EP track

Event Processing Track Summary

Patricia McBride (Fermilab)

and Stephen Gowdy

CHEP 2007

Victoria, BC

August 7, 2007

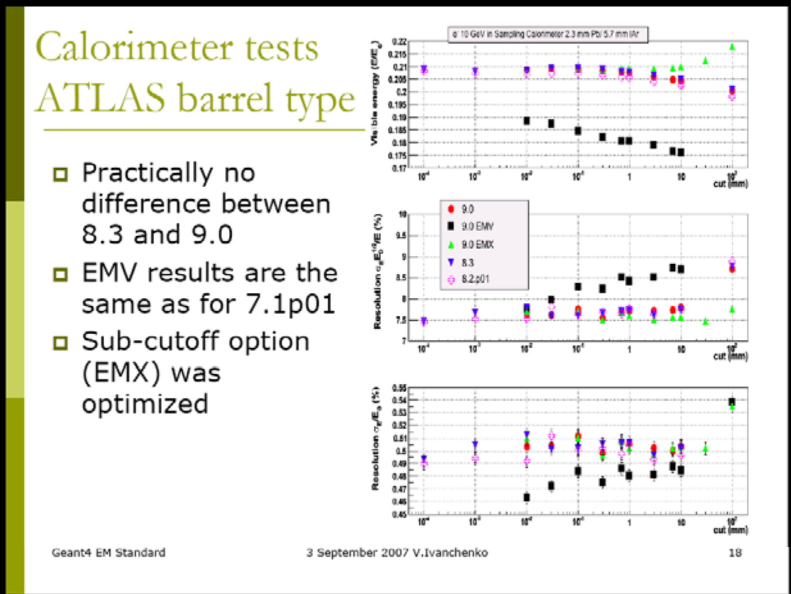
Track Overview

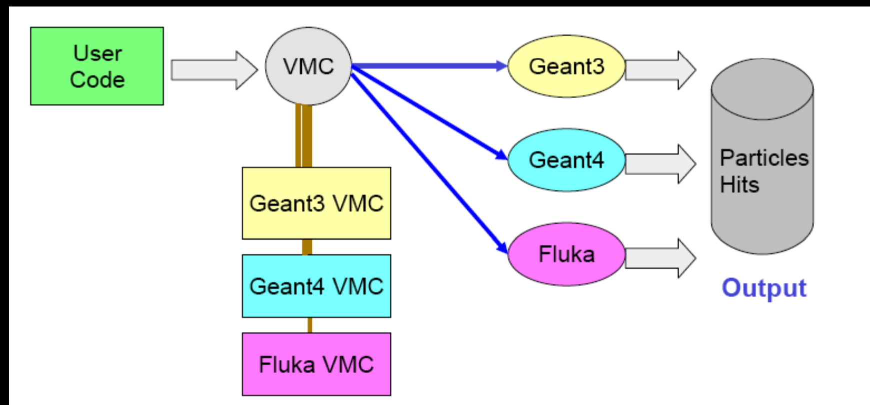
- Event processing track - topics:
  - Event simulation and reconstruction;
  - Physics analysis;
  - Event visualization and data presentation;
  - Toolkits for simulation and analysis;
  - Event data models;
  - Specialized algorithms for event processing
- 63 contributions to the track
  - The majority came from the LHC experiments (32)
  - Only a few from running experiments
  - Medicine, astrophysics, future experiments
  - Generic tools (14)
  - 7 sessions; 35 oral presentations

Apologies to the contributors and the audience. I will not cover all topics or presentations in the summary.

Simulations

- Lots of work since last CHEP on validation, geometry and integration into frameworks for the experiments.
- Validation continues…
  - Experiments want to take advantage of improvements in physics processes in Geant4 Geant4 9.0 released on June 29



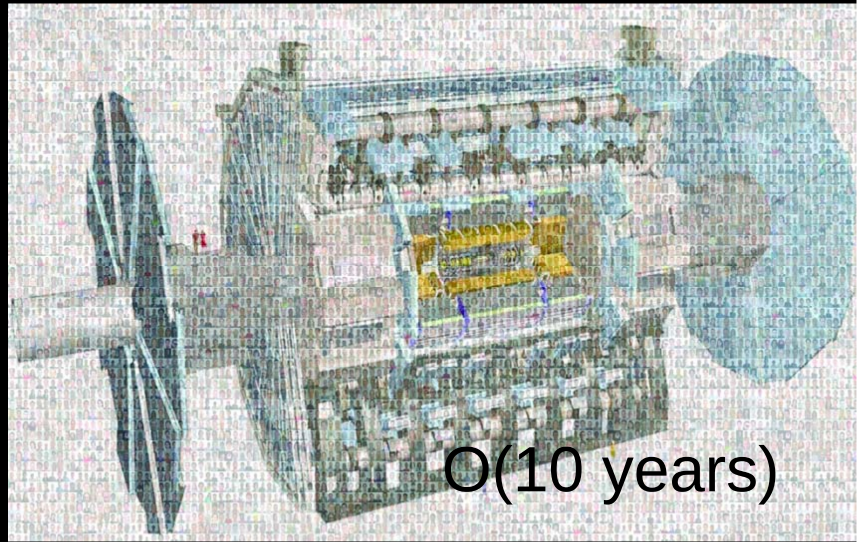


EP track

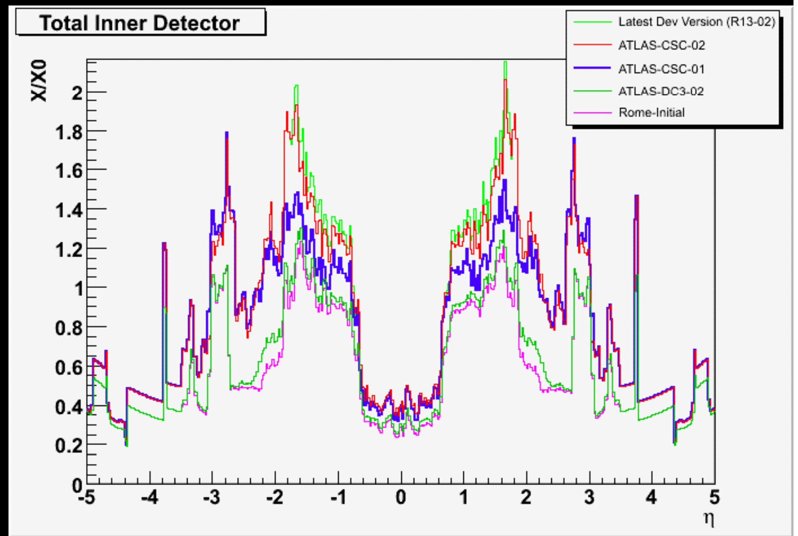
Atlas Simulations

The Atlas Simulation application is:

- Assembled and configured @runtime
- Steered using Python scripts
    - -Providing interactivity to the C++-based applications
    - -Better maintainability and robustness
- Infrastructure quite stable in the past year



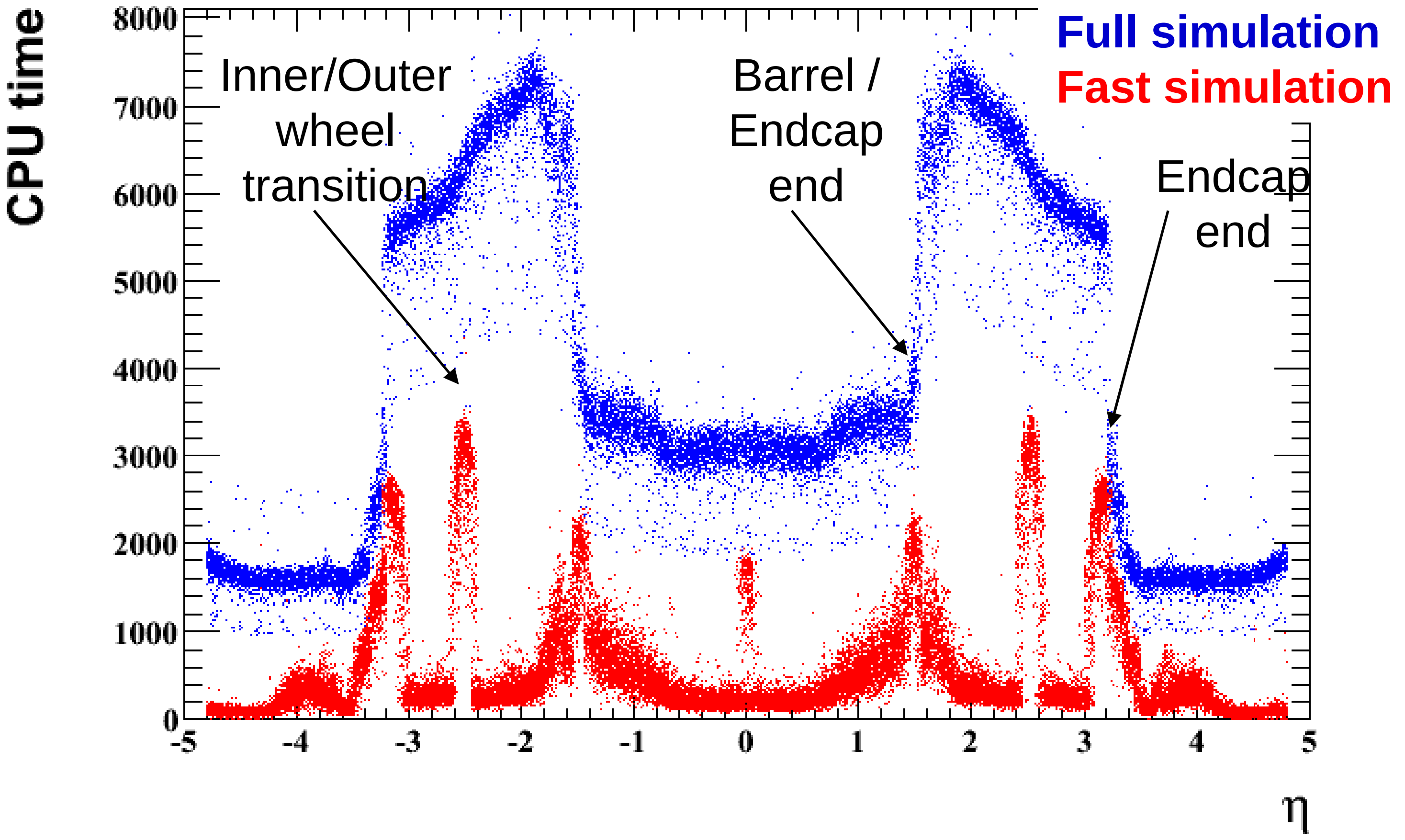
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation
validation validation validation validation validation validation validation



Results - Timing (ATLAS Fast Simulation)

Single electrons/positrons with E=50 GeV from IP:

- **average time gain of 10**
- **Cracks and intersections clearly visible**



Performance and Production

- With the new/upgraded software: nearly 250 million events simulated by the production team since July 2006 (100 million with Geant 4.7.1 during CSA06 and validation efforts and 145 million with Geant 4.8.2.p01 during CSA07)
- Do extensive test/validation between G4 version changes
- Failure rate: <5% (arithmetic problem; trap NaN; skip event)

  expect to improve as we switch to Geant4.8.3 (in October)
- Speed [Intel(R) Xeon(R) CPUE5335 @ 2.00GHz, Geant4.8.2.p01 with QGSP_EMV physics list, interactive testing] very preliminary :

  Minimum bias events : 23 seconds per event

  t-tbar : 170 seconds per event
- CMS strategy:

  equal number of simulated and real events (~ $1.5\text{x}10^9$/year)

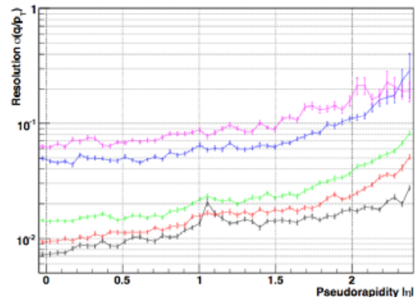
  Aim to achieve this with a mixture of full and fast simulation

CMS Reconstruction...

- CSA06 (Sept/Oct 06): Computing/Software and Analysis challenge
  - Reconstruction enhanced with
    - Tracking
    - Electrons (initial version)
    - Photons (initial version)
    - B/tau tagging
    - Vertexing
    - Jets/MET
  - First definition of data Tiers (FEVT, RECO, AOD)
  - Re-reconstruction, skimming demonstrated

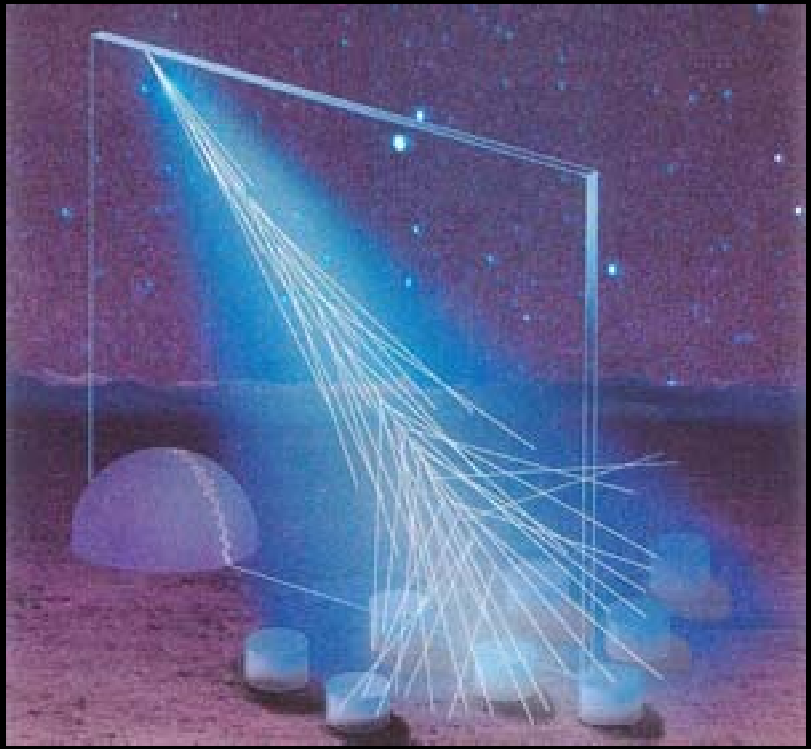
Success!

- Total events processed>100M
- Performance
  - < 25 sec/ev (on 1kSi2k CPUs) even on ttbar
  - Memory tops at 500 MB/job after hours/thousands of events
  - Crash rate < 10^{-7}/event



Pierre Auger Offline Software

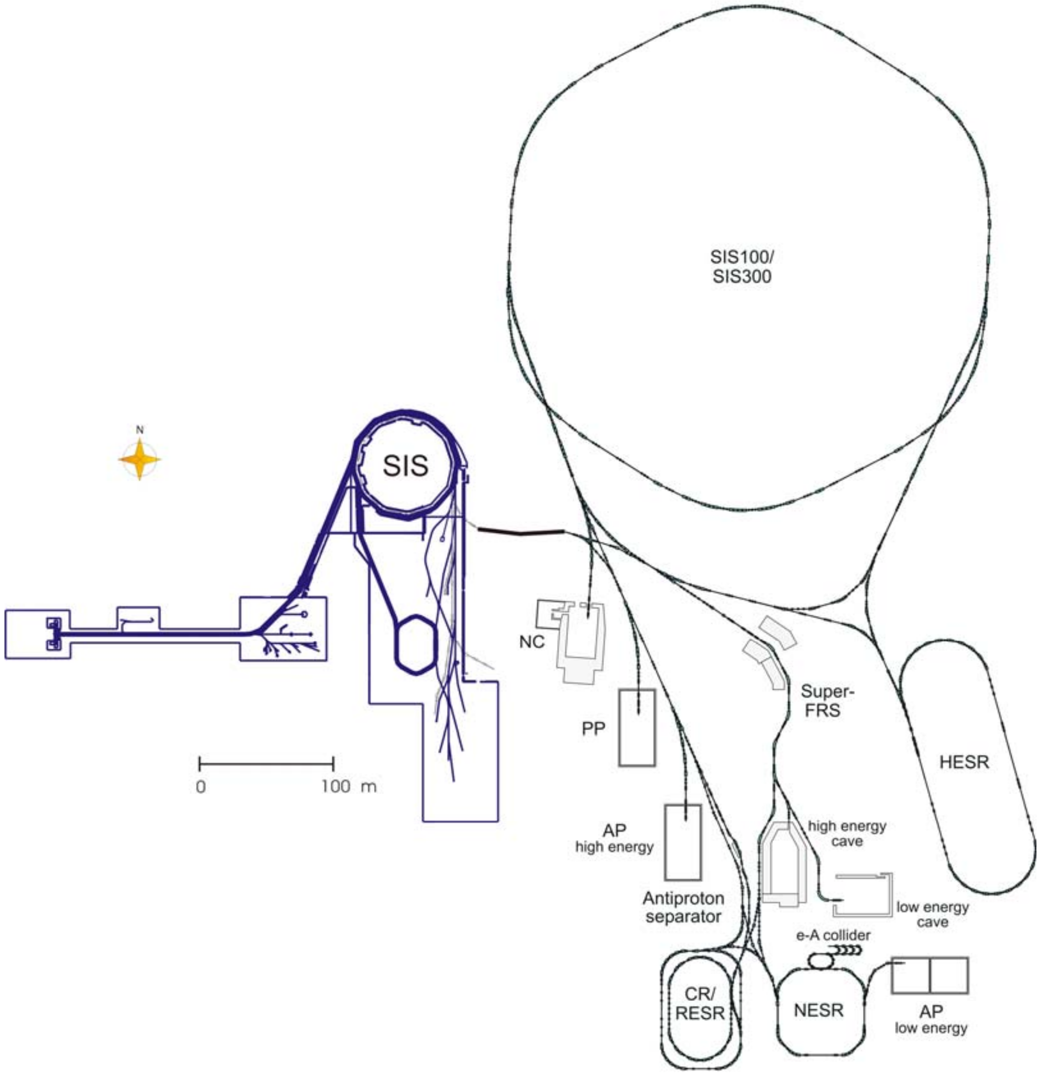
- The Auger software framework provides:
  - Event data model
  - Communication backbone between algorithms
  - Ability to read/write various formats
  - Detector description
  - Unified access to time-dependent detector data in various sources/formats
  - Plug-in framework for modules
  - Physics algorithms for simulation and reconstruction
  - Service modules for I/O, event selection, visualization
  - Module sequencing control
  - Configuration management
  - Utilities
  - Geometry, Error logging, XML parsing, Math, Physics, ...



EP task

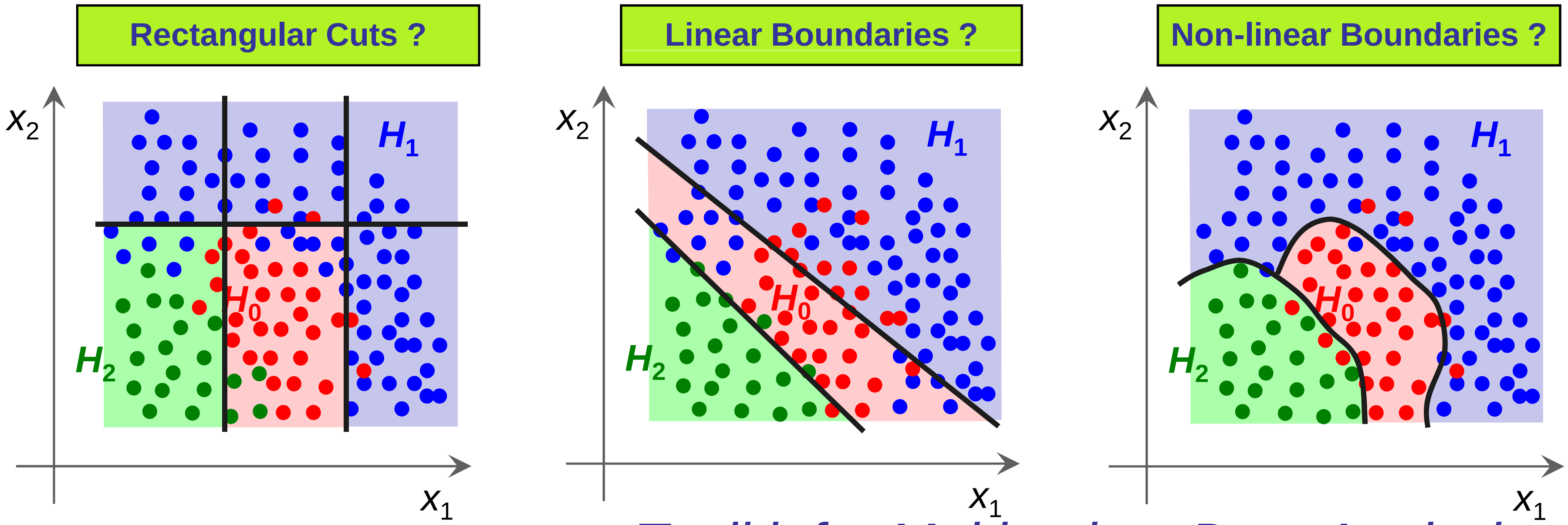
FairRoot

- FairRoot features
  - Geometry Interface
  - Runtime Database and Parameter Handling
  - Integrated Track follower (Geane)
- FAIR experiments design studies are using FairRoot common infrastructure:
  - CBM
  - PANDA
  - HADES



The General Classification Problem

- General definition of a classifier f: $R^n \rightarrow N$, $\boldsymbol{x} \rightarrow$ {**0**, **1**, **2**,…}
  - Sample $\boldsymbol{x}$ (n discriminating input variables) in different categories
  - The problem: How to draw the boundaries between $\mathbf{H_0}$, $\mathbf{H_1}$, and $\mathbf{H_2}$ such that f($\boldsymbol{x}$) returns the true nature of $\boldsymbol{x}$ with maximum correctness



→ *Toolkit for Multivariate Data Analysis*

Which method is best to find the optimal boundary?

Large n → Let the machine decide !

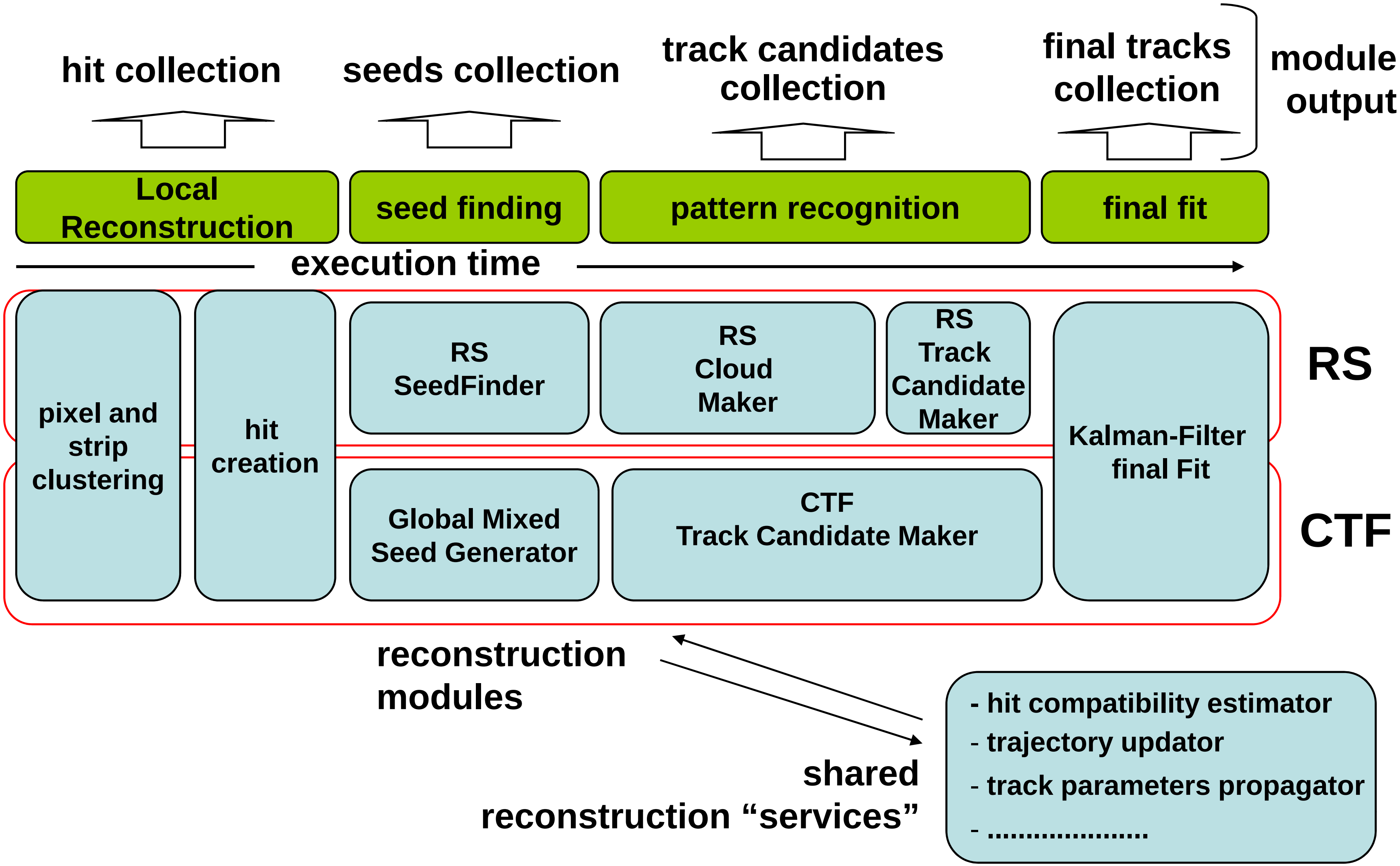
Machine Learning

Tracking

- Experimenters have demonstrated the need to have more than one tracking algorithm depending on the task.
  - Flexible, modular frameworks allow switching between tracking algorithms at run time. (CMS and ATLAS)
- Reuse of tracking code -
  - For example, BES III is using tracking modules from Babar and Belle - *with Gaudi framework*

general purpose tracking

the implementation



special tracking and interaction with other reconstruction modules

Service for track parameters propagation with electron mass hypothesis

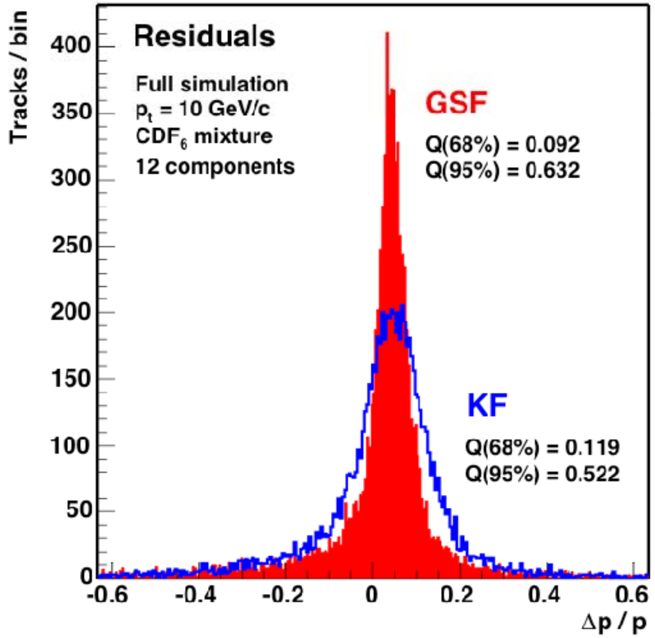
+

Final fit module based on a *Gaussian Sum Filter*

(it takes properly into account bremsstrahlung and subsequent kinks in the electron's trajectory)

+ rest of the CTF tracking sequence

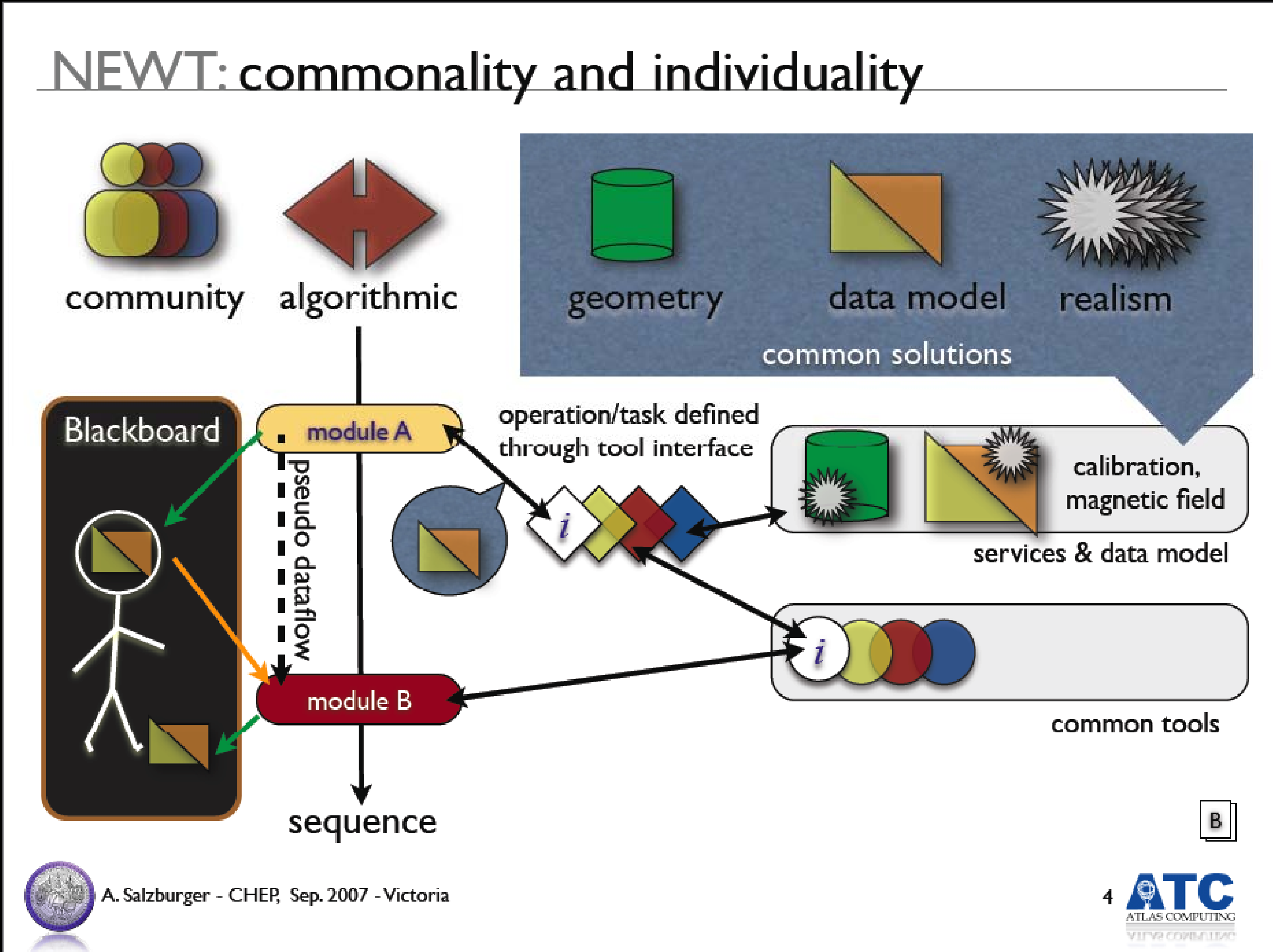
→ **tracking for electron reconstruction**



see specific poster:
http://indico.cern.ch/contributionDisplay.py?contribId=193&sessionId=21&confId=3580

ATLAS tracking reconstruction

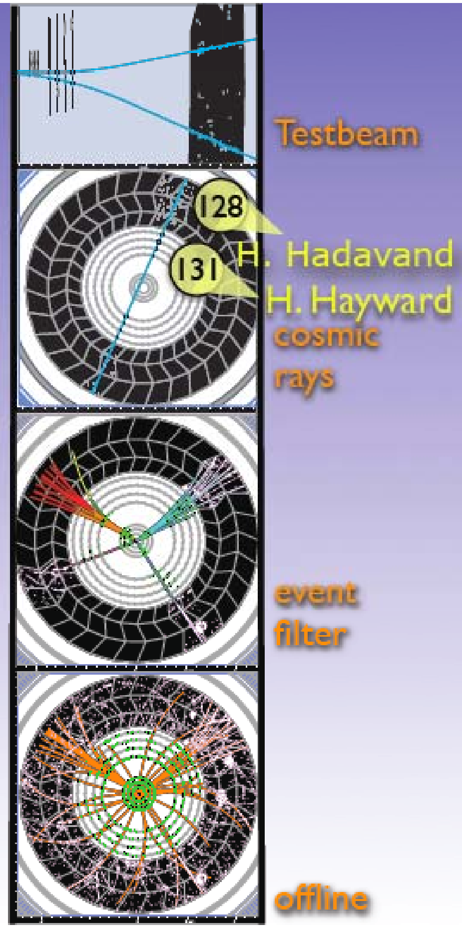
NEWT: commonality and individuality



ATLAS Tracking

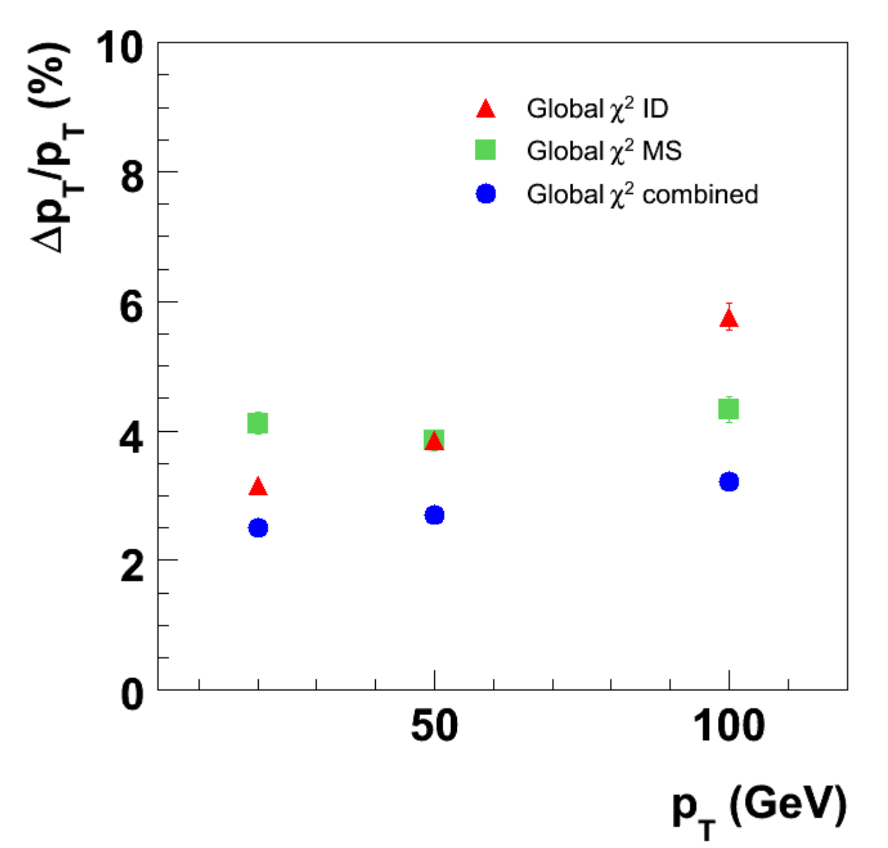
Modularity gain

- NEWT runs in a similar configuration for several setups using same underlying tools
- Number of algorithmic components increased dramatically
  - e.g. from 2 track fitters to 6 different fitters (dedicated electron fitters, high hit occupancy, fast trigger fit, etc.) (144) T. Cornelissen/M. Elsing
- Commonly used validation framework
  - allows inter-module comparison on different levels
- Faster development cycles, since single tasks can be assigned to individual authors
  - necessary to integrate feedback from detector tests and commissioning runs
- Expansion of reconstruction tools to user analysis
  - extrapolation, vertex and kinematic fitting, etc.



Combined Muon Tracking in ALTAS

- Incorporates Inner Detector and Muon Spectrometer measurements into a single track fit with O(100) degrees of freedom. Has several advantages over ID and MS standalone fits:
  - Gives best possible momentum resolution
  - Allows to perform global ID-muon alignment
  - Reduces fakes from e.g. pion decay
- Energy loss in the calorimeter can not be ignored
  - becomes additional parameter in fit
  - fit can use either a parametrized or a measured energy loss
  - calorimeter measurement is preferred if a strong brem is detected, and if the track is isolated.



Alignment

- Track based alignment procedures are under development for the LHC experiments.
  - Number of elements is large; interested in microns
  - Algorithms can be cpu & memory intensive
  - A variety of algorithms used including Global χ^2.
  - Experience from previous experiments has been important and helpful.
  - Millepede II in use by several collaborations (CMS and BES III)

Full Scale Tracker Alignment Study

The **simultaneous alignment strategy** is tested for the **full strip and pixel tracker** of CMS. No reference modules are fixed.

Misalignment:

- Initial misalignment reflects starup-condition of CMS. Only pixel sensors are roughly prealigned to 15 μm precision.

Data sets:

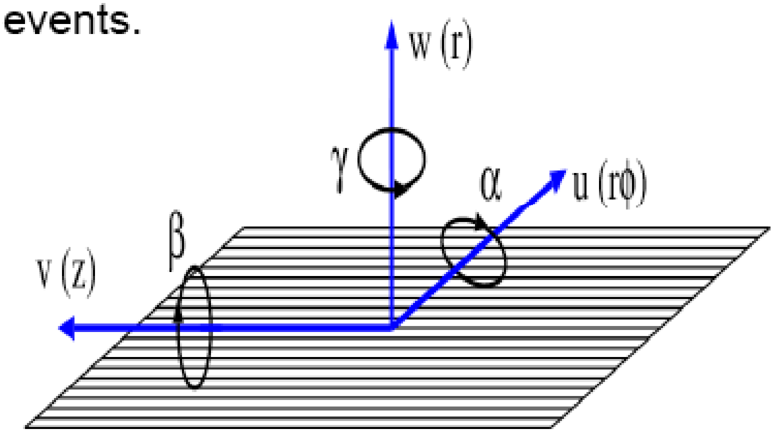
- 0.5 M $Z^0 \rightarrow \mu\mu$ (0.5 fb^{-1}) events with mass and vertex constraint.
- 25 k cosmic μ with momentum > 50 GeV.
- Single μ of 1.5 M $Z^0 \rightarrow \mu\mu$ ~ 3 M W $\rightarrow \mu\nu$ (0.5 fb^{-1}) events.

Alignment parameters:

- All silicon modules (pixel+strip).
- 3 (2 for 1D) translation and the rotation around normal of sensor.

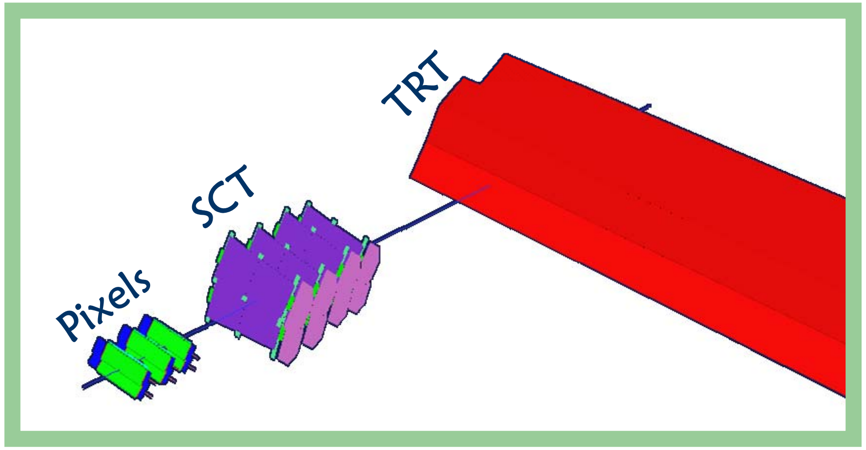
Coordinate Definition:

- Center of the pixel barrel sensors.
- Rotation of pixel barrel fixed.



Algorithms validation : CTB

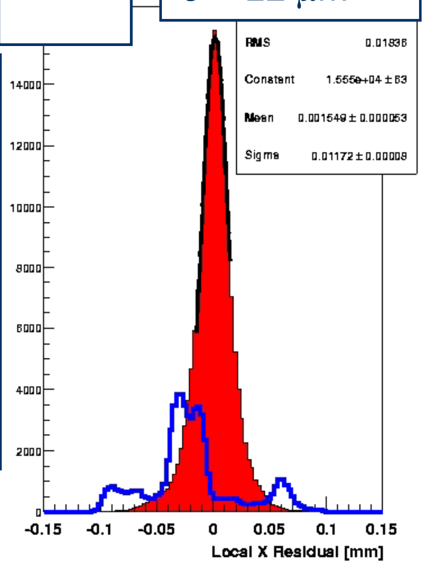
- Combined Testbeam (2004)
- ATLAS barrel slice ⇒ detectors from all different ATLAS subsystems
- Data-taking program:
  - e, π, μ, γ ; 2 up to 180 GeV/c
  - without and with B-field (1.4 T)
- ~20M validated events for the ID



Robust alignment

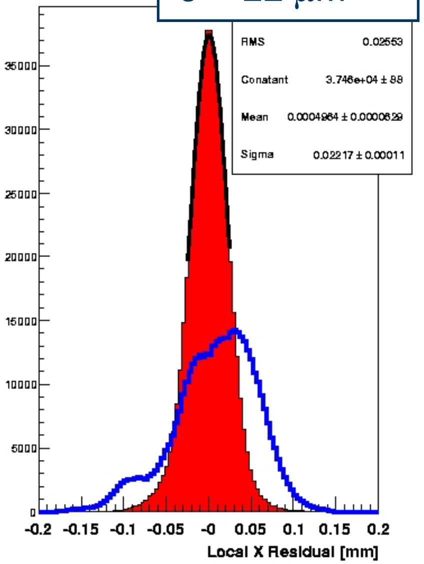
Pixel

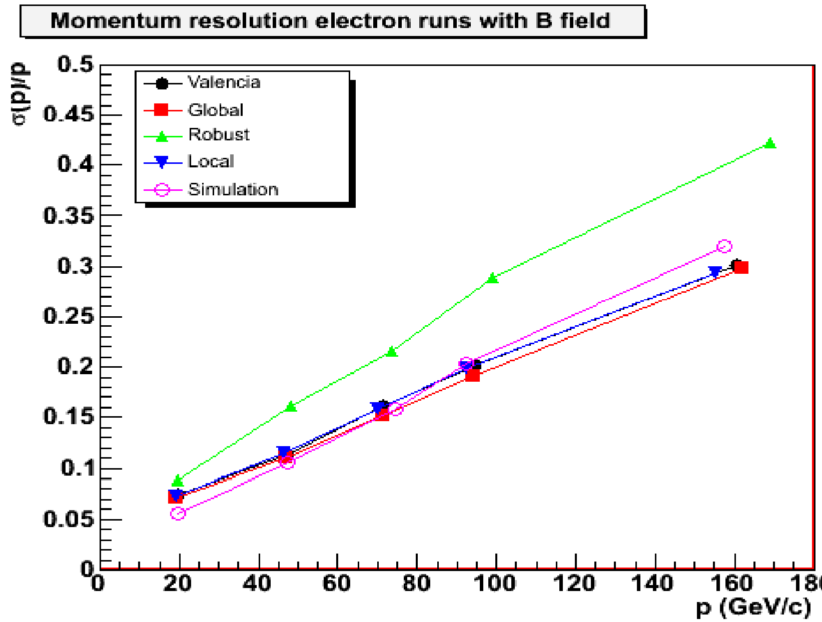
μ = 1 µm
σ = 12 µm



SCT

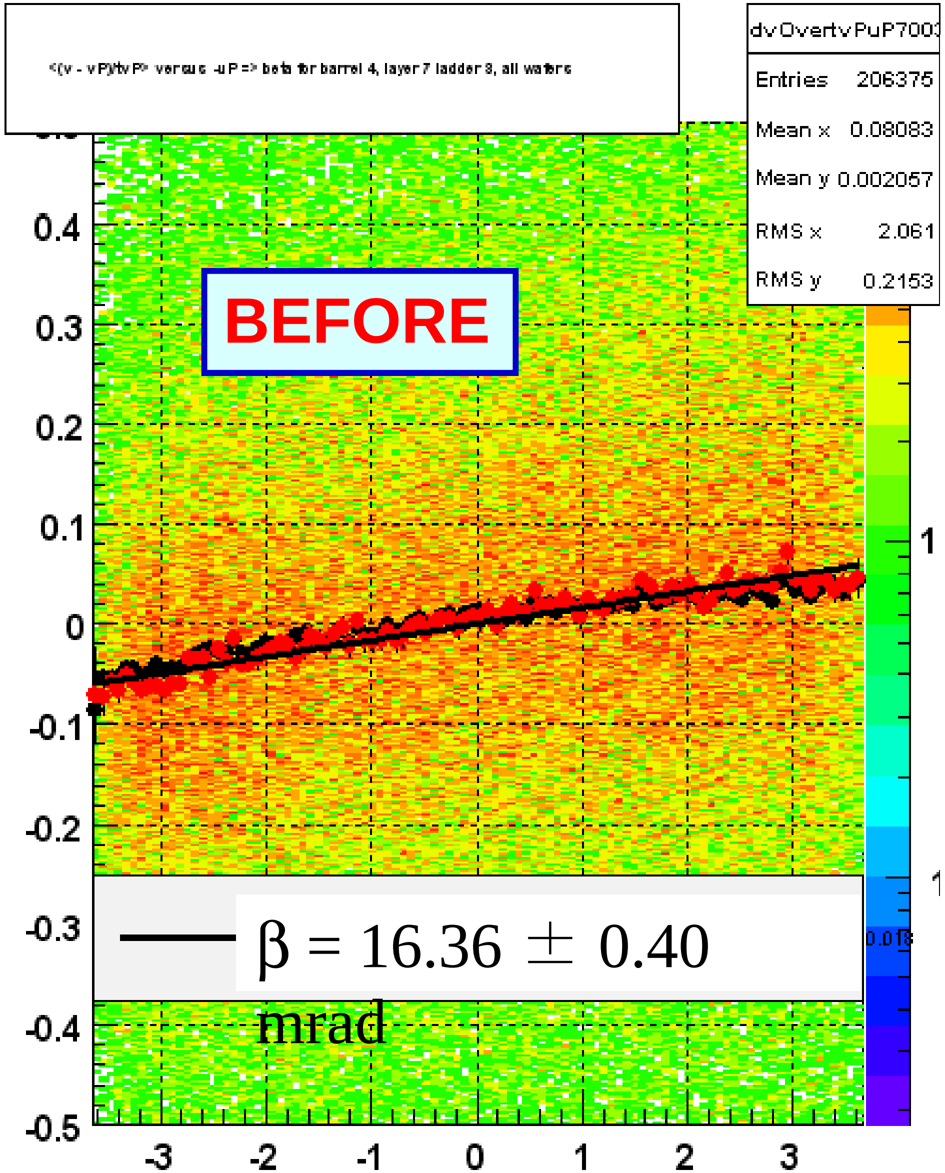
μ = 0.5 µm
σ = 22 µm

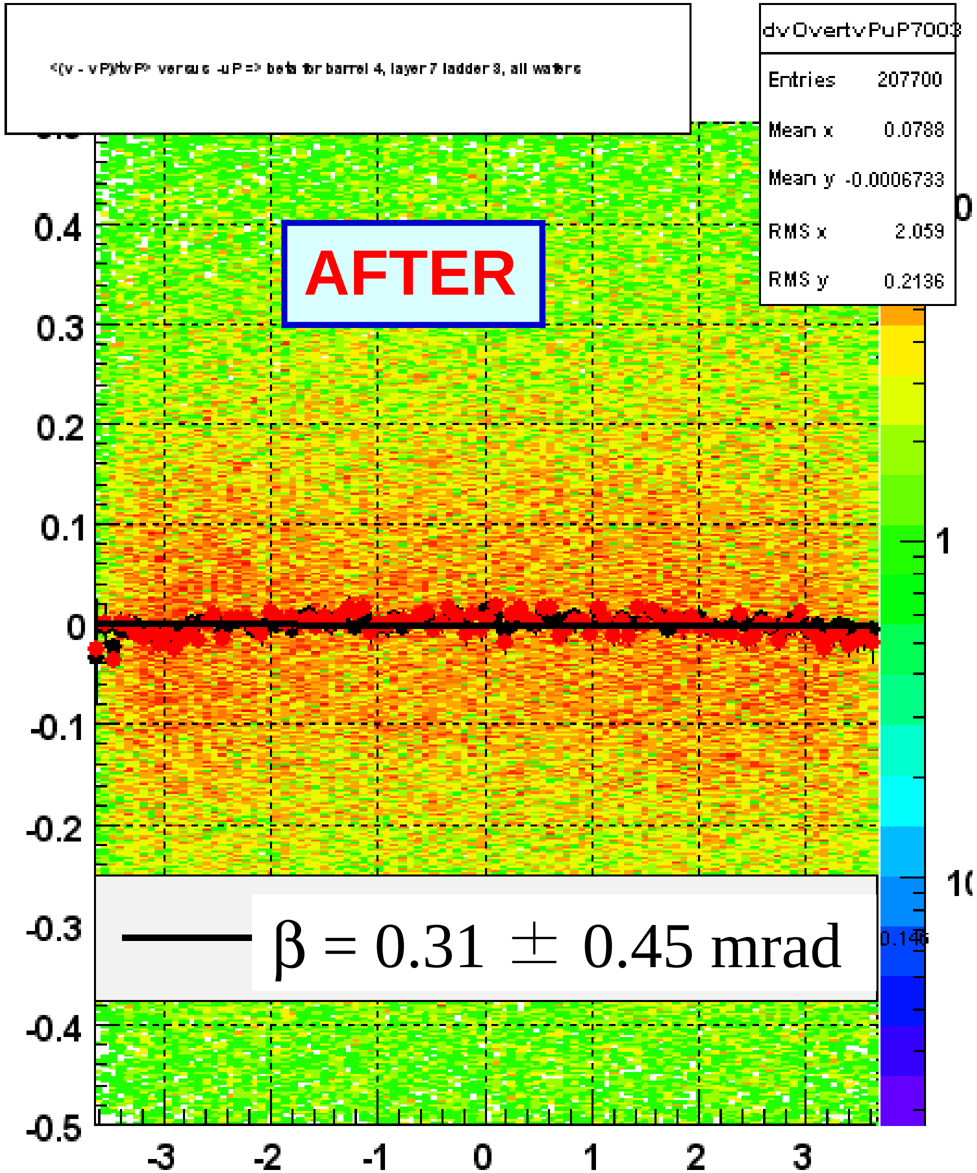




Example of correcting a SSD individual ladder rotation around the v-axis (local Y) (β).

EP track





Commissioning: LHC detectors

- The LHC detectors are actively commissioning their components:
  - Software
  - Hardware
  - Triggers
  - Computing systems
- Visualization and data quality monitoring must provide for remote viewing.
- Performance optimization of reconstruction algorithms is well underway.
  - Physics validation
  - Programs of optimization for speed/memory are underway.

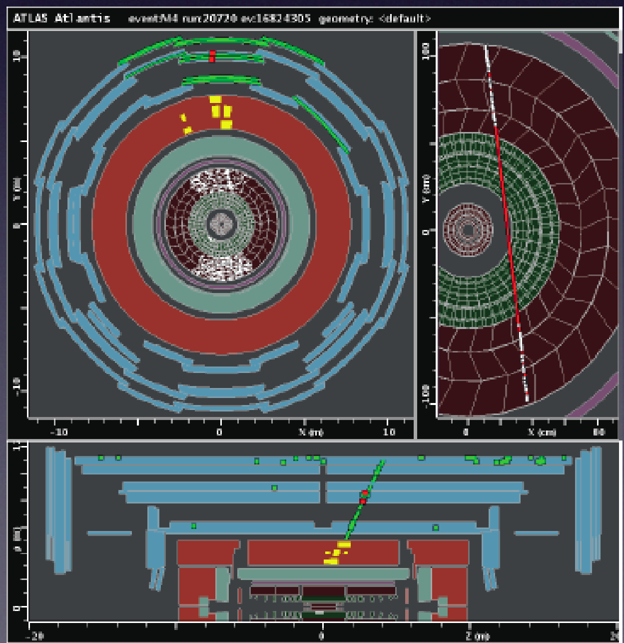
Commissioning with Data

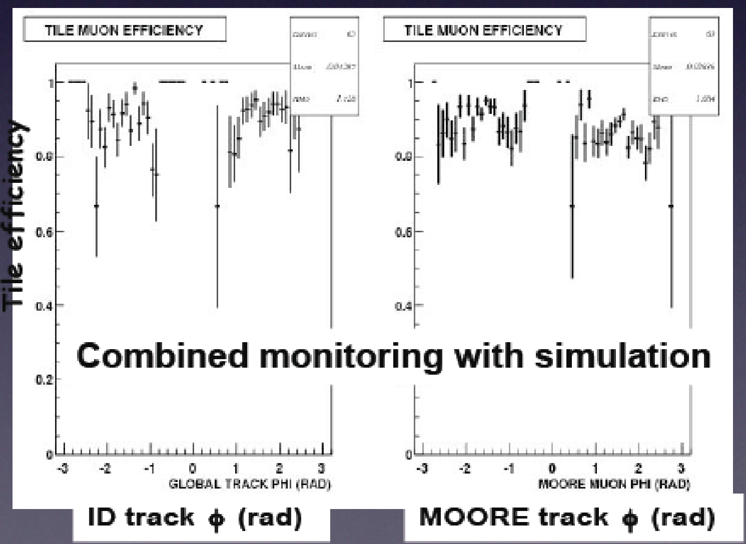
Offline Reconstruction

Cosmics reconstruction is performed by standard ATLAS reconstruction algorithms (with modified cuts), and/or by dedicated algorithms

Code needs to deal with tracks that don't point to the vertex, and that are not synchronized with the `beam' clock

- E.g. drift times need to be corrected for the trigger-clock phase





10

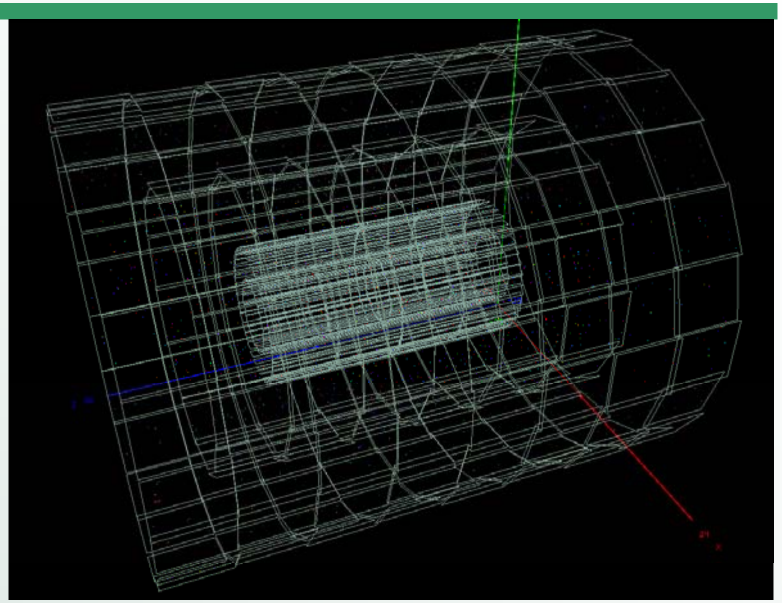
Intermediate-level raw-data inspection

Two common problems:

I. detectors hide each other

II. individual digit is too small

3D view nonsensical …



I. Planar layout w/ pager

View as many modules as possible

Arrange them in pages

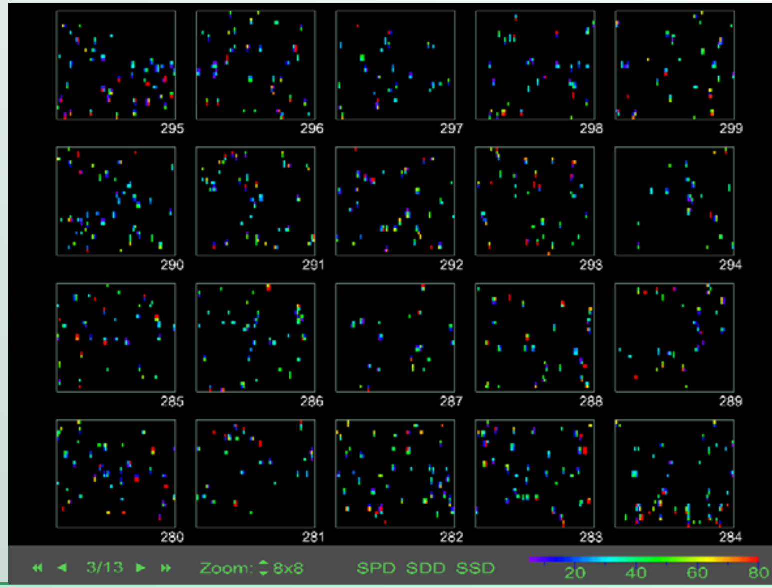
Provide selection (by type, phi, eta, …)

II. Digit scaling

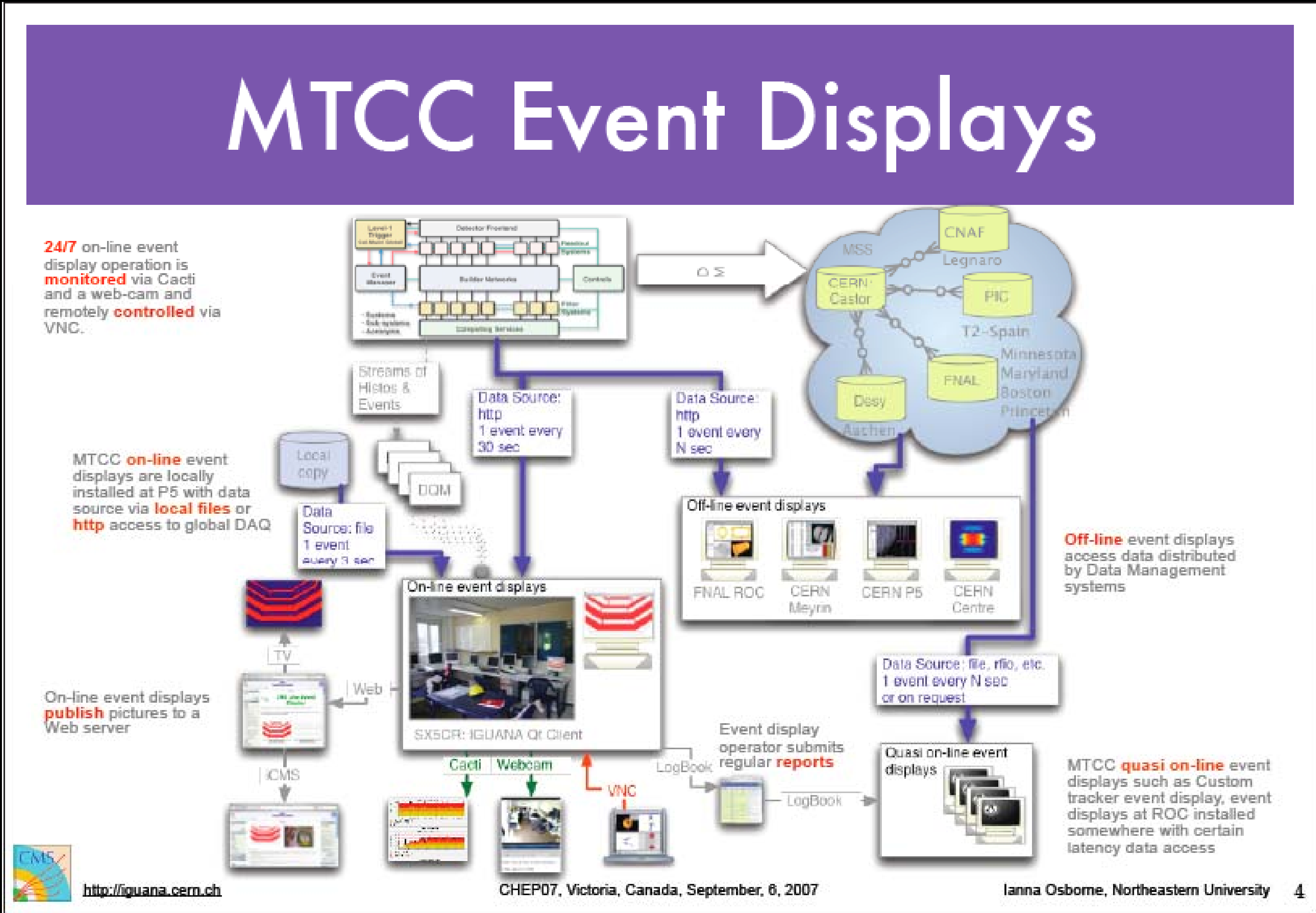
Accumulate nearby digits.

Show statistical quantities for group:

- average, RMS
- occupancy
- min / max values



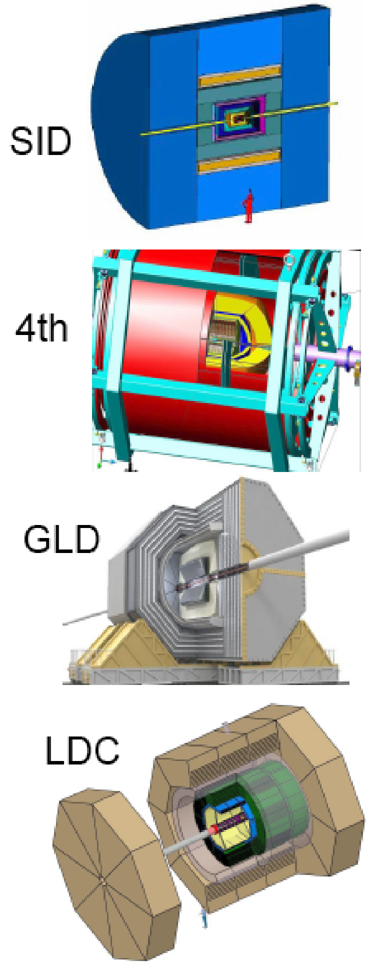
CMS Event Display and DQM



Towards the ILC

Introduction

- 4 international detector concept studies for the ILC ongoing
  - DCRs written this year
  - 3 LOIs planned for 2008 (joined LDC/GLD)
  - 2 EDRs planned for 2010
- 4 independent sw frameworks exist
  - some interoperability provided through use of common event data model/ file format LCIO
- "Marlin et al" is the LDC concept's framework
  - design presented at CHEP2006
  - this talk: Evolution of the framework



Towards the ILC

example: PandoraPFA (M.Thomson,Cambridge)

rms90

E_{JET}	$\sigma_E/E = \alpha/\sqrt{(E/GeV)}$ |cosθ|<0.7	σ_E/E
45 GeV	0.295	4.4 %
100 GeV	0.305	3.0 %
180 GeV	0.418	3.1 %
250 GeV	0.534	3.3 %

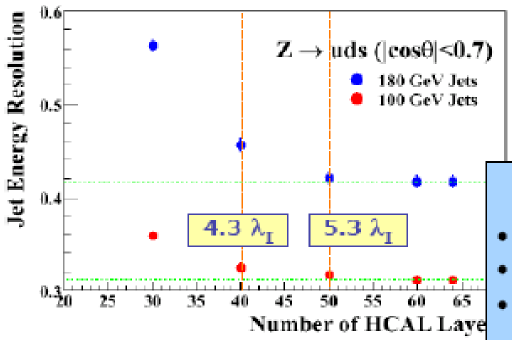
0.35 at LCWS06

For jet energies < 100 GeV ILC "goal" reached !!!

★For a Gauge boson mass resolution of order $\Gamma_{W/Z}$

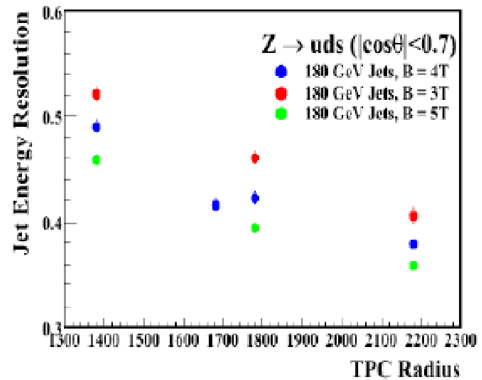
E_{jj}/GeV	$\alpha(E_j)$	σ_{Ej}/E_j
91	< 26 %	3.8 %
200	< 38 %	3.8 %
360	< 51 %	3.8 %
500	< 60 %	3.8 %

'proof of concept' for PFA @ILC
-> use for detector optimization



PFA improves with:
- thicker Hcal
- larger Tracking radius
- higher Bfield

- can use PFA for cost conscious optimization



Frank Gaede, CHEP 2007, Victoria, Canada Sep 2-9, 2007

17

Summary and Outlook

- Preparations for the LHC experiments dominated the EP sessions.
  - Reco, simulation, tracking, analysis tools, QA
  - Optimization and validation programs underway
  - Fast simulation tools are under development.
- Sharing of tools and components between experiments has been demonstrated - particularly in the smaller experiments.
- Visualization tools and DQM packages are (nearly) ready for data.
- Already looking ahead to the ILC…