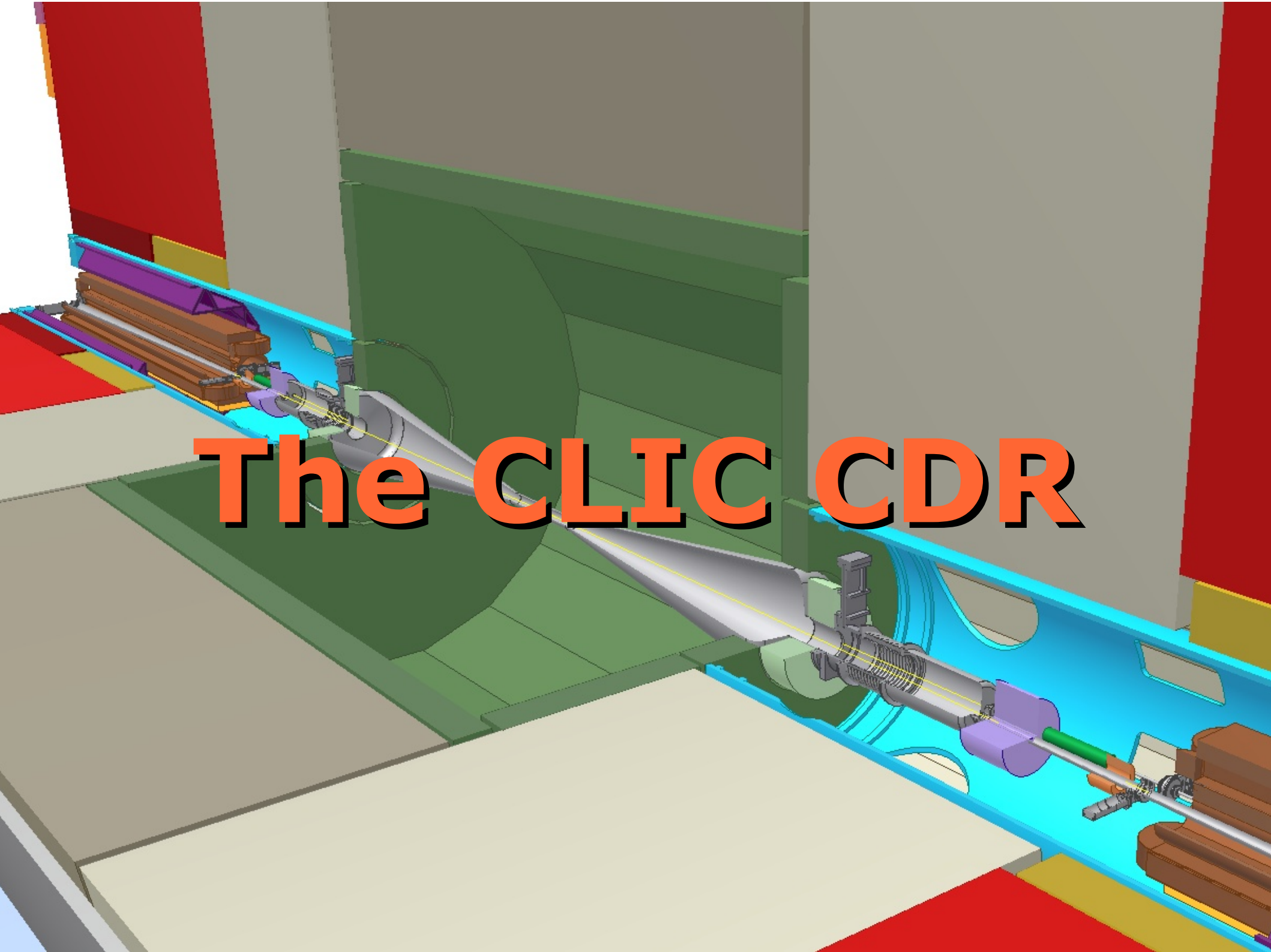
Detector studies for CLIC

Marcel Stanitzki
STFC-Rutherford Appleton Laboratory

Outline

- The CLIC CDR
- The CLIC experimental conditions
- Detectors for CLIC
- Recent Highlights

The CLIC CDR



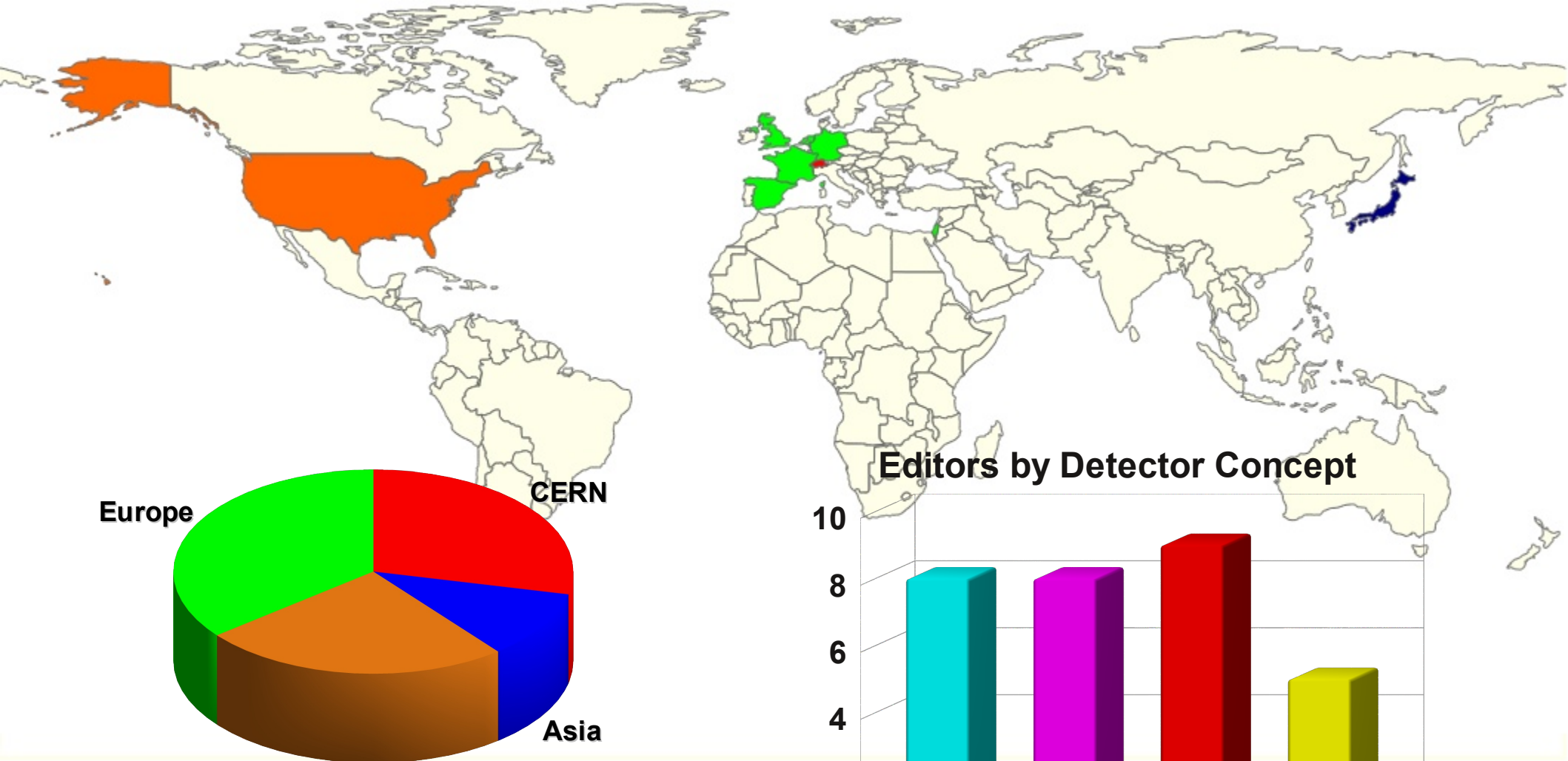
CLIC Conceptual Design Report

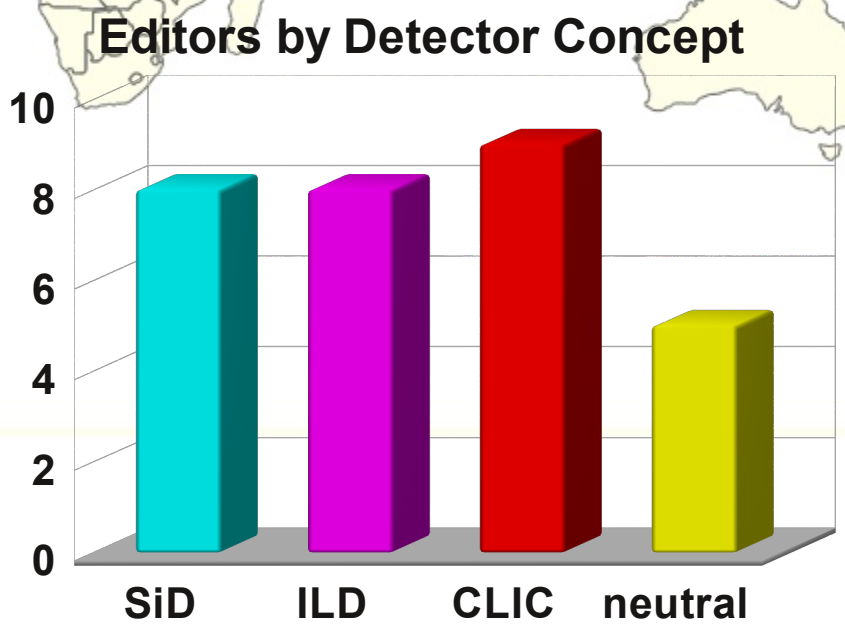
- Three volumes (due August 2011)
  - Vol. 1 Executive Summary
  - Vol. 2 Accelerator
  - **Vol. 3 Physics & Detectors**
- Will focus on Vol. 3
  - It will be carried by the entire Linear Collider Community, the Editors represent all regions
  - Input from ILC detector concepts, R&D collaborations, theorists
  - CDR to focus on 3 TeV case
- Goals of Vol. 3
  - Describe the CLIC physics potential
  - Show that CLIC physics can be measured with adequate precision

CDR Main Editors

- Four Main Editors were appointed
  - Lucie Linssen (CERN)
  - Akiya Miyamoto (KEK, Asia)
  - Marcel Stanitzki (RAL, Europe)
  - Harry Weerts (ANL, Americas)
- Responsible for the overall CDR
  - Individual Chapters handled by Chapter Editors
- First point of contact for questions/contributions

CLIC CDR Editors





CDR Editorial team

Main Editors

Physics Potential
G. Giudice (CERN)
J. Wells (CERN)

Performance requirements
M. Battaglia(UCSC,CERN)
M. Thomson(Cambridge)

CLIC Detector concepts
J. Brau (Oregon)
D. Schlatter (CERN)
F. Simon (MPI)
G. Wilson (Kansas)

Vertex Detectors
S. Worm (RAL)

Tracking
M. Demarteau (FNAL)
C. Lacasta (Valencia)
T. Matsuda (KEK)
T. Nelson (SLAC)
J. Timmermans(NIKHEF)

Calorimetry
F. Sefkow (DESY)
T. Takeshita (Shinshu U)
A. White (UTA)

Solenoids
A. Gaddi (CERN)
Y. Makida (KEK)

Muon system
B.Schmidt (CERN)

Forward
H. Abramowicz (Tel Aviv)
W. Lohmann (DESY)

Detector Integration
H, Gerwig (CERN)
M. Oriunno (SLAC)

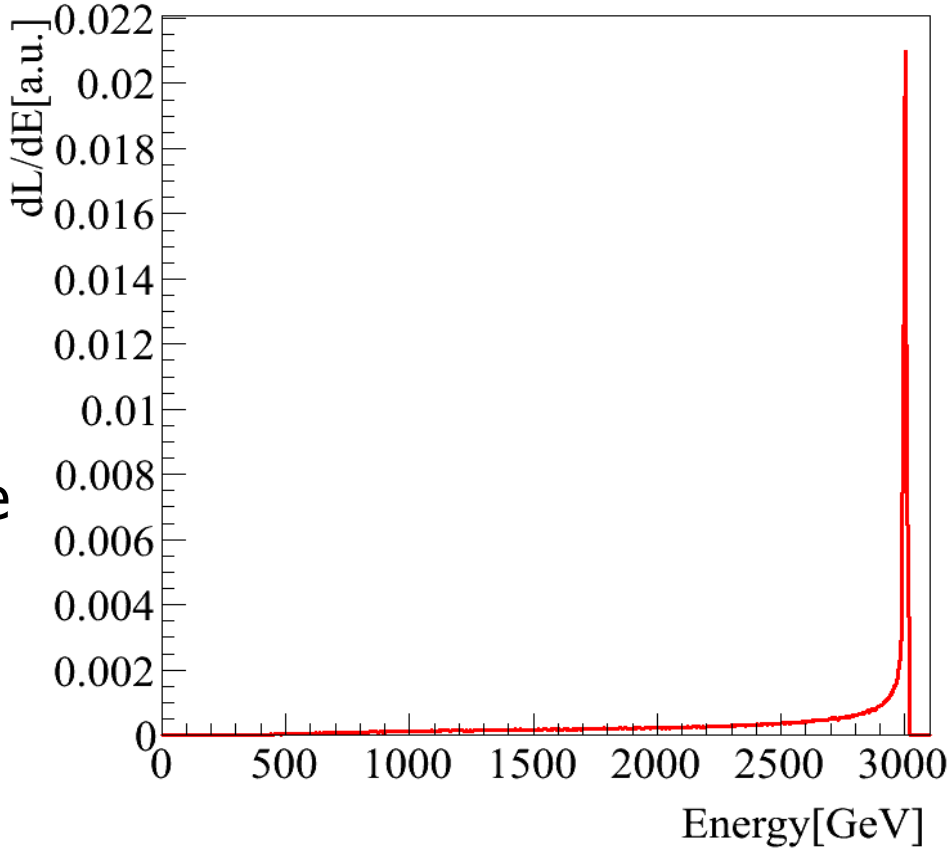
Benchmarking
J.J. Blaising (Annecy)
J. Strube (RAL)
F. Teubert (CERN)

Costing
M. Breidenbach (SLAC)
C. Clerc (LLR)
M. Nordberg (CERN)

CLIC Experimental conditions

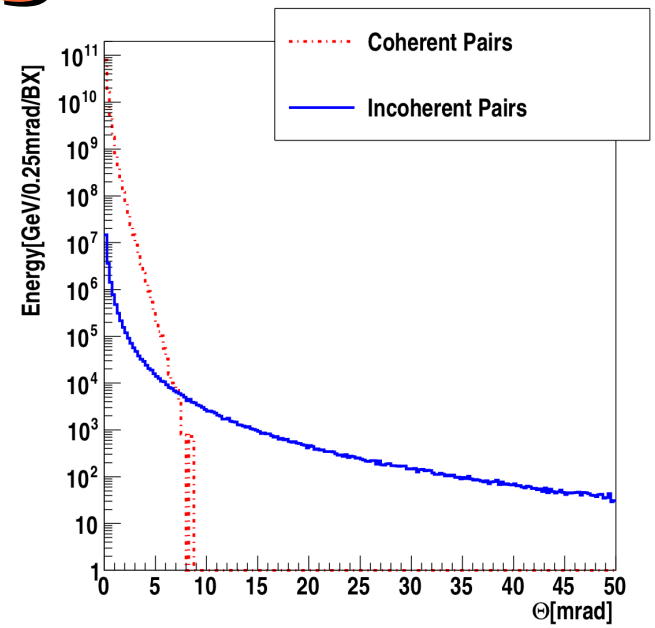
Conditions at CLIC

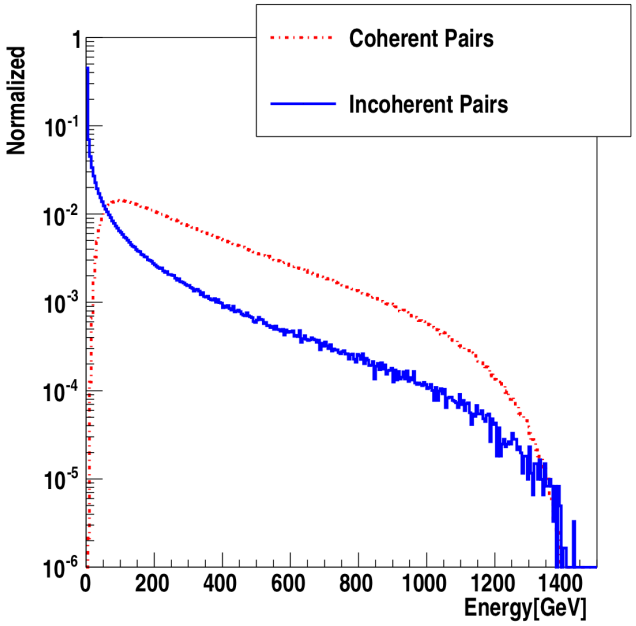
- CLIC Bunch structure
  - 312 bunches, 0.5 ns bunch spacing
  - 50 Hz repetition rate
- Luminosity profile
  - 30 % of the Events are inside 1% nominal Energy interval
- Beam Background more challenging
  - Higher rates



Beam Backgrounds

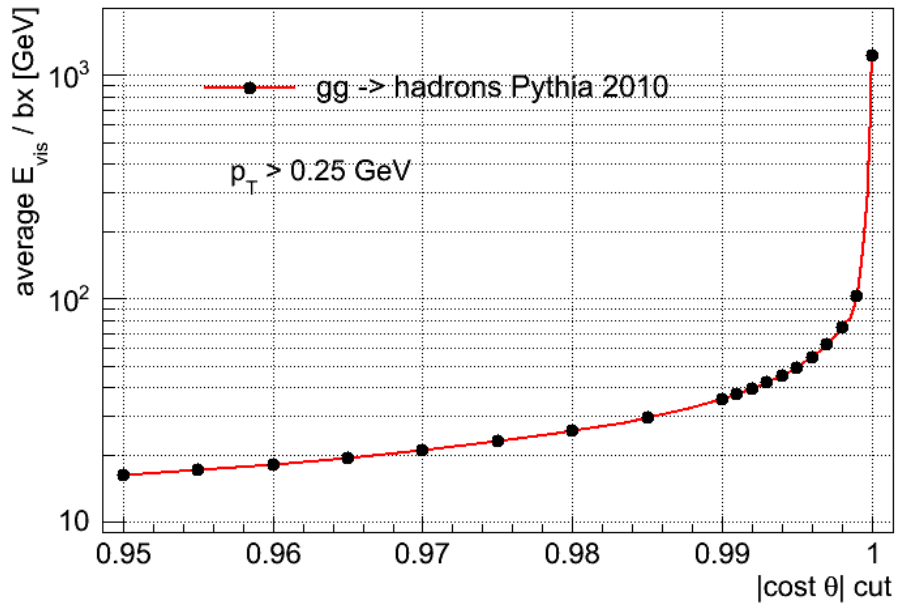
- Incoherent e^+e^- Pairs
  - Photons interacting with other electron/photon
  - Peak at lowest Energies
  - few 10^5 particles/BX
- Coherent e^+e^- pairs
  - Direct photons conversion in strong fields
  - Cutoff at near 10 mrad
  - 10^8 particles/BX

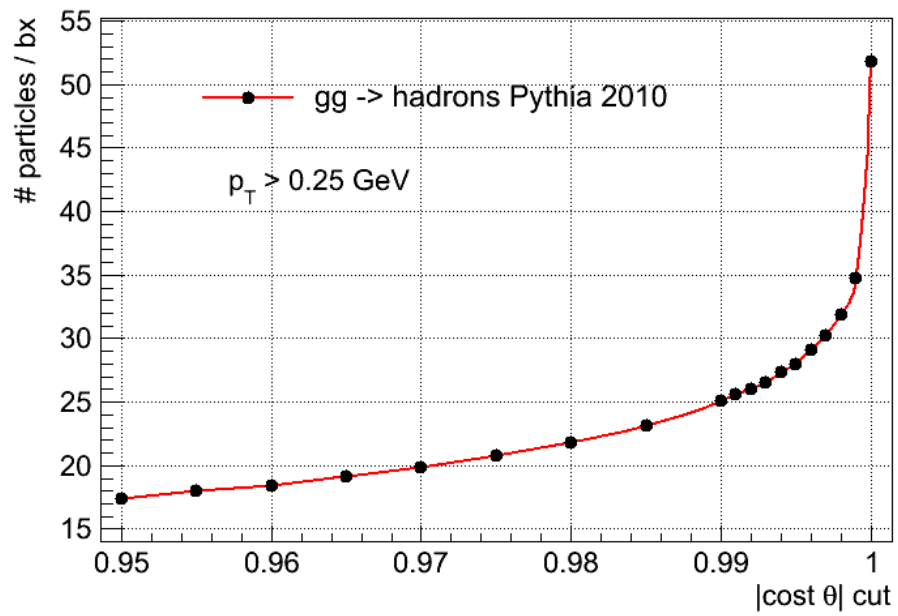




$\gamma\gamma \rightarrow$ Hadrons

- 3.3 events/BX
  - 30 particles hit detector
  - Deposit ~ 50 GeV
  - Forward-peaked
- 15 TeV dumped in the detector per 156 ns bunch train !
- Reconstruction Challenge
  - Mini-jets
  - Overlap with physics events



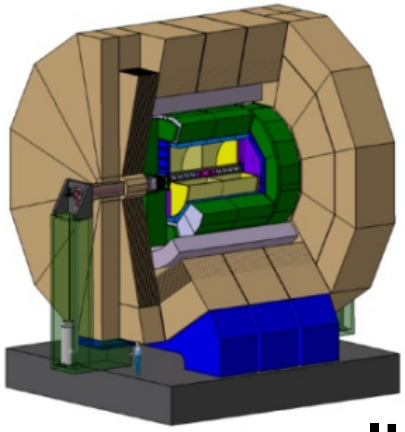


This means for the detectors

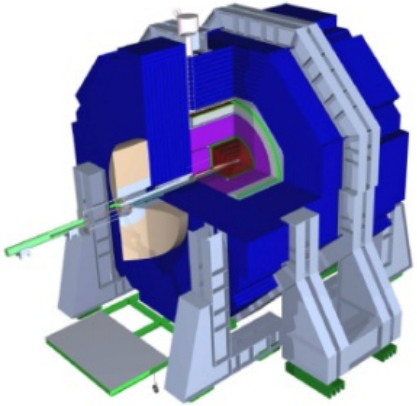
- Due to beam-induced background and short time between bunches:
  - High occupancy in the inner regions (incoherent pairs)
  - Jets scale and resolution are affected ($\gamma\gamma \rightarrow$ hadrons)
- Time-stamping is a must for almost all sub-detectors
- Narrow jets at high energy
  - Calorimeter has to measure high-energy particles (leakage)
  - Track separation in dense jets

Detectors for CLIC

The validated ILC detectors



ILD

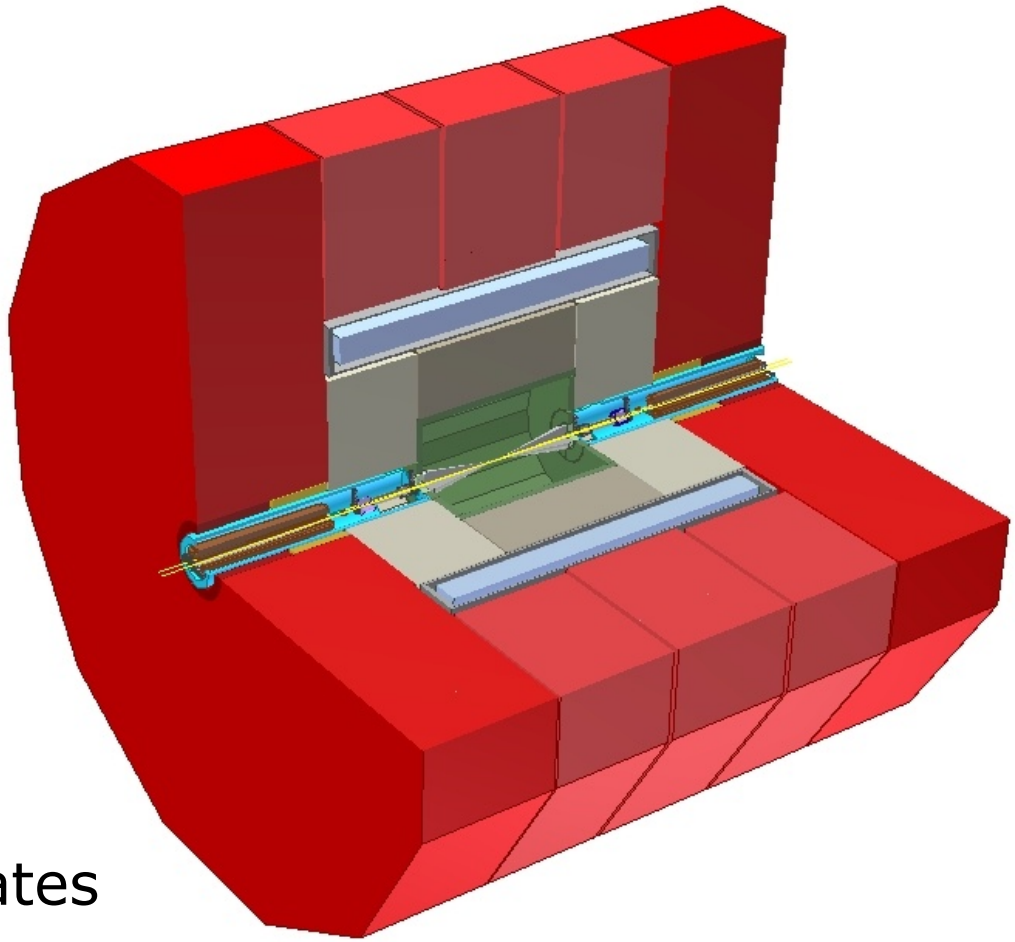


SiD

- Both ILD & SiD build on
  - particle flow paradigm
- ILD & SiD have complementary approaches
  - Field, radius, tracking …
- CLIC detector concepts are based on SiD and ILD.
  - Modified to meet CLIC requirements

Modifications for CLIC

- Crossing angle
  - Changed to 20 mrad
- Vertex detector
  - Moves outwards to r~ 2.5-3.0 cm
  - due to beam background
- HCAL
  - Barrel: 7.5 Λ_i , 1 cm W plates
  - Endcaps:7.5 Λ_i , 2 cm steel plates
  - Changes in Coil radius and length
- Modified MDI/Forward region



CLIC_SiD

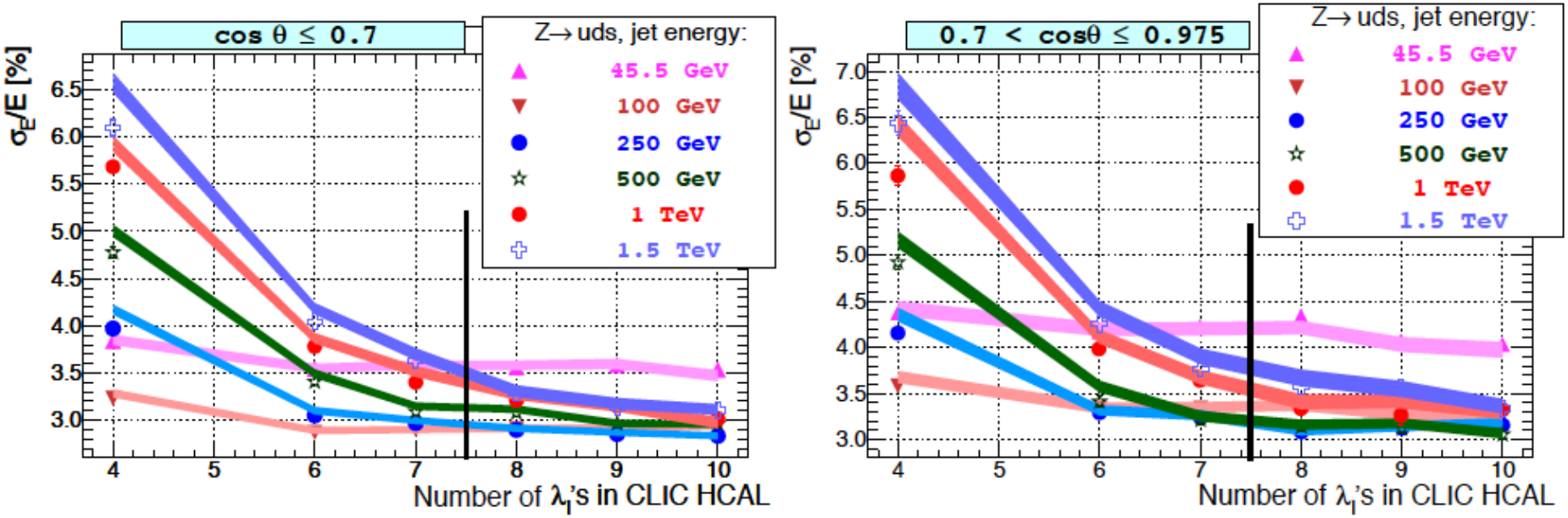
CLIC_SiD and CLIC_ILD

	CLIC_SiD	CLIC_ILD
Vertex detector	inner radius 2.7 cm 5 single barrel layers 6 single layer forward disks	inner radius 3.1 cm 3 double layers 3 double layer pixel forward disks
Tracker	Si, unchanged	TPC, unchanged
ECAL	unchanged	unchanged
HCAL Barrel	W+Scintillator, 3x3 cm tiles 7.5 Λ_i 1 cm plates W+RPC, 1x1 cm tiles 7.5 Λ_i 1 cm plates	W+Scintillator, 3x3 cm tiles 7.5 Λ_i 1 cm plates
HCAL Endcap	Fe+Scintillator, 3x3 cm tiles 7.5 Λ_i 2 cm plates Fe+RPC, 1x1 cm tiles, 7.5 Λ_i 2 cm plates	Fe+Scintillator, 3x3 cm 7.5 Λ_i 2 cm plates
Coil	5T, Radius=2.68 m	4T, Radius=3.35 m

More details :

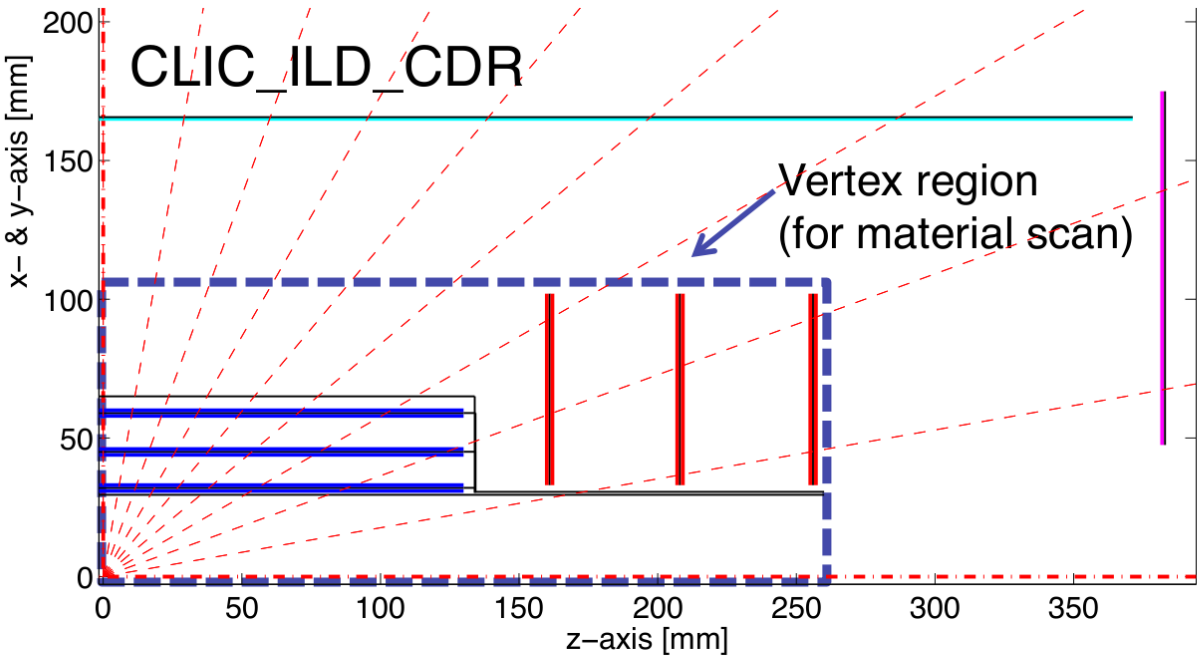
https://twiki.cern.ch/twiki/bin/view/CLIC/ClicCDRNumbers

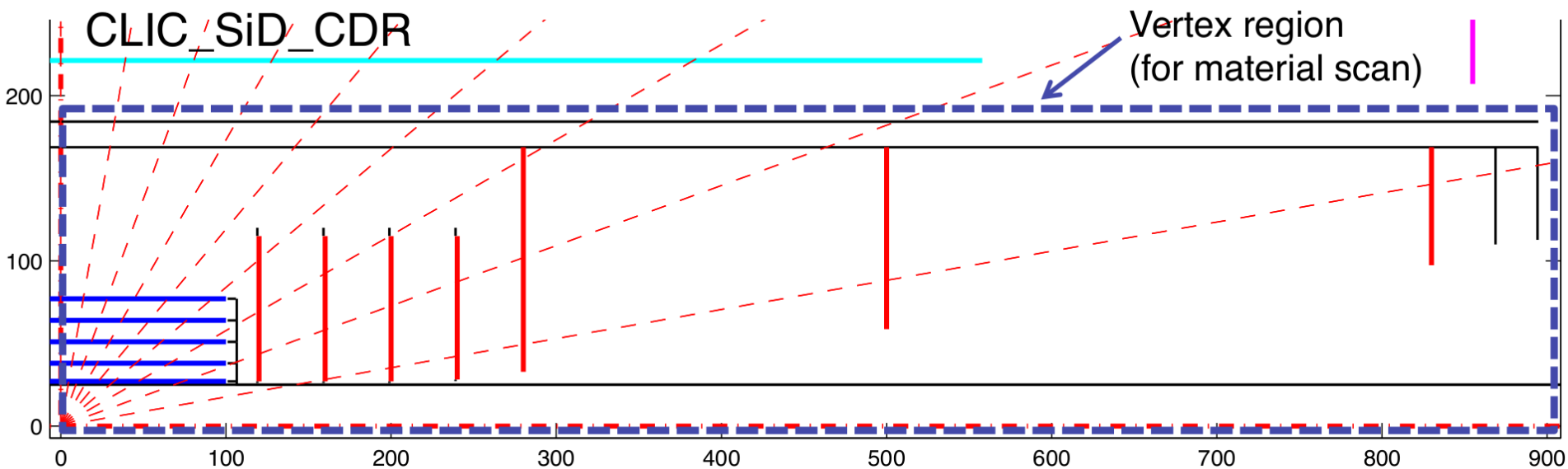
Rationale for 7.5 Λ_i



- Study done using PandoraPFA
- Tail-Catcher (points) brings little improvements
- 7.5 Λ_i gives good jet energy resolution up to 1.5 TeV

Vertex Detector modifications

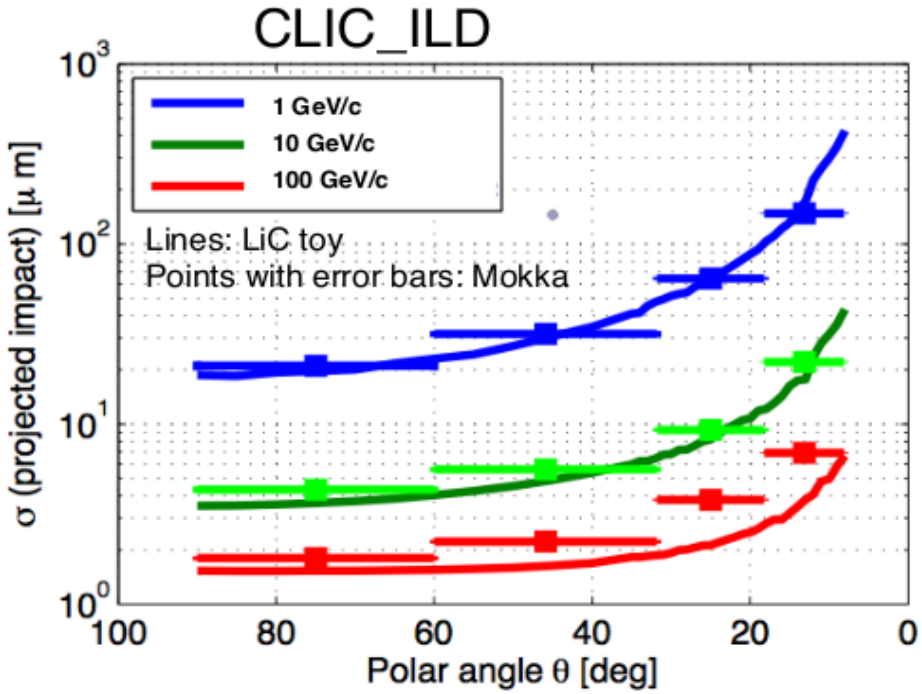


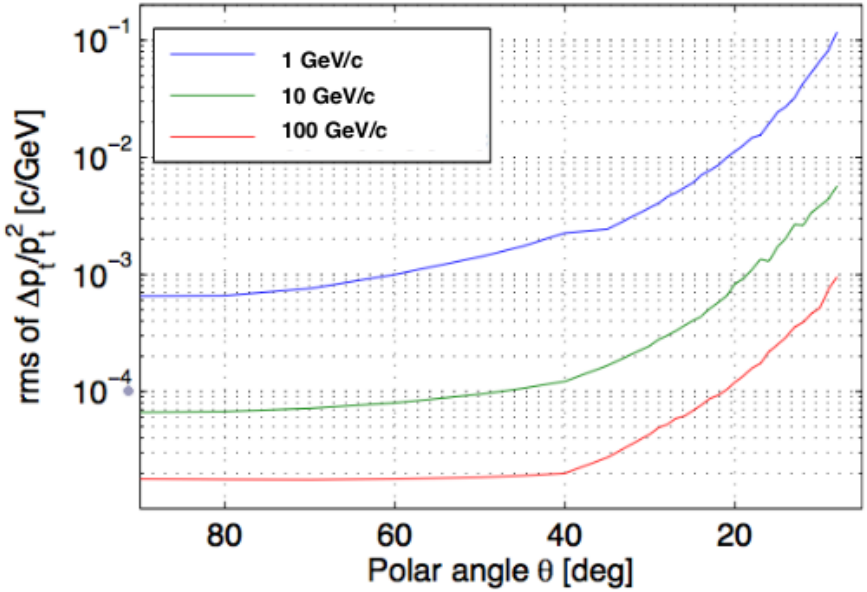


Impact parameter resolution

- Implementing the CLIC_ILD model
  - 20 µm pixels, analog readout
- Studied with
  - LiC Detector Toy
  - Full simulation (Mokka)
- *a*~1.8 µm, =*b*~20 µm / GeV (in barrel)
- Good agreement between both approaches

  Except for large momenta in the forward region, to be investigated further"

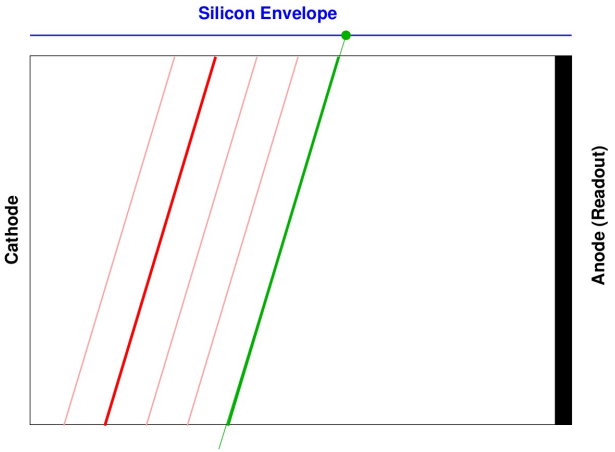


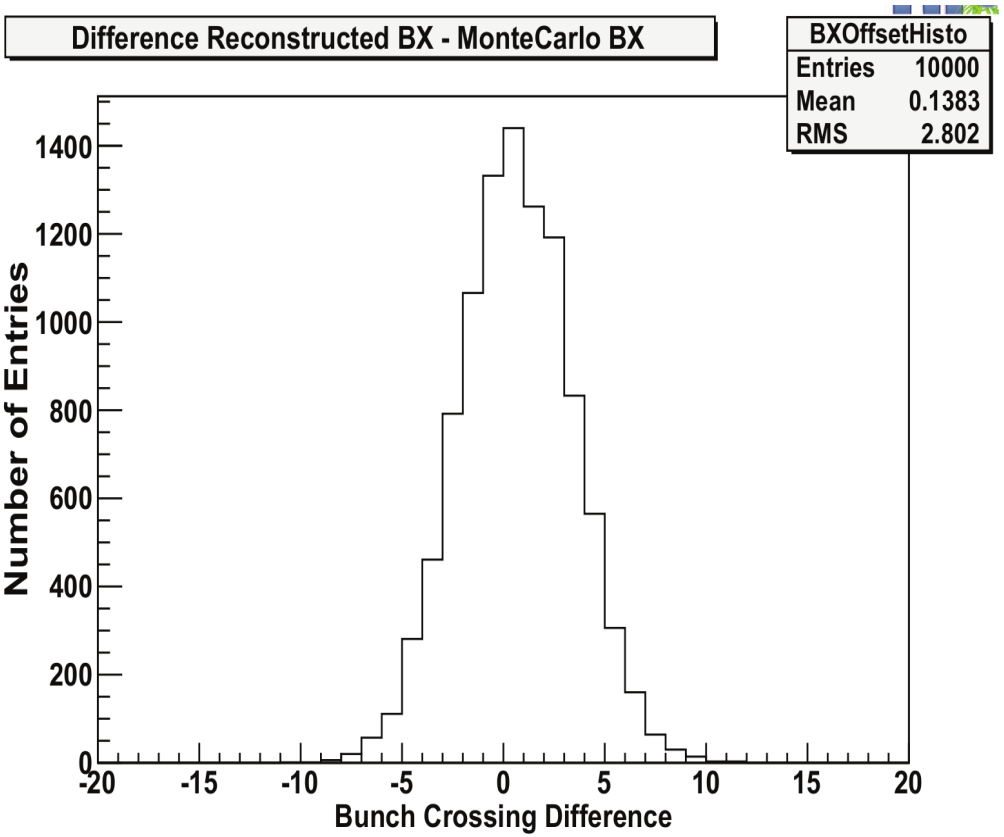


Recent Highlights

TimeStamping with the TPC

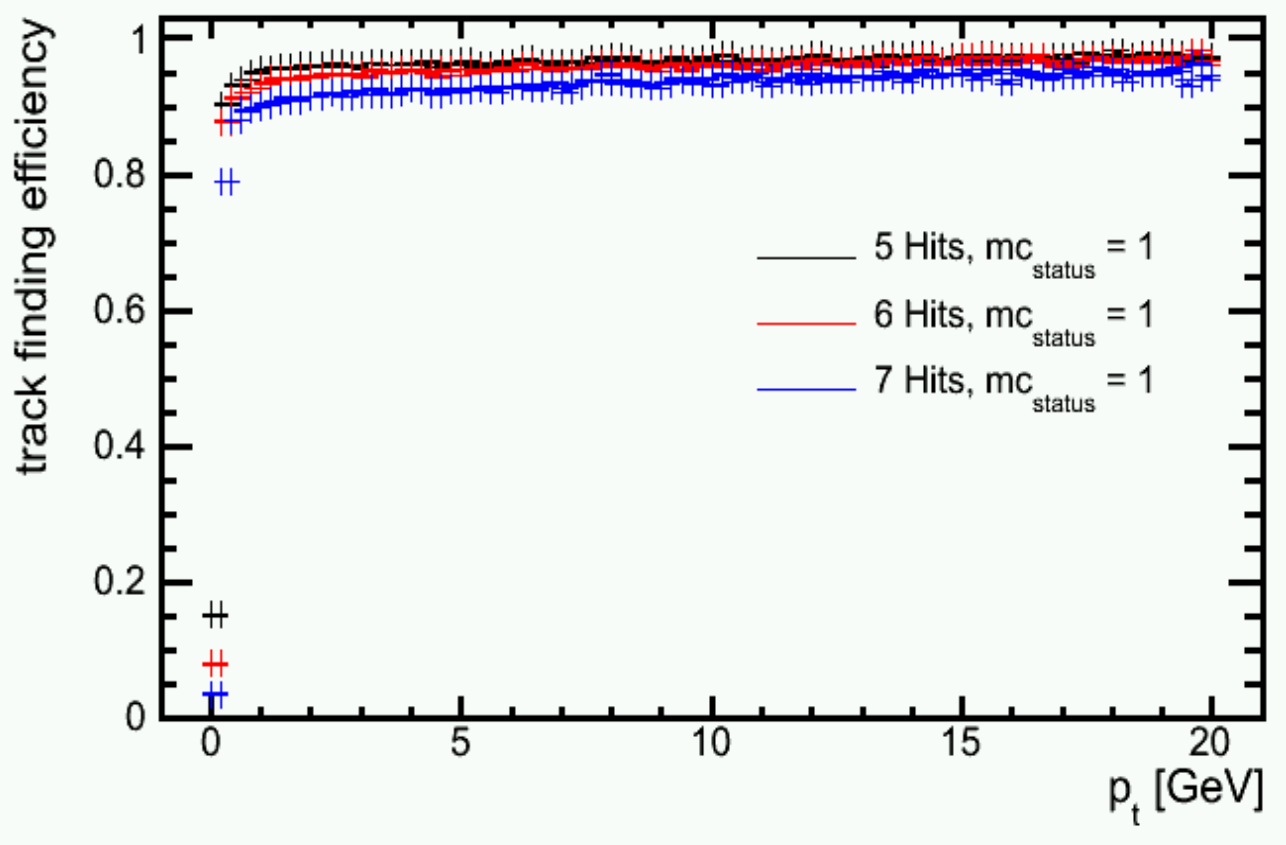
- Barrel time stamping
  - Combination with an external silicon detector
- TPC measures time since beginning of the bunch train
  - $z = (t_{drift} + BX\ \Delta tBX)v_{drift}$
  - The silicon sensor measures z directly
- From this the time stamp BX ΔtBX is determined





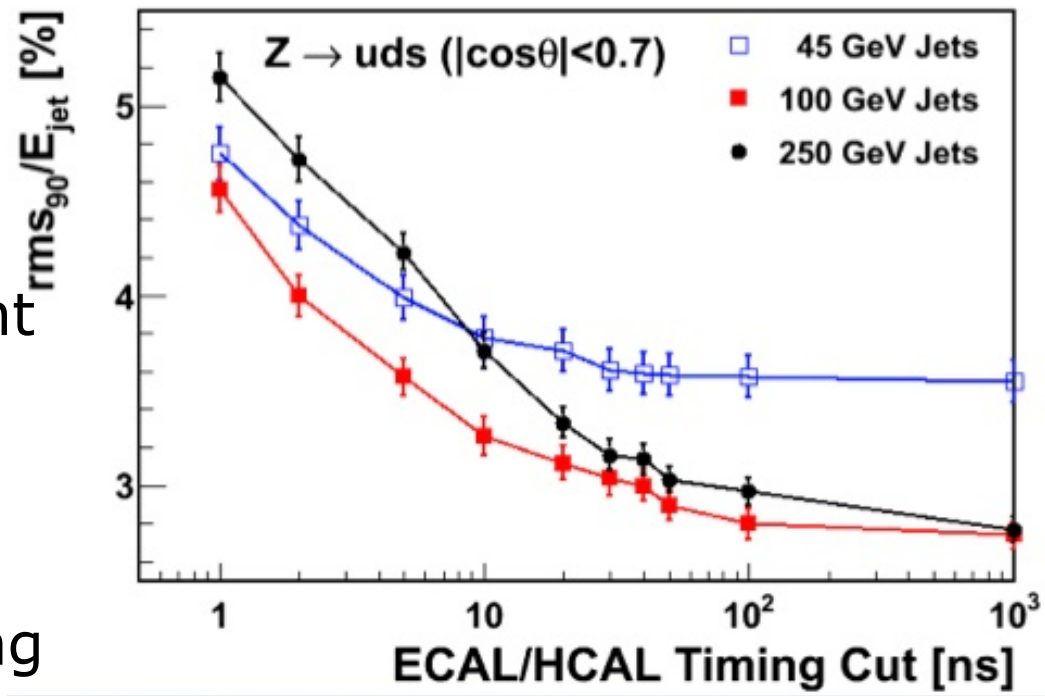
Si Tracking in CLIC_SID_CDR

- Findable tracks
  - $\theta > 8°$
- Different strategies
  - No of hits required
- Using dijets
  - $Z \rightarrow uds$
  - $E_{CMS}=3$ TeV



W-HCAL studies

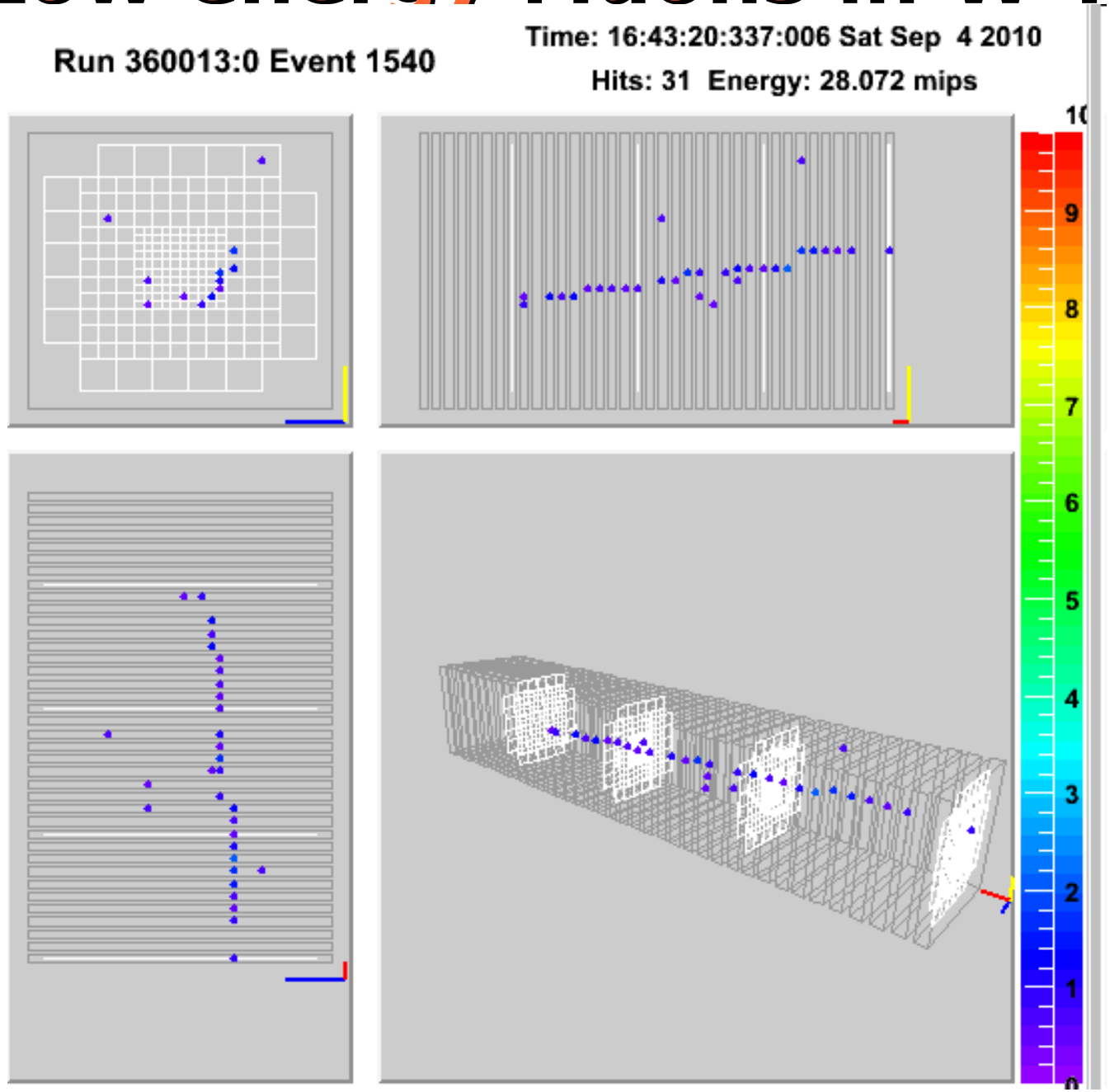
- Tungsten as absorber
  - Larger slow neutron component
  - Slower shower development
- Timing cuts important
  - Drive Resolution
  - Sets scale for time stamping
- Build prototype
  - Verify Simulation
  - Test beam is starting



W-HCAL testbeam

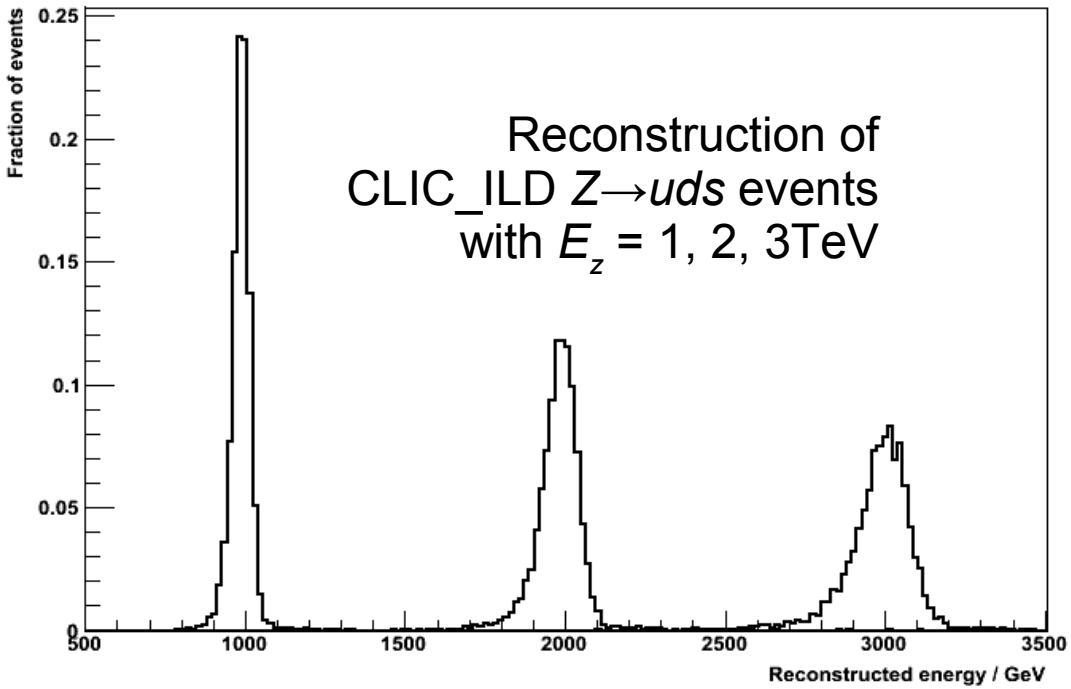
- Prototype tests together with CALICE
- W -Absorbers
  - 30-40 layers
  - Thickness1 cm
  - 80 cm Ø
- Different active materials
- Start Nov 2010 with PS beam
  - 30 W plates
  - AHCAL Scintillator planes 3x3 cm

Low energy Muons in W-HCAL



PFA at CLIC

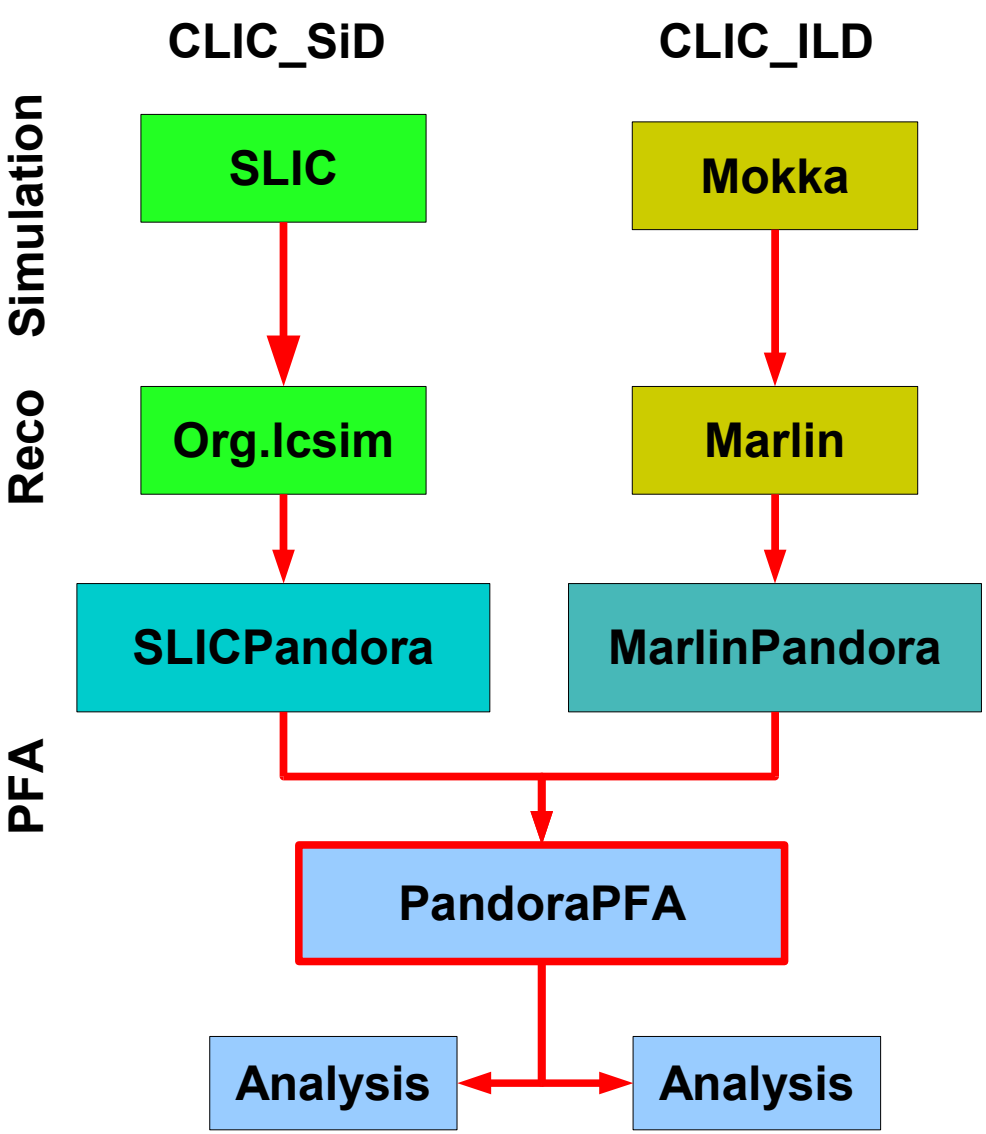
- CLIC uses PFA-based detectors
  - Algorithm needs tuning for high energies
- Current Status is very promising

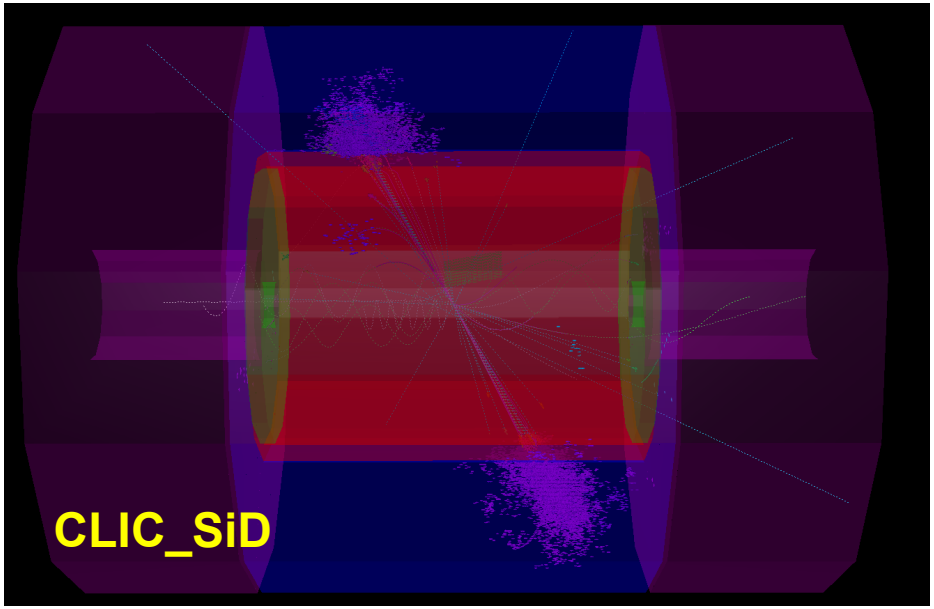


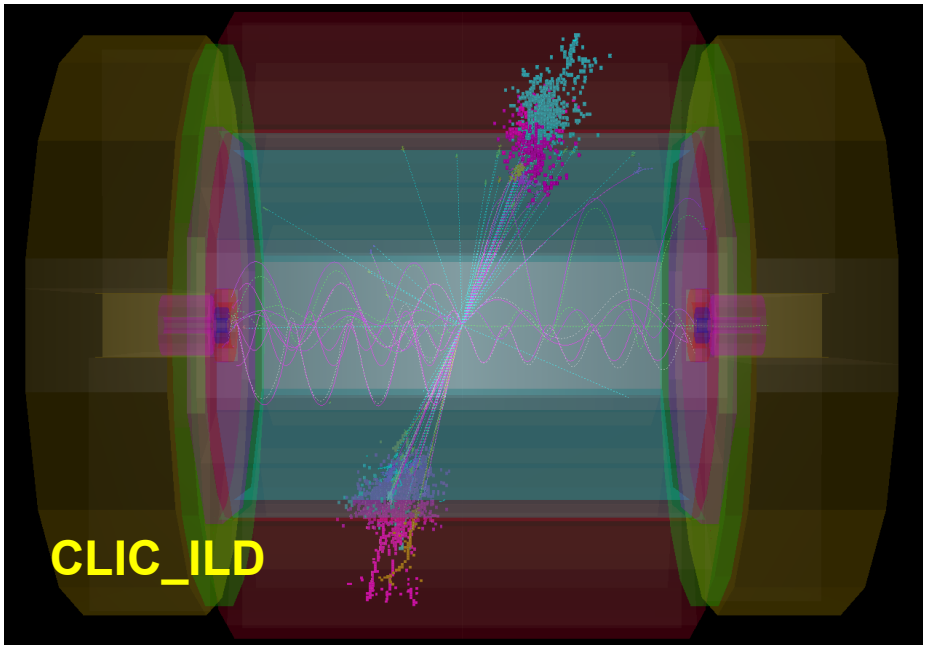
CLIC_ILD, Ej	45GeV	100GeV	250GeV	500GeV	1TeV	1.5TeV
PandoraPFANew, rms90(Ej) / Ej	3.55 ± 0.11	2.93 ± 0.08	2.84 ± 0.07	2.96 ± 0.04	3.19 ± 0.04	3.21 ± 0.05

ILD, Ej	45GeV	100GeV	180GeV	250GeV
PandoraPFANew, rms90(Ej) / Ej	3.62 ± 0.05	2.94 ± 0.04	3.10 ± 0.04	3.29 ± 0.04

Two detectors, one PFA

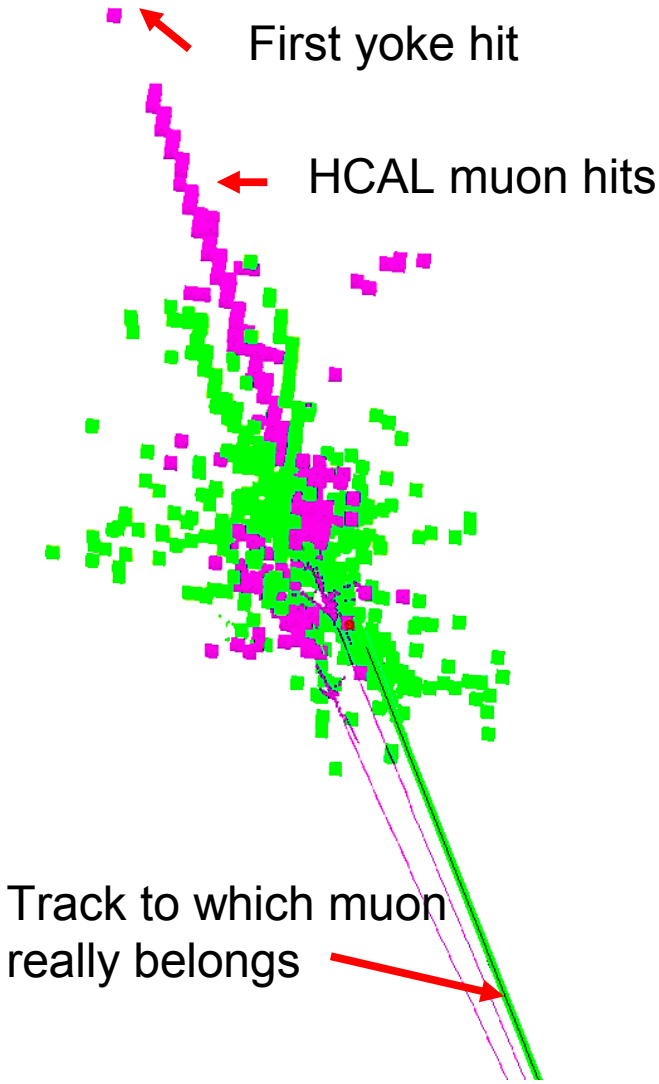






Muon ID in dense jets

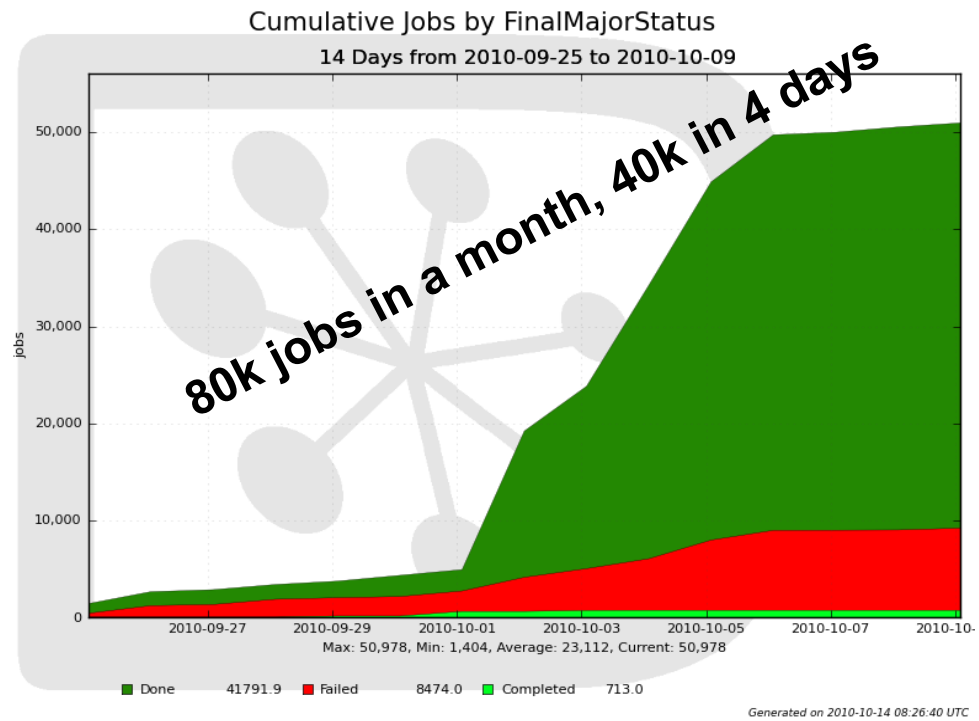
- Pandora clusters the hits outwards
  - In dense environments it occasionally has wrong hit assignment for muon hits in the HCAL.
- To prevent this:
  - Match Inner Detector tracks to tracks in the yoke.
  - Assign HCAL hits along the new defined muon track



Green and purple are two reconstructed PFOs.

ILCDIRAC

- DIRAC developed by LHCb
  - Aim: provide easy access to GRID resources
  - User-friendliness & more stability
  - Built-in production system
- ILCDIRAC implements ILC specific features
  - Software: Whizard, Mokka, Marlin, SLIC, LCSIM
  - 6 months to develop ILCDIRAC
- Active users are not only at CERN: RAL and LAL

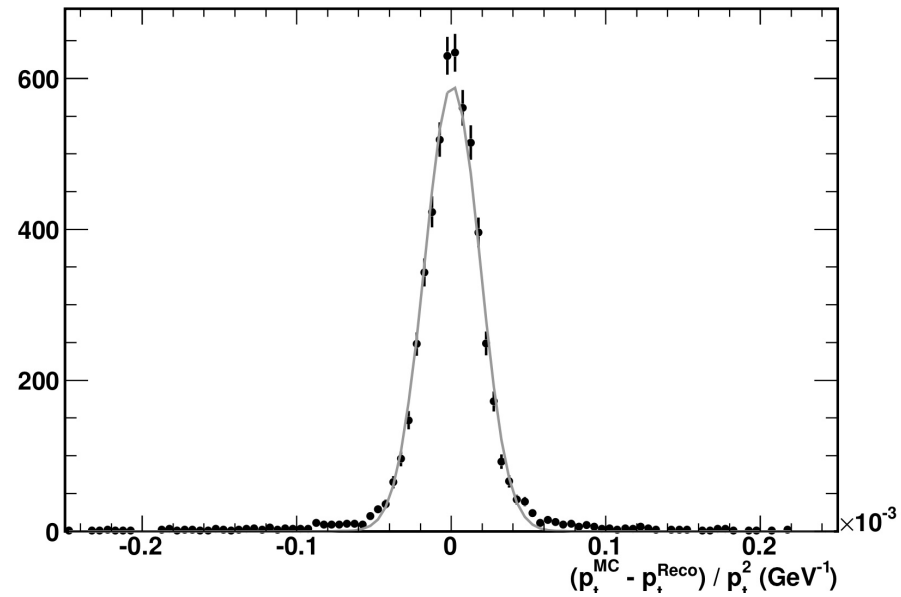


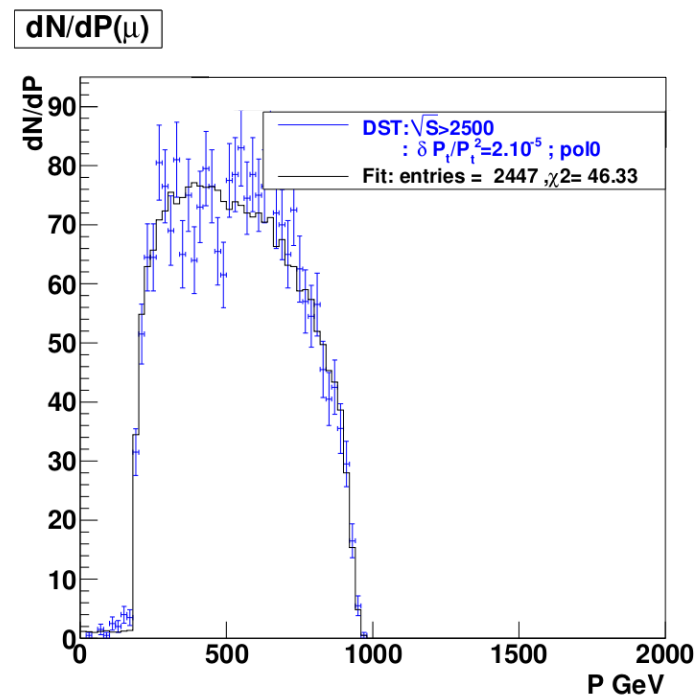
CDR Benchmarks

- 5+1 benchmark channels for the CDR
- At 3 TeV
  - $e^+e^- \rightarrow H\nu_e\nu_e$ $H \rightarrow bb$, $\mu\mu$ (m_H=120 GeV)
  - $e^+e^- \rightarrow H^+H^- \rightarrow tbtb$ $e^+e^- \rightarrow HA \rightarrow bbbb$ ($m_{H,H+,A}$=900 GeV)
  - $e^+e^- \rightarrow \tilde{q}_R\tilde{q}_R$ $m_{\tilde{q}R}$= 1.1 TeV
  - $e^+e^- \rightarrow \tilde{l}^+\tilde{l}^-$ m_l=423,696 GV
  - $e^+e^- \rightarrow \chi^+\chi^-, \chi^0\chi^0$
    $m\chi^0$=340 GeV
- At 500 GeV
  - $e^+e^- \rightarrow tt$ (same as ILC Benchmark)

A First look

- Example : Smuon analysis
- Currently using K' point
  - $\tilde{\chi}_1$ = 554.3 GeV
  - $\tilde{\mu}_R$ =1108.8 GeV
- Full simulation
- Measured
  - $\tilde{\chi}_1$ = 569.1± 1.5 GeV
  - $\tilde{\mu}_R$ =1118.4± 3.0 GeV





Summary

- CLIC CDR is a collaborative effort of the LC community
  - Editors represent all the regions
- CDR is due in August 2011
  - Oral presentation to the Scientific Policy Committee in June 2011
- More details
  - 25 scheduled presentations on Detectors for CLIC in the parallel sessions
  - LCD notes http://lcd.web.cern.ch/LCD/Documents/Documents.html
- Acknowledgments
  - Everybody in the CLIC detector study group