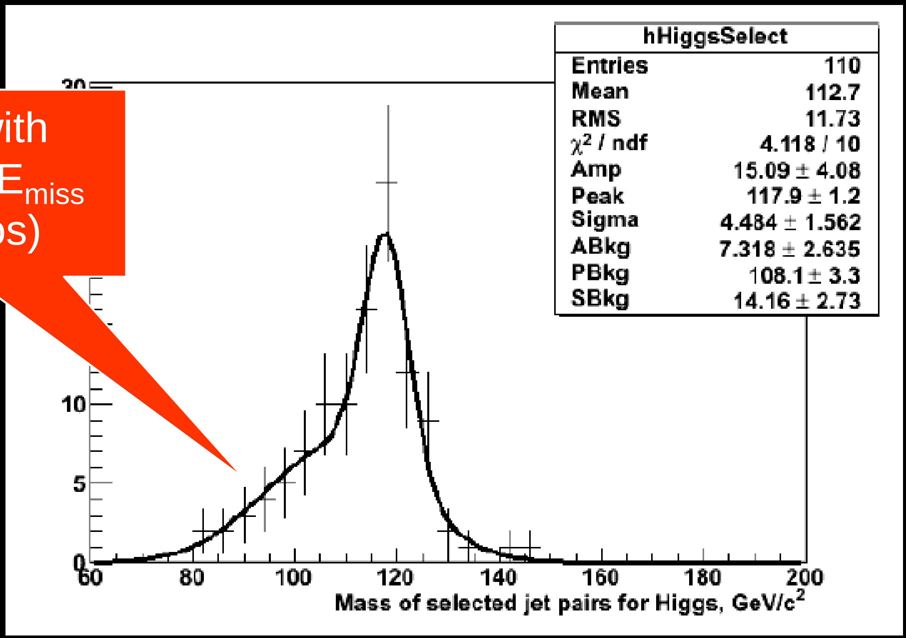
$e^+e^- \rightarrow Z^oH^o$; $Z^o \rightarrow u\bar{u}$ $H^o \rightarrow c\bar{c}$ $\sqrt{s}$=250 GeV

Signal only
No Background

Analysis strategy

1. Select Event with 4 jets (use jet finder with recursive y_{cut})
2. Select M_{j1j3} and M_{j2j4}
3. Requires 1 combination within 10 GeV from nominal Z° mass
4. Plot the other combination

Events with significant E_{miss} (neutrinos)

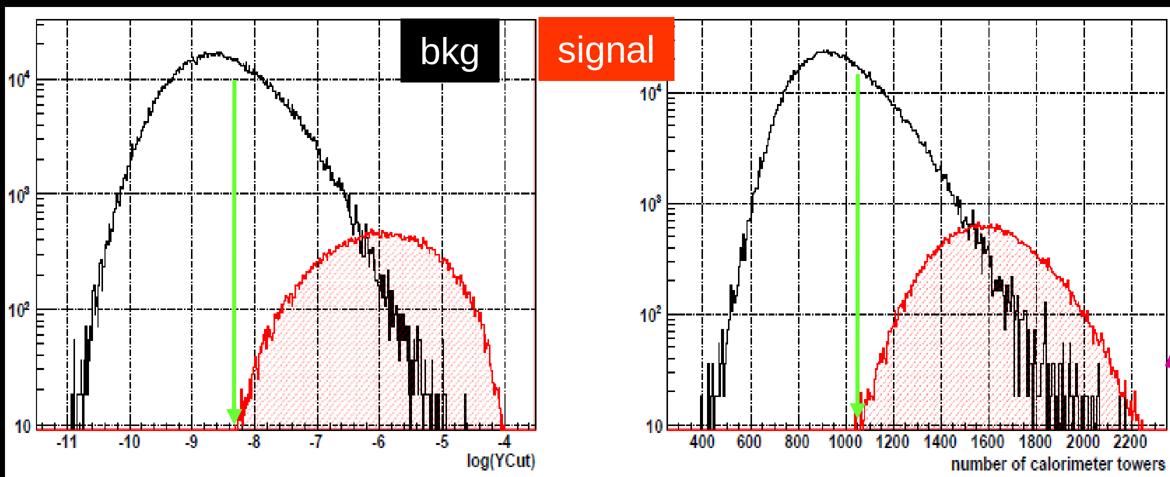


Analysis is still in progress

Y. C. Chen

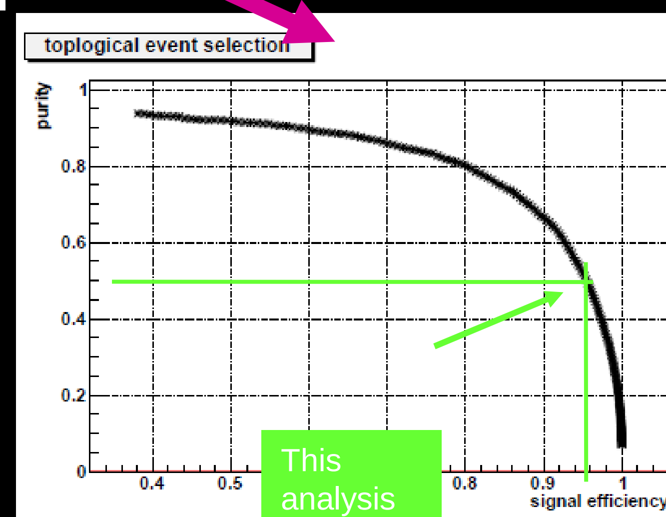
$e^+e^- \to t\bar{t} \to W^+bW^-\bar{b} \to q\bar{q}bq\bar{q}\bar{b}$ $\sqrt{s}=500$ GeV

1. Disentangle 6-jets from 2 and 4-jets events



Final State
signal: $e^+e^- \to t\bar{t} \to q\bar{q}b\ q\bar{q}\bar{b}$
4 jets bkgnd: $e^+e^- \to W^+W^- \to q\bar{q}\ q\bar{q}$

2. Choose best jet-jet combination with a χ^2 based on M_{jj} close to M_W
3. 7-C Kinematic fit (MarlinKinFit)
   - $\sum \vec{P}_i = 0$
   - $\sum E_i = 500$ GeV
   - $M_{W1} = M_{W2} = 80.4\ \mathrm{GeV}/c^2$
   - $M_t - M_{\bar{t}} = 0$
4. Final cut: $\chi^2/ndf<45/7$



F. Ignatov

$e^+e^- \rightarrow t\bar{t} \rightarrow W^+bW^-\bar{b} \rightarrow q\bar{q}bq\bar{q}\bar{b}$ $\sqrt{s}=500$ GeV

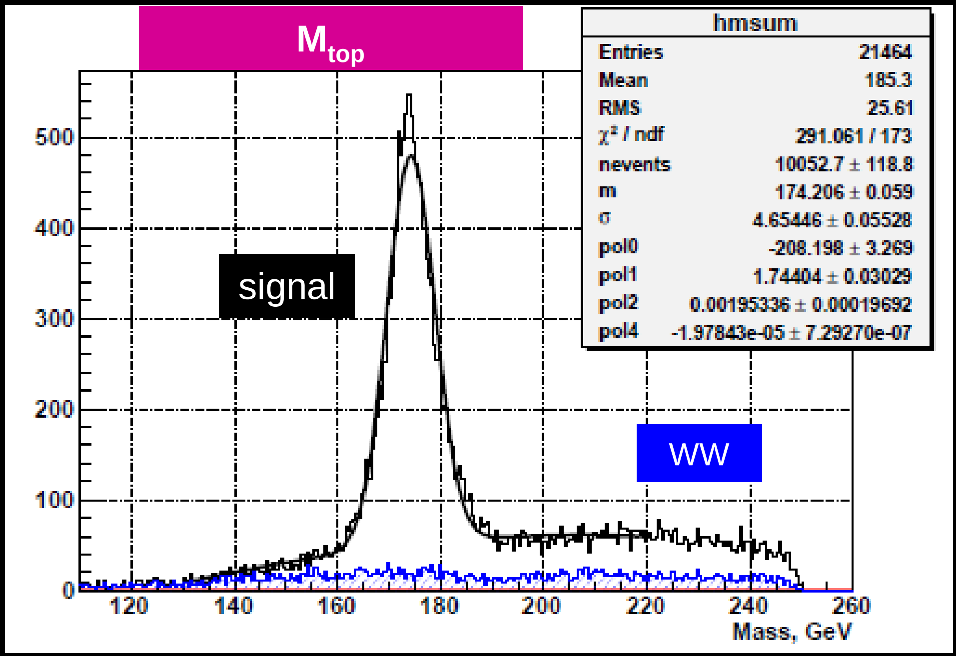
Results

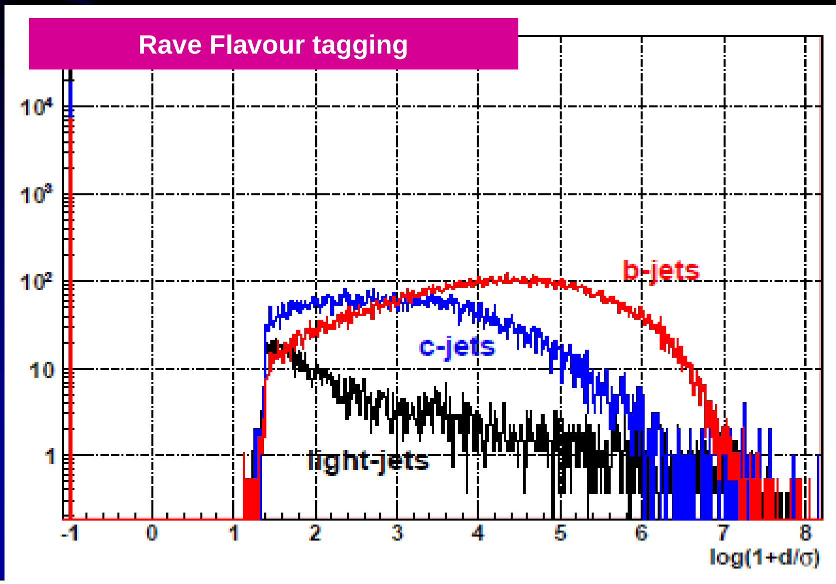
$$M_{top} = 174.21 \pm 0.06\ GeV/c^2$$

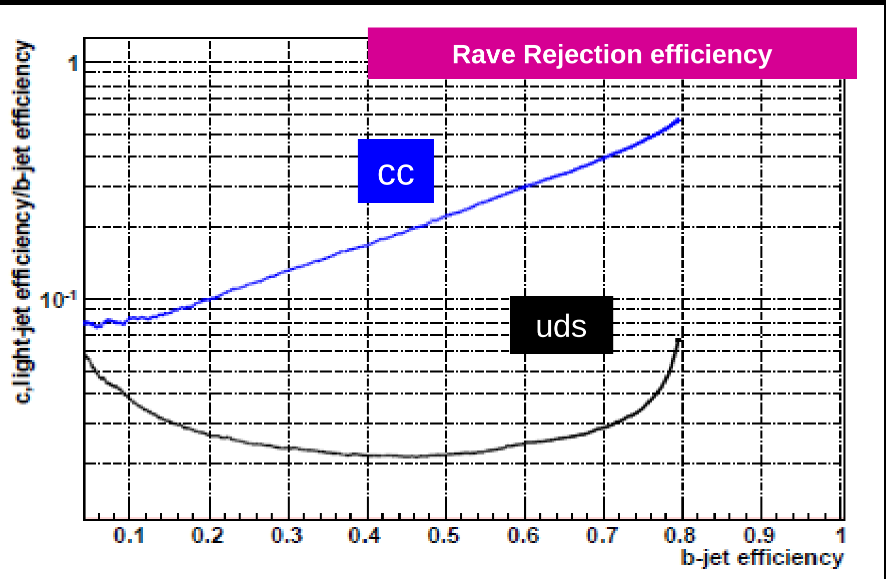
$$\sigma_{top} = 4.65 \pm 0.06\ GeV/c^2$$

$$\varepsilon_{reconstruction} = 16\%$$

Next step is to complete
the flavour tagging analysis







$e^+e^- \to \tau^+\tau^-$; $\tau \to \rho\nu$ $\sqrt{s}$=500 GeV

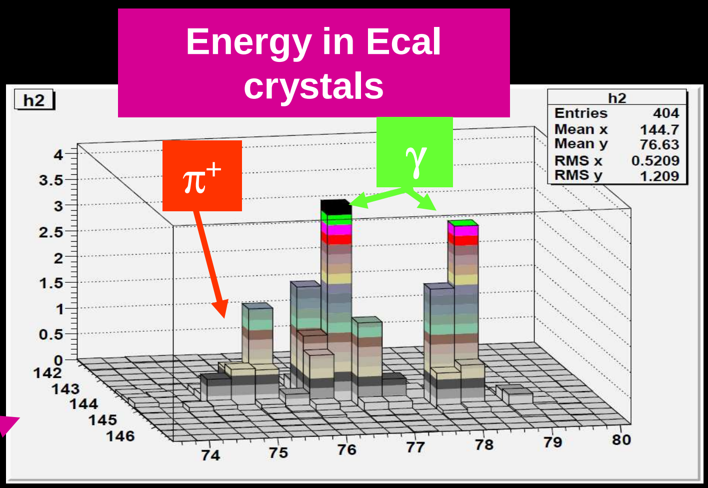
	Final state
signal	$e^+e^- \to \tau^+\tau^-, \quad \tau \to \rho\nu$
bkgnd	$\gamma\gamma \to \tau\tau$
	$W^+W^- \to ll\nu\nu$

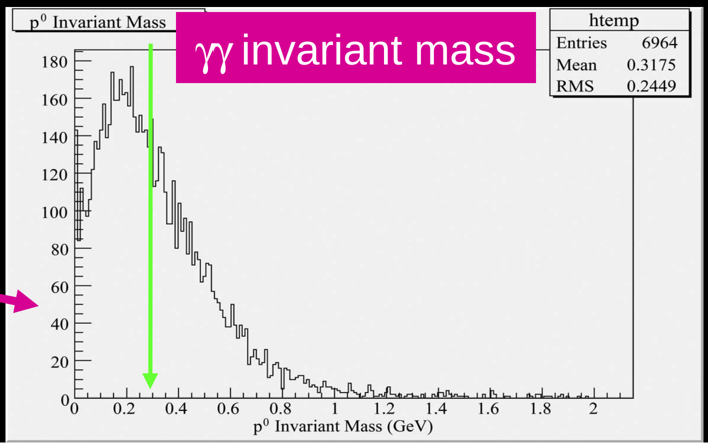
Analysis strategy

1. $\tau^+\tau^-$ selection
   - N_{tracks}<6
   - Two narrow jets (calo only)
   - E_{calo} > 45 GeV (suppress $\gamma\gamma \to \tau\tau$)
   - Angle between two jets > 175°
   - Bhabha rejection (θ > 15°)

2. Hadronic τ decay selection
   1. Muon veto (use Muon Spectrometer)
   2. Electron veto (combined DCH, ECAL and HCAL)

3. $\tau^+ \to \rho\nu$ selection
   1. $\pi\,\gamma\,\gamma$ unfolding
   2. Cut $M_{\gamma\gamma}$ close to nominal $M_{\pi°}$



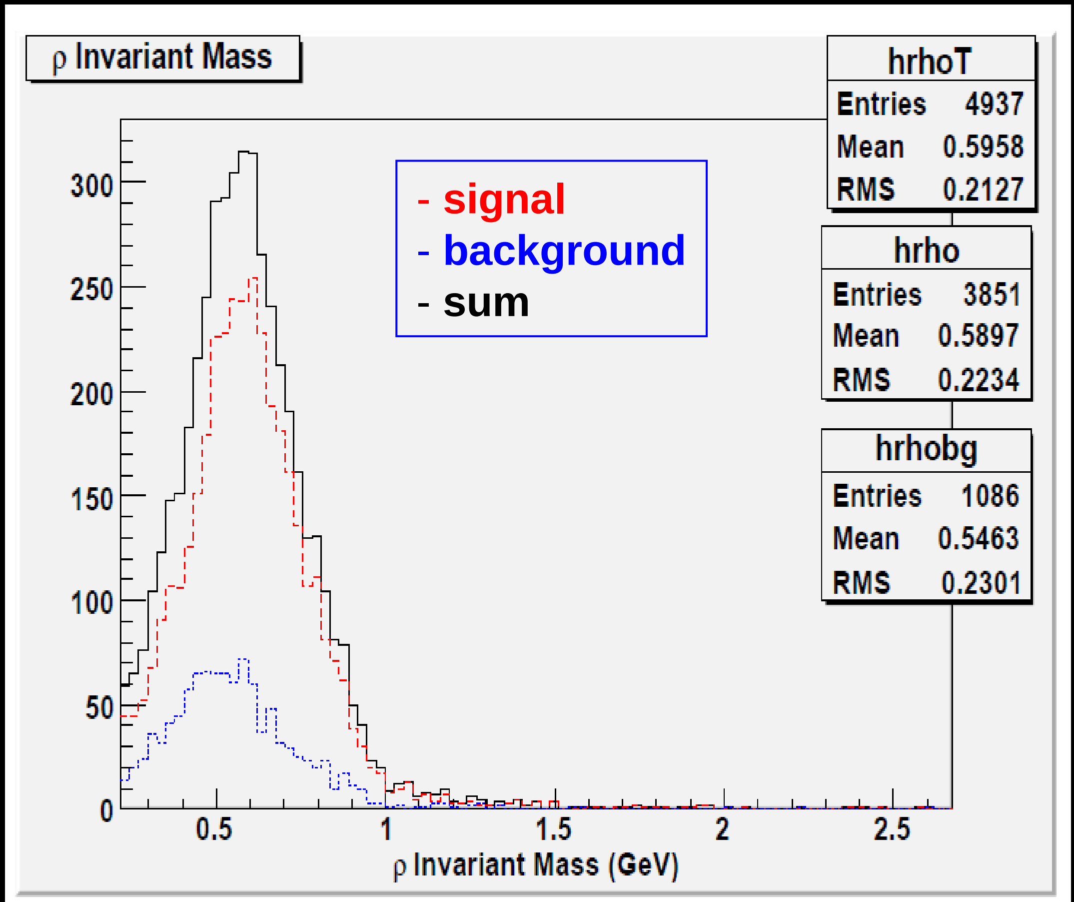


V. Di Benedetto

$e^+e^- \to \tau^+\tau^-$; $\tau \to \rho\nu$ $\sqrt{s}$=500 GeV

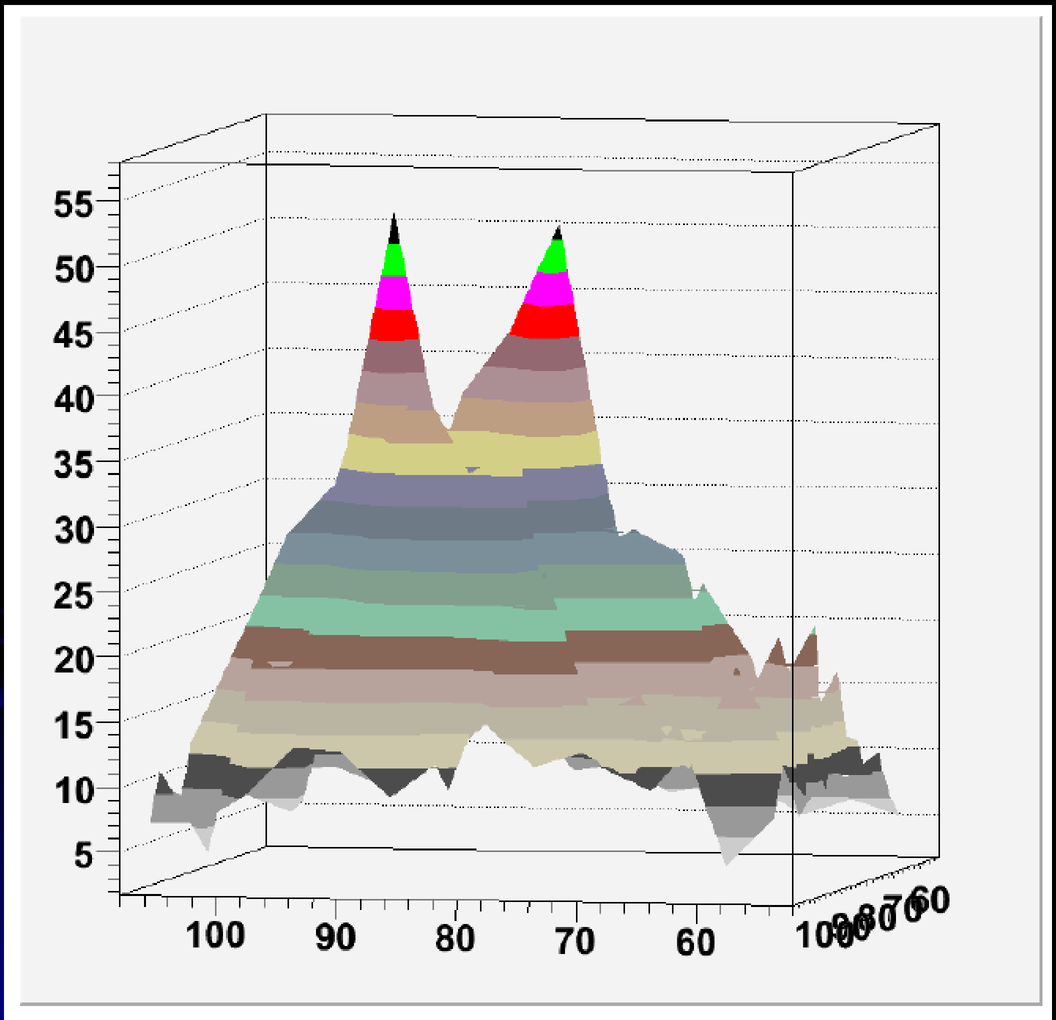
Results

Only ρ mass at present
Analysis is still in progress



V. Di Benedetto

W/Z Mass Separation



$$e^+e^- \rightarrow W^+W^-\nu\bar{\nu}, Z^oZ^o\nu\bar{\nu}$$

- KEK event sample
- Simple Durham jet-finder a la L3 (recursive y_{cut}) used for this analysis
- No combined information with tracking yet (3 entries/evt)
- No ECAL
- 4-jets finding efficiency: 95%

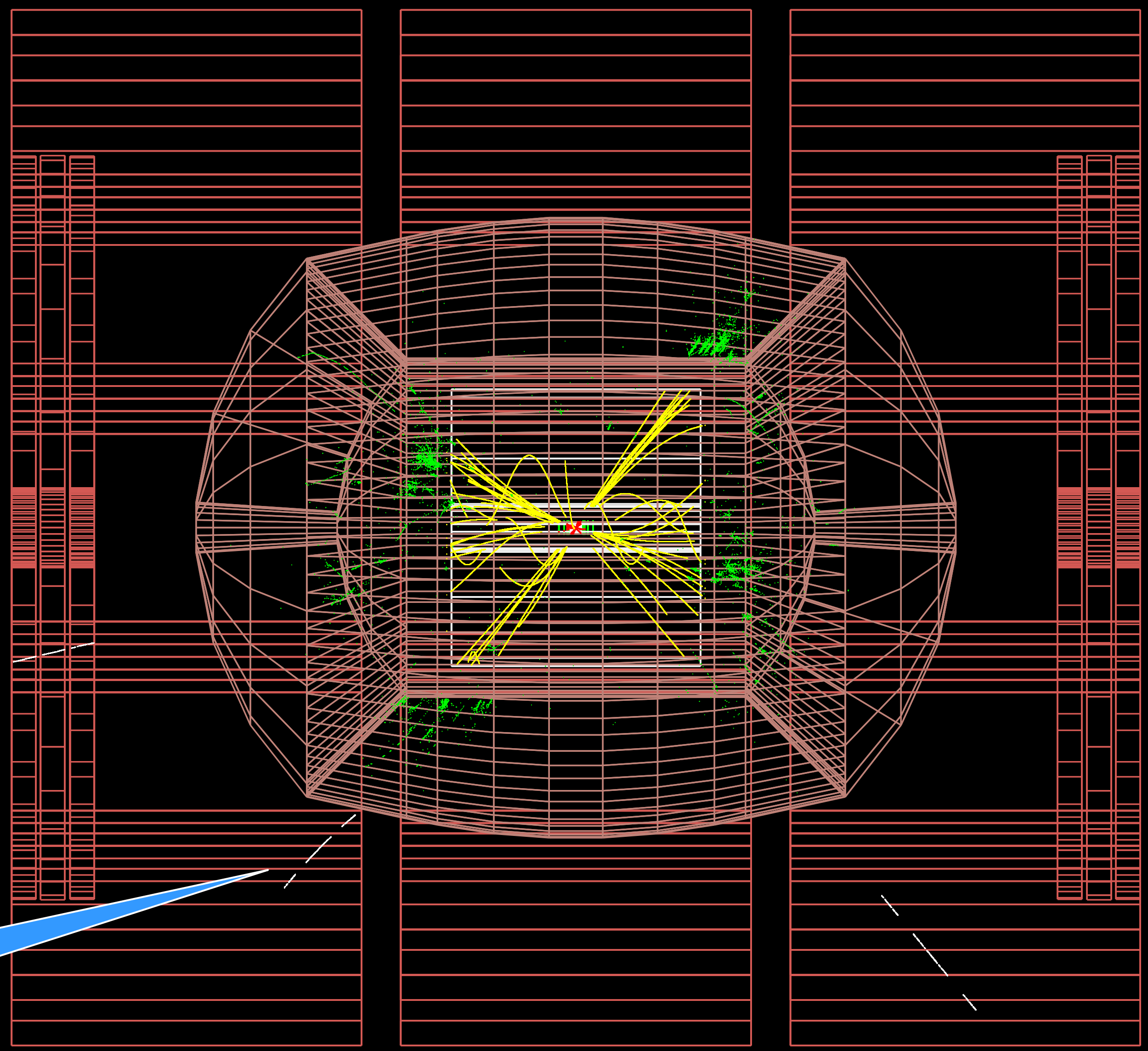
A. Mazzacane

Event Display in ILCroot

$e^+e^- \rightarrow H^oH^oZ^o$

–> 4 jets 2 muons

ECM = 500 GeV



Conclusions

- Detector simulation is well under way
- Most critical issues have been pinpointed:
  - DCH needs Si in fwd region: CLUCOU + SiLC (A. Savoy-Navarro, F. Grancagnolo)
  - **Crystal and fiber calorimeter are finally working in sinergy**
  - Performance of calorimeter is very good in data and simulation:
  - need much more work to go from Technique R&D to a Detector design
- Benchmark processes studies have started. Will be improved in the future
- More background channels will be considered
- Overall performance of 4th Concept detector is excellent
- Software framework (ILCroot) has run flawlessly along the benchmark process (200-1000 CPU on Fermi-GRID almost no-stop since August 2008)

Backup slides

Outline

- The simulations in the *4th Concept*
  - ILCroot
  - Detector simulations
- Performance & Optimization
- Physics benchmarks for the LoI
- Future prospects

The Virtual Montecarlo Concept

- Virtual MC provides a virtual interface to Monte Carlo
- It allows to run the same user application with all supported Monte Carlo programs
- The concrete Monte Carlo (Geant3, Geant4, Fluka) is selected and loaded at run time
  - Compare Montecarlo performance and possible flows
  - Choose the optimal Montecarlo for the study

Perfect Tool for Designing/Optimizing new Detectors

4th Concept Software Strategy: ILCroot

- CERN architecture (based on Alice's Aliroot)
- Full support provided by Brun, Carminati, Ferrari, et al.
- Uses ROOT as infrastructure
  - All ROOT tools are available (I/O, graphics, PROOF, data structure, etc)
  - Extremely large community of users/developers
- TGenerator for events generation
- Virtual Geometry Modeler (VGM) for geometry
- Based on Virtual Montecarlo
- Could it ever evolve into a general purpose entity for the HEP community (as ROOT)?
- Growing number of experiments have adopted it: Alice, Opera, CMB, (Meg), Panda, 4th Concept
- Six MDC have proven robustness, reliability and portability

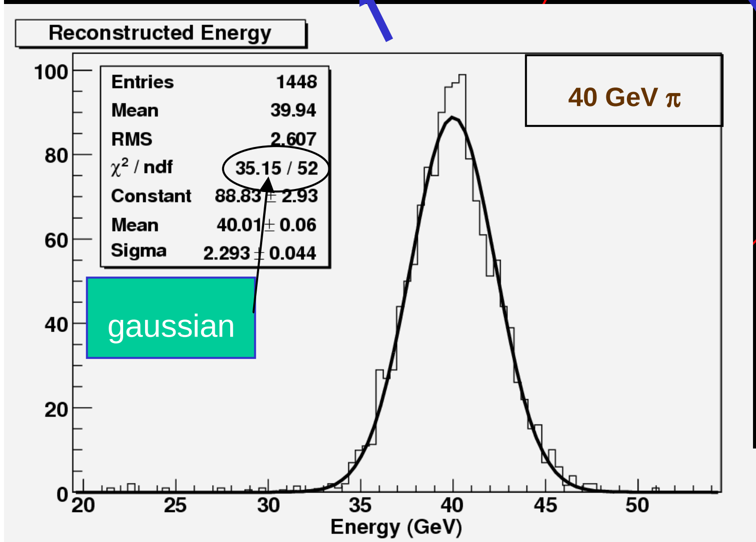
Do not Reinvent the wheel

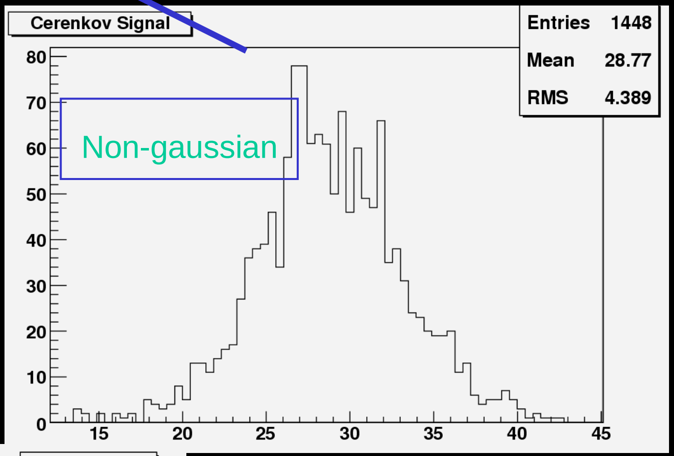
Concentrate on Detector studies and Physics

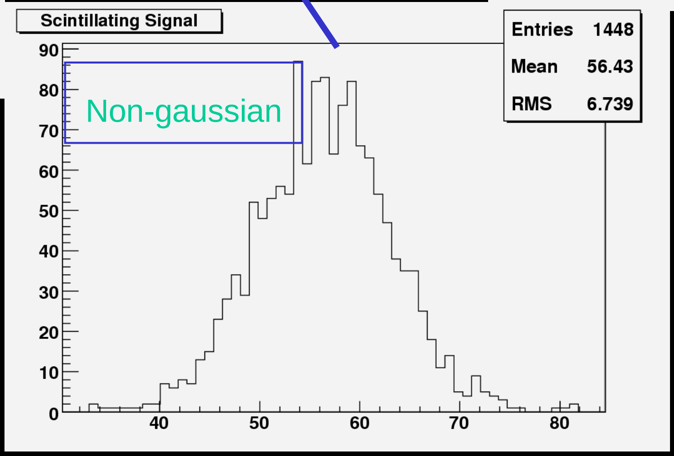
Dual Readout Calorimetry

Total calorimeter energy: use two measured signals and two, energy-independent, calibration constants

$$E_{HCAL} = \frac{\eta_S \cdot E_S \cdot (\eta_C - 1) - \eta_C \cdot E_C \cdot (\eta_S - 1)}{\eta_C - \eta_S}$$







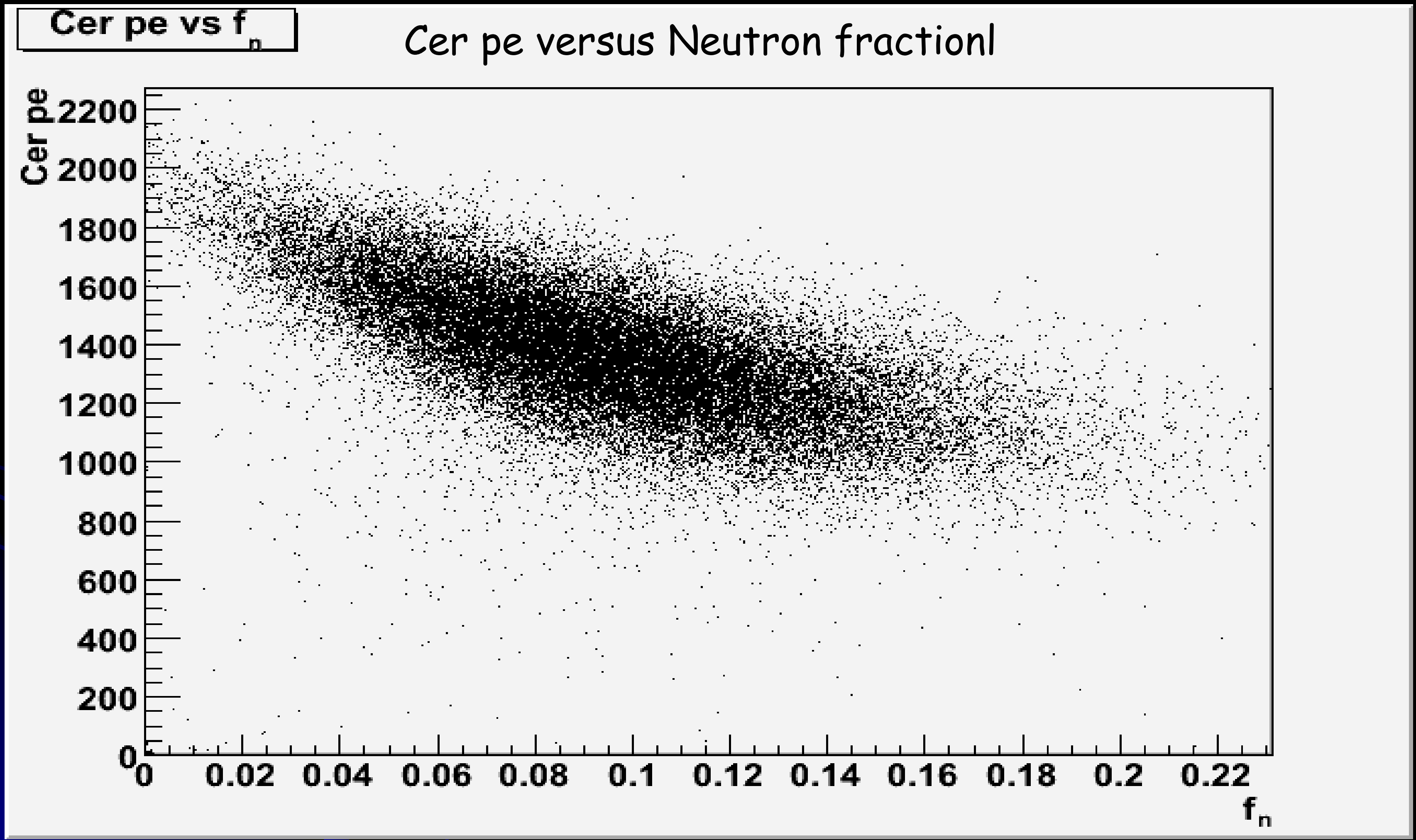
$$\eta_c = \left(\frac{e}{h}\right)_C \qquad \eta_S = \left(\frac{e}{h}\right)_S$$

From calibration

@ 1 Energy only

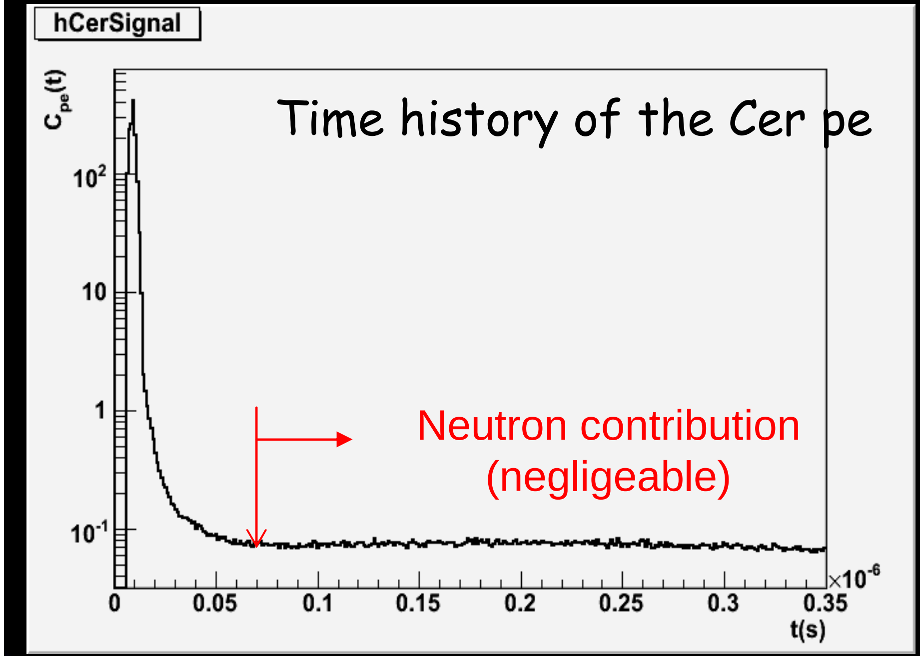
Improving the Energy Resolution: The Effect of Neutrons

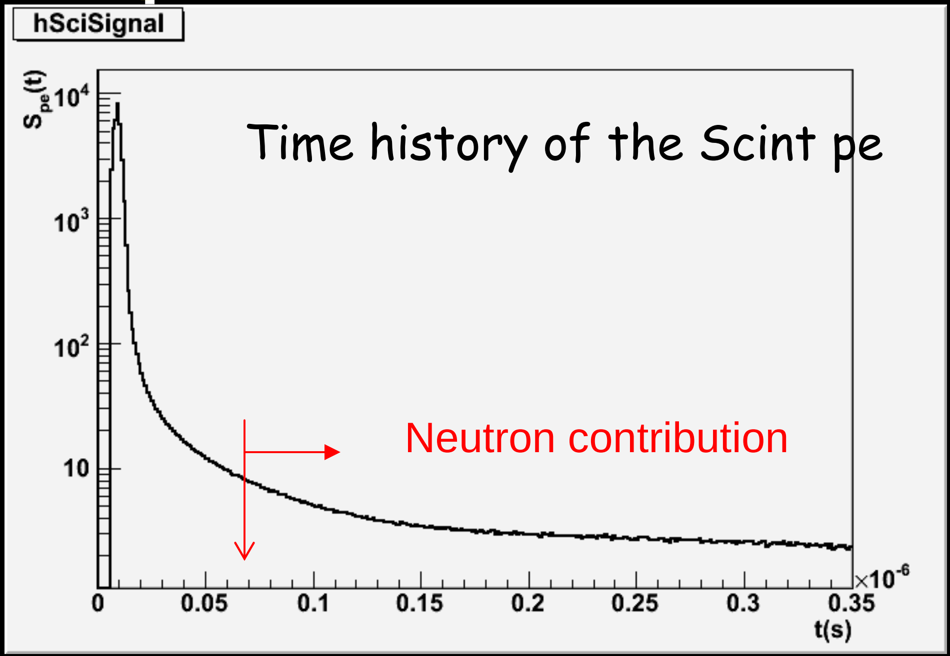
45 GeV π^-



ILCRoot simulation

From Dual to Triple Readout





45 GeV π^-

$$E_{HCAL} = \frac{\eta_S \cdot E_S \cdot (\eta_C - 1) - \eta_C \cdot E_C \cdot (\eta_S - 1)}{\eta_C - \eta_S} + \eta_n \cdot E_{neutrons}$$

Triple readout aka Dual Readout with time history readout

ILCRoot simulation

Compensation with ECAL and HCAL

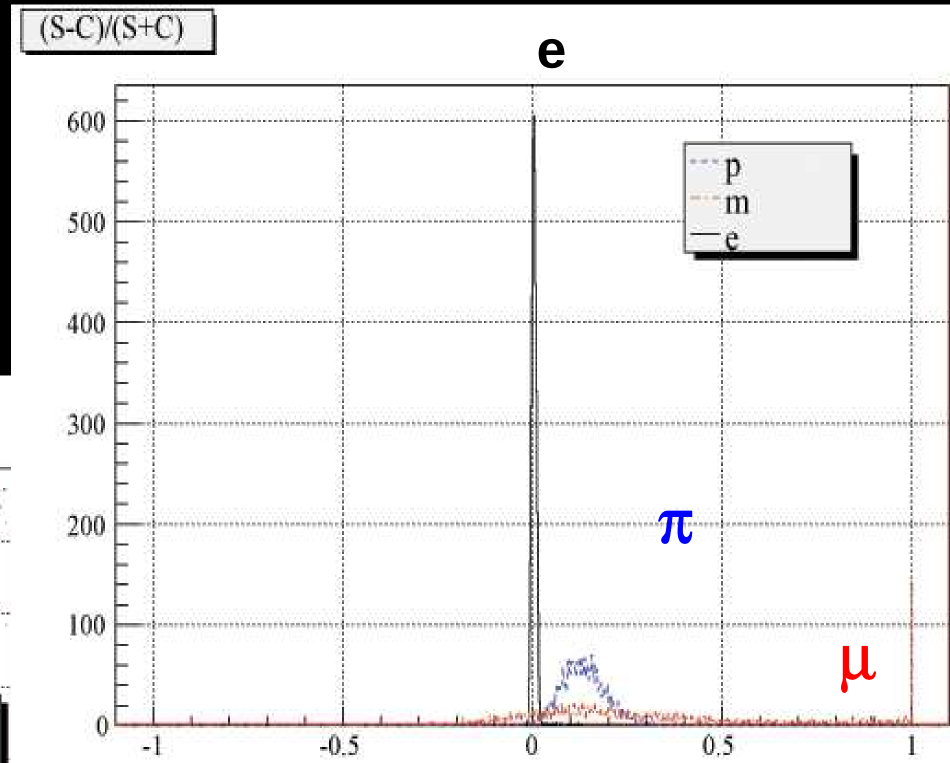
- Get E_{Scint} and E_{Cer} from ECAL (disregard neutrons as Z_{BGO} >> 1)
- Get E_{Scint}, E_{Cer} and E_{neutr} from HCAL
- Then:

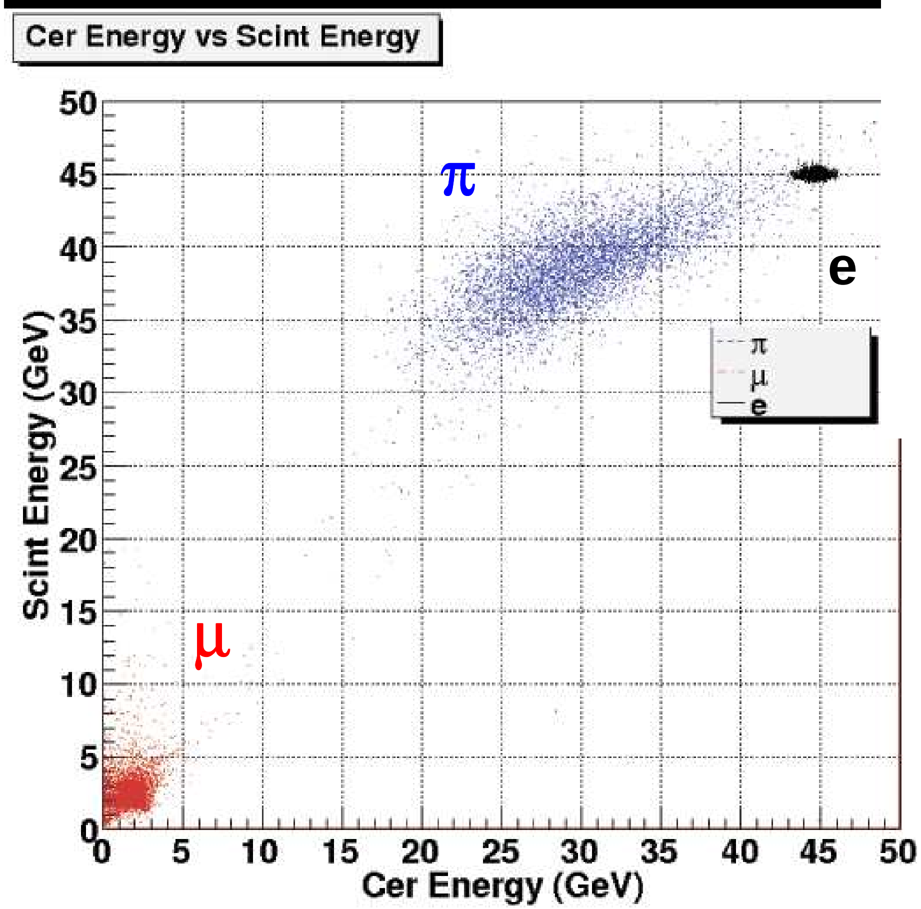
$$E_{Total} = \frac{\eta_S \cdot (E_{Sc\,int}^{ECAL} + E_{Sc\,int}^{HCAL}) \cdot (\eta_C - 1) - \eta_C \cdot (E_{Cer}^{ECAL} + E_{Cer}^{HCAL}) \cdot (\eta_S - 1)}{\eta_C - \eta_S} + \eta_n \cdot E_{neutrons}^{HCAL}$$

- Estimate η_C, η_S and η_{neu} from a 45 GeV run (π^- and e^-) by minimizing the spread of E_{tot}

Particle Identification with Triple Readout

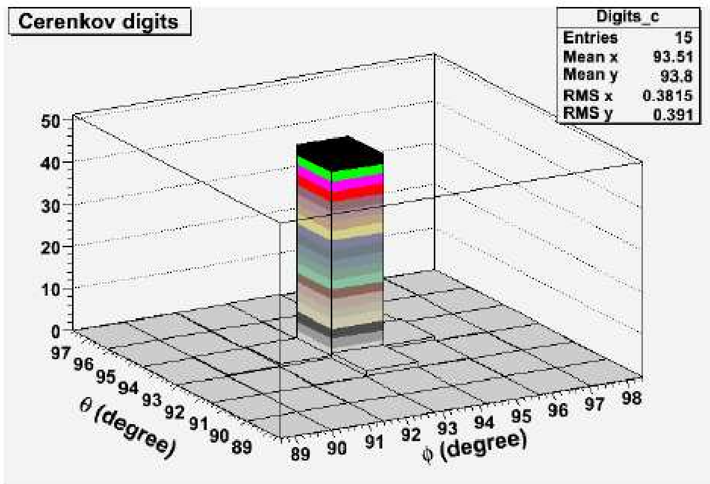
45 GeV particles

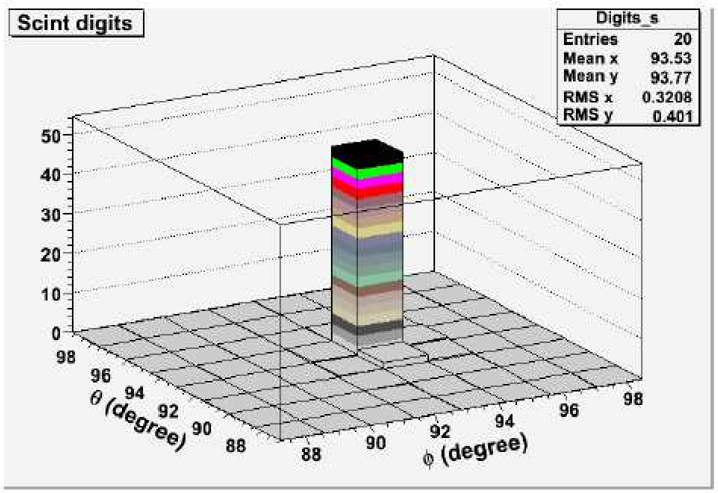




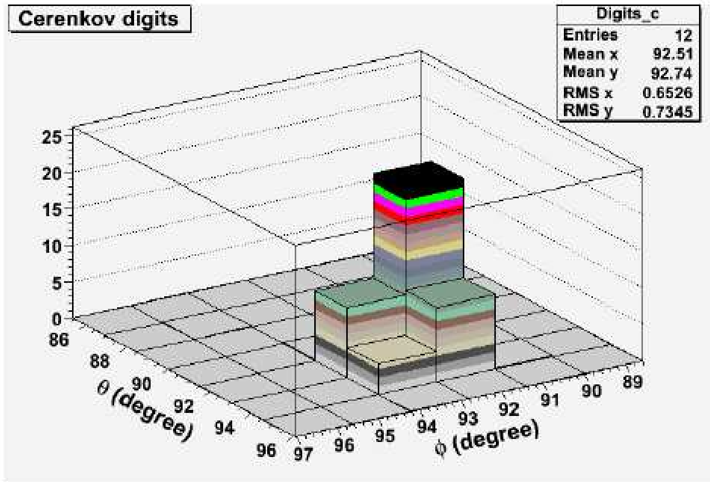
ILCRoot simulation

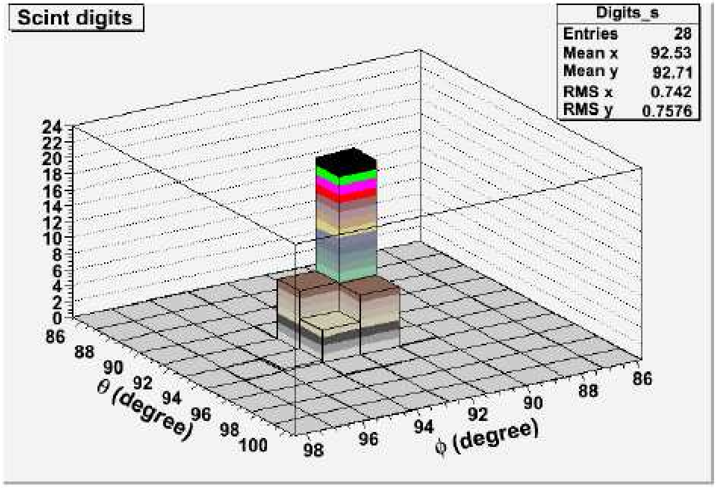
Calorimeter Response for 45 GeV e⁻





core

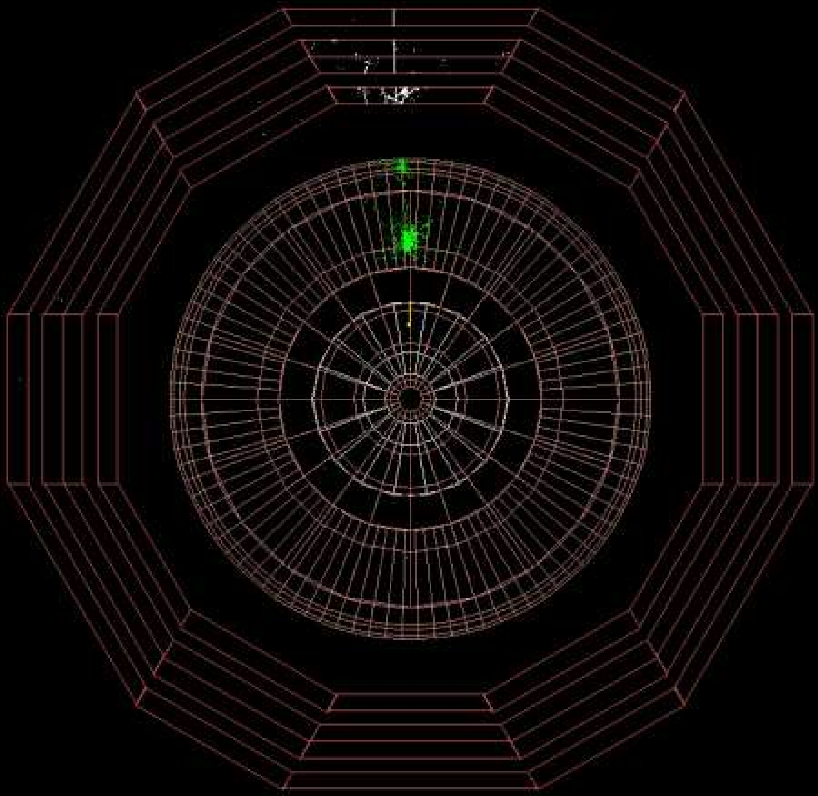


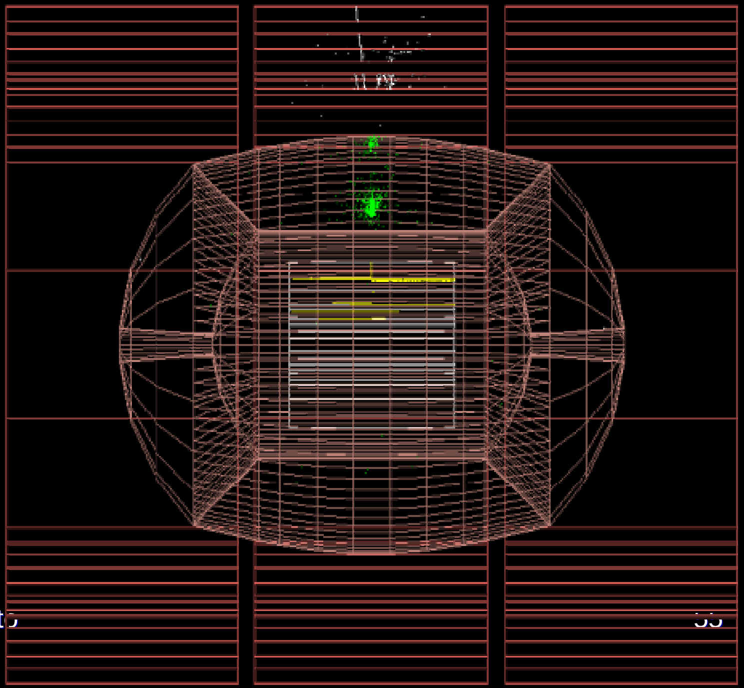


boundary

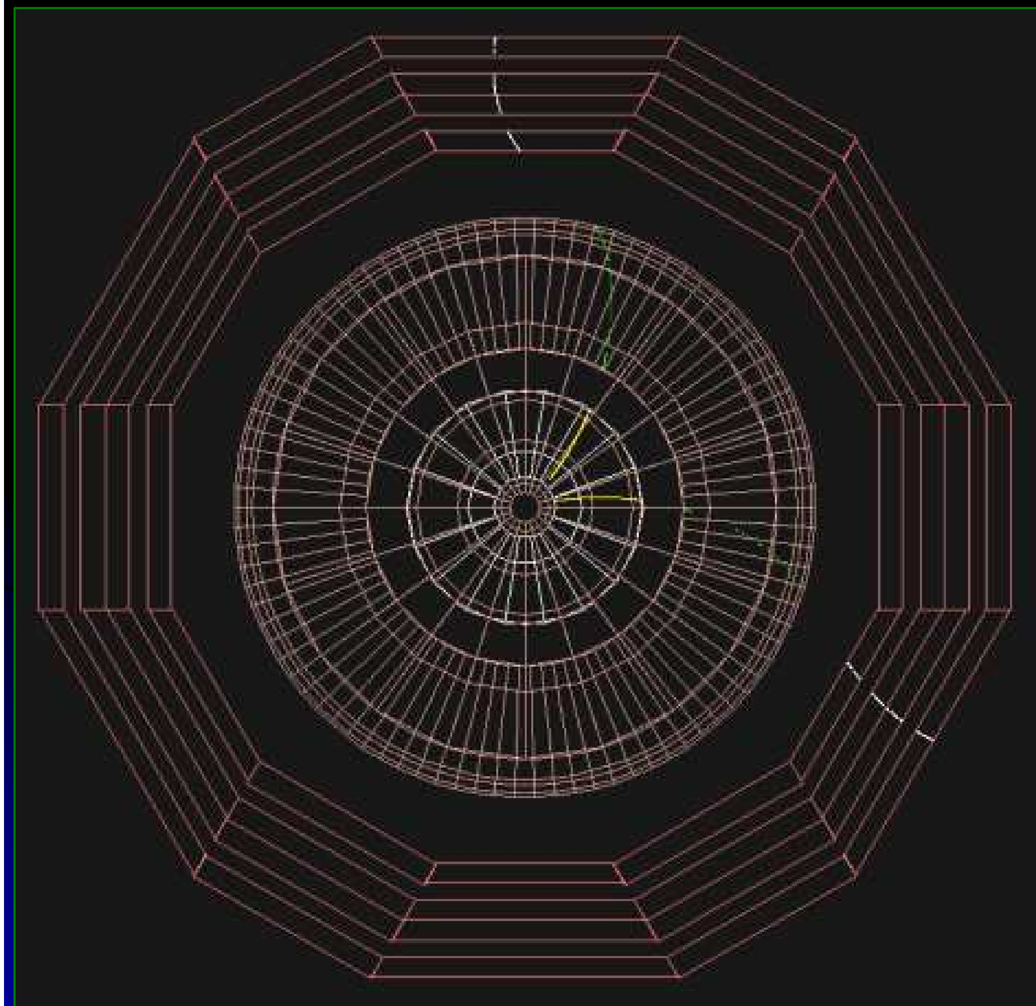
80 GeV jet with escaping particles

ILCRoot simulation





$\mu^+ \mu^-$ at 3.5 GeV/c

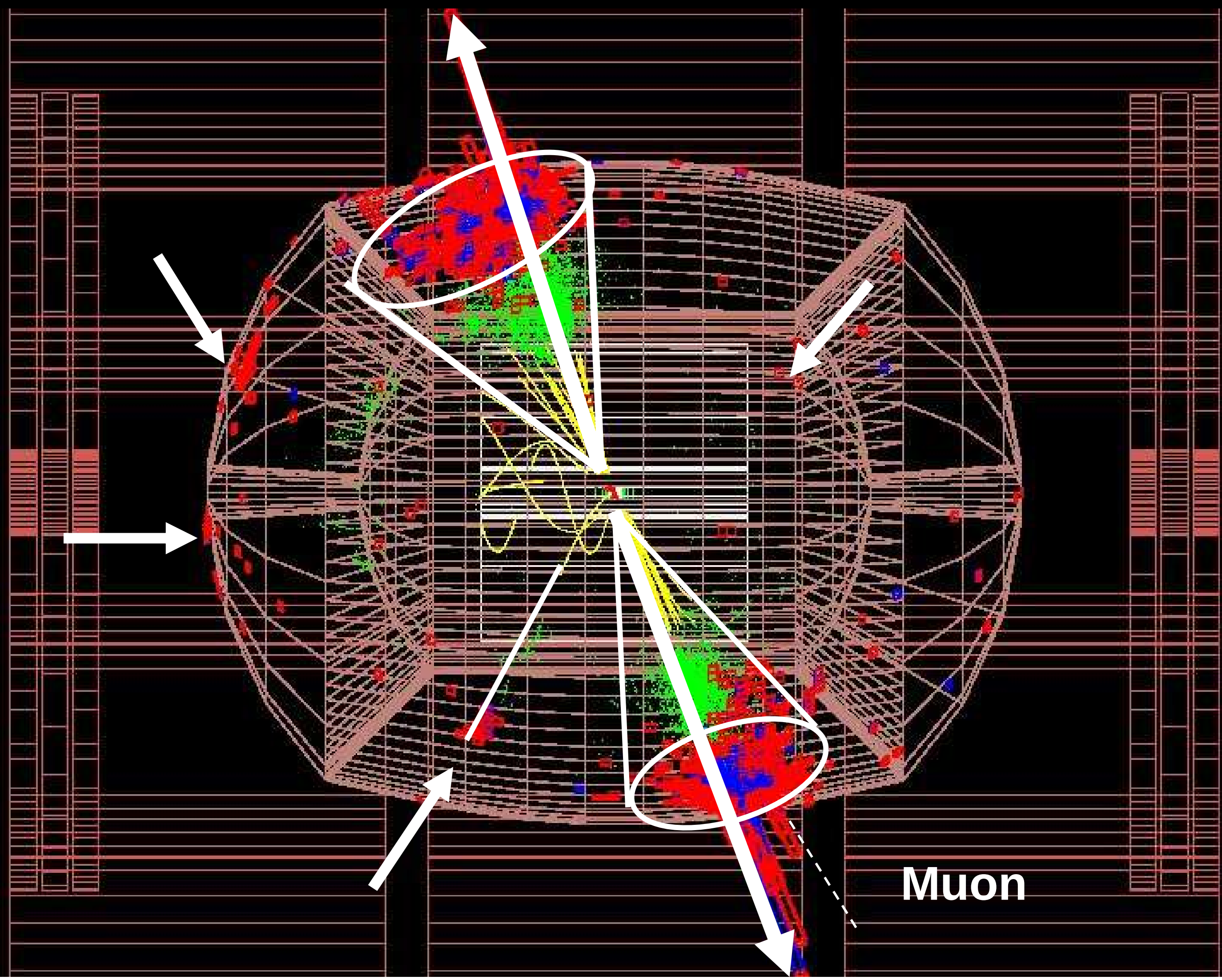


ILCRoot simulation

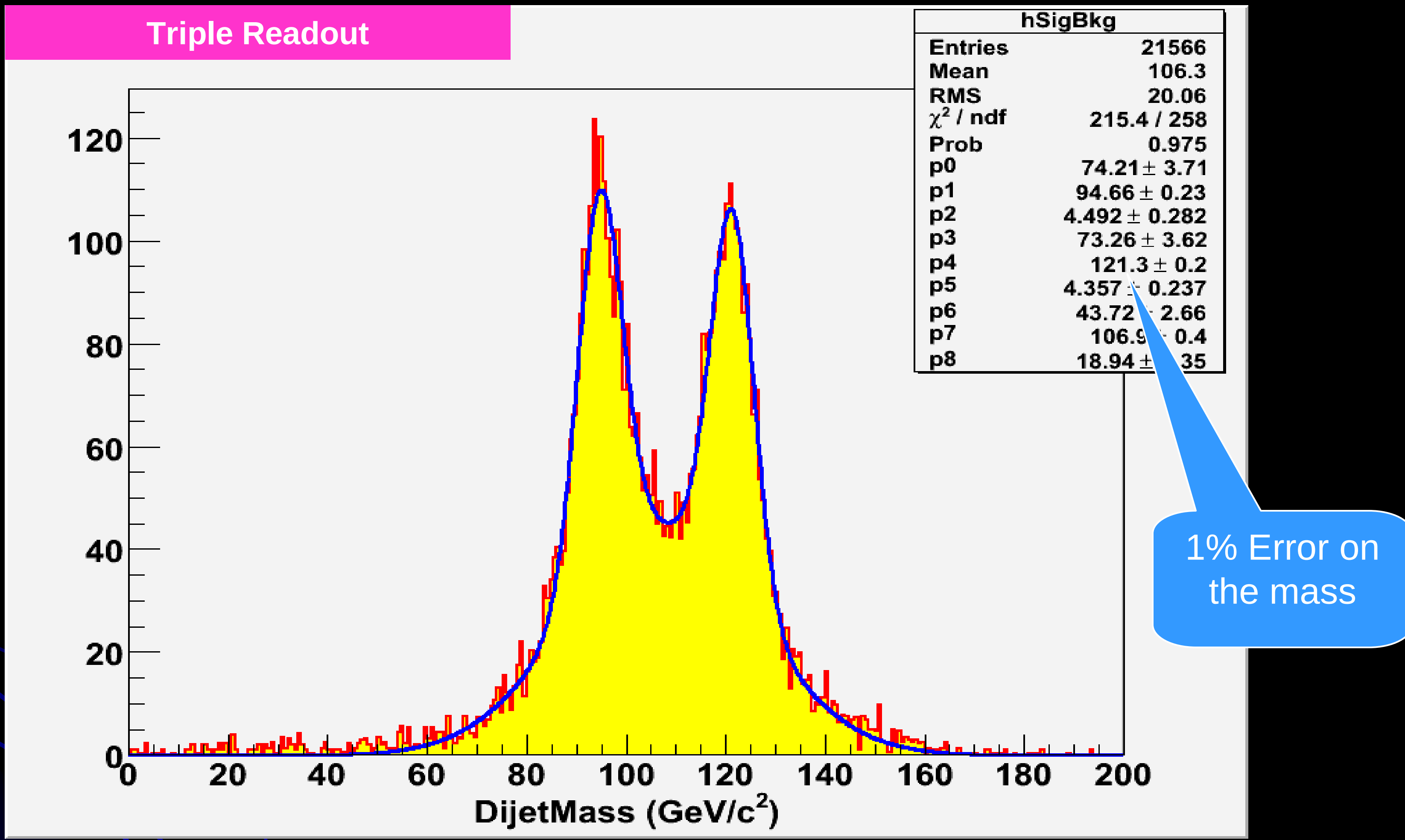
Jet reconstrucion: combine calorimetric and tracking informations

(work in progress)

Jet Reconstruction Strategy



$e^+e^- \rightarrow Z^oH^o \rightarrow \nu\bar{\nu}\, c\bar{c}$ + ZZ Background



- Signal + ZZ background
- Requires 2 jets from jet-finder
- Evis > 130 GeV
- **No flavor tagging**
- Fit with three gaussians
- Selection Efficiency = 80.2%