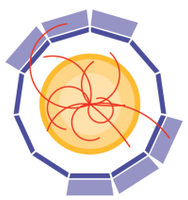
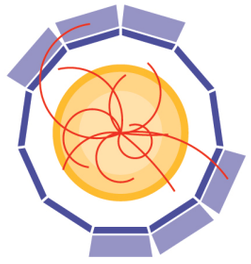
Calorimetry in AIDA: Adequateness of Geant 4 shower models

Felix Sefkow



AIDA Final Meeting
Dec 9-11, 2014

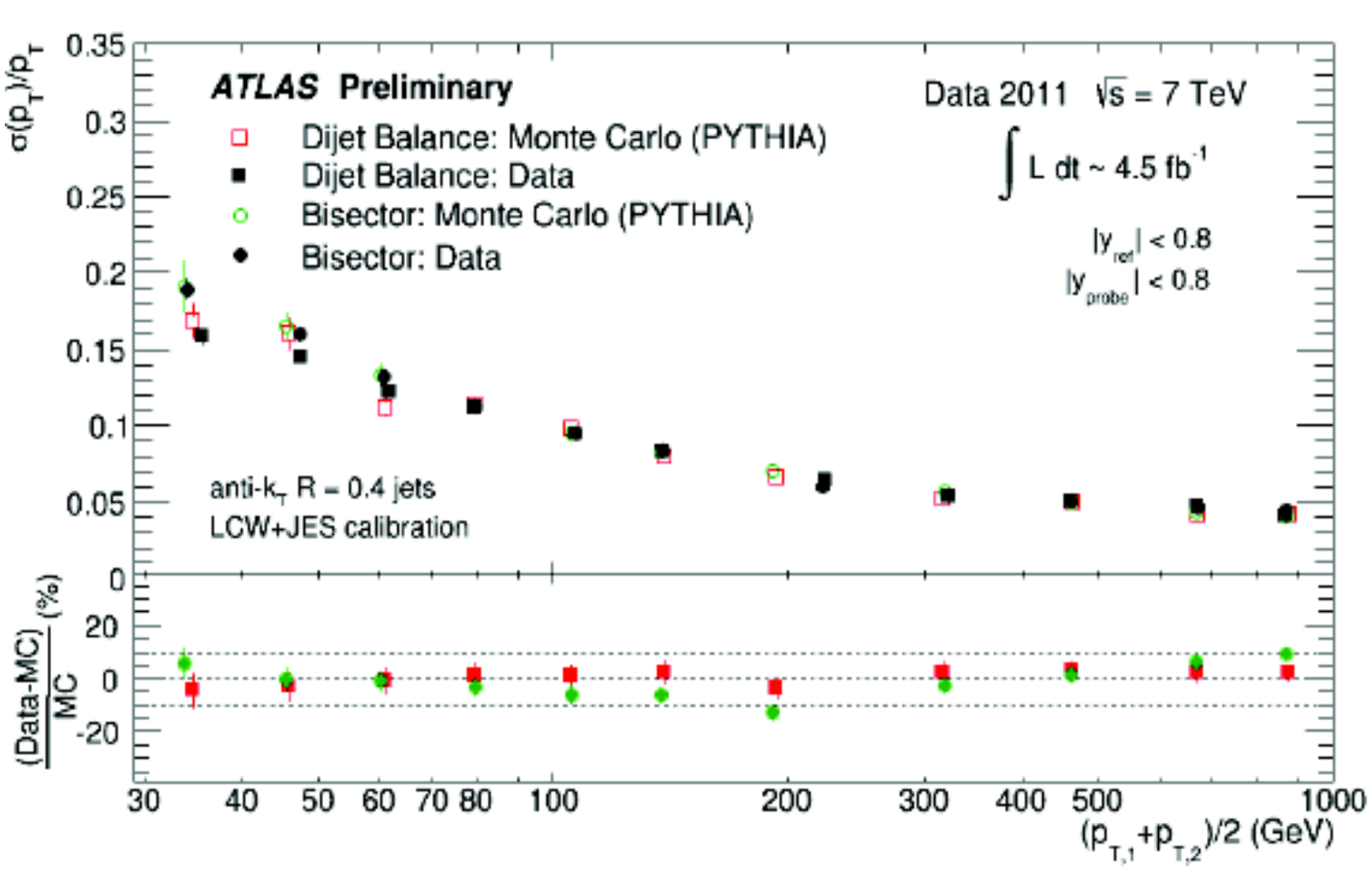


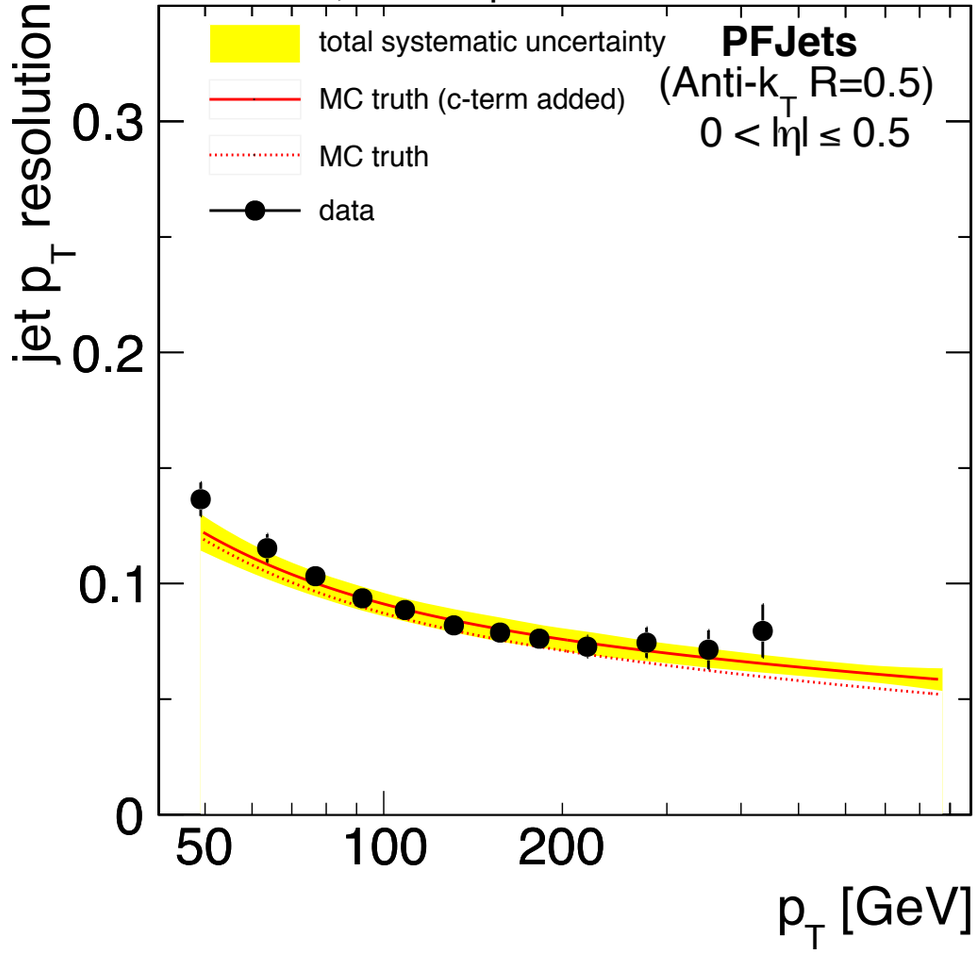
Outline:

- Motivation
- AIDA contributions
- Summary of results

Geant4 for precision physics with jets

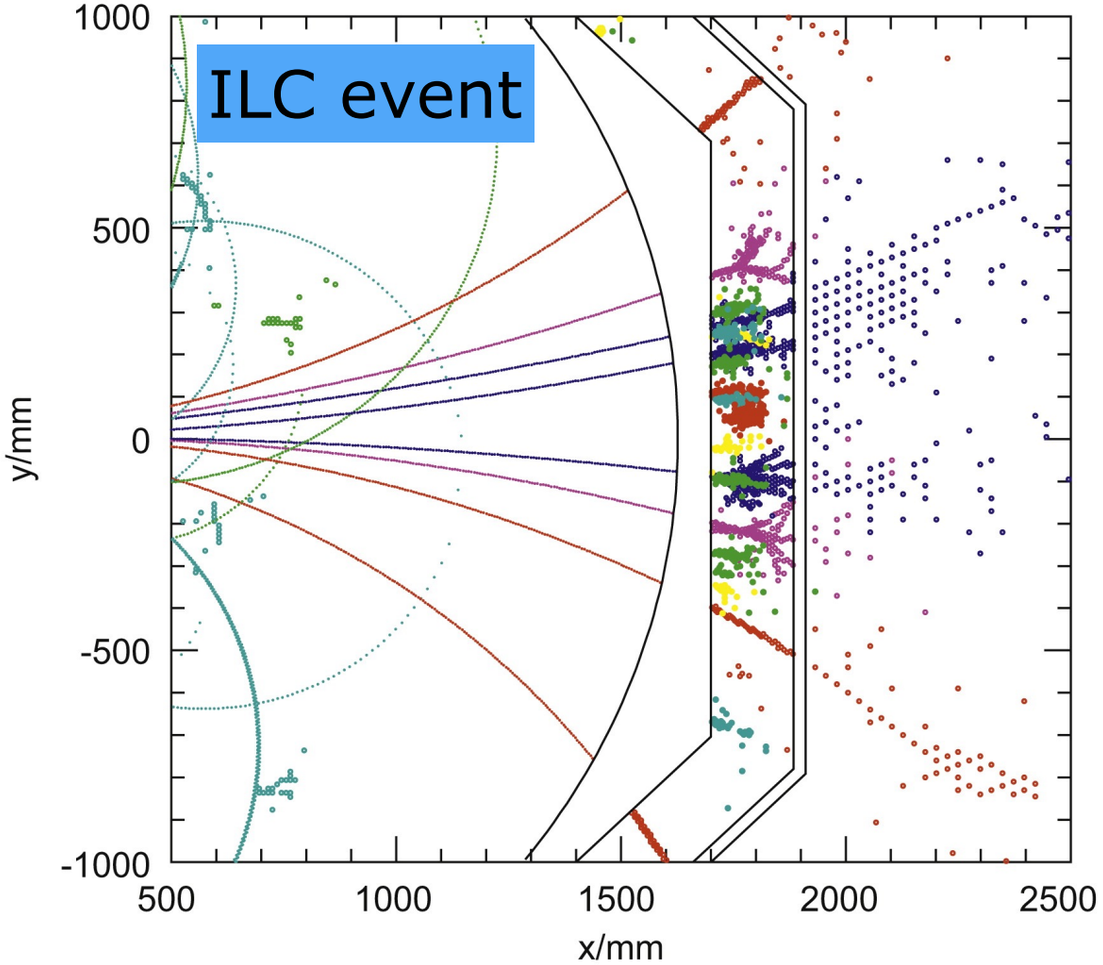
- Experiments at LHC and LC pose increasing demands on precision in modelling jet final states
- Validation feedback from LHC calorimeter test beam experiments triggered considerable improvement over the past decade





Higher granularity

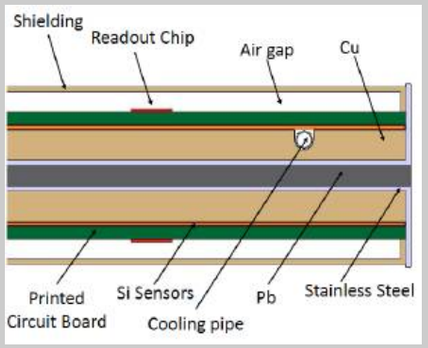
- Trend towards highly granular readout amplifies the challenge
- Initially motivated by particle flow approach for reconstruction at linear colliders - now inspiring LHC upgrades, too
- CALICE data with highly granular prototypes have taken over as working horse for validation

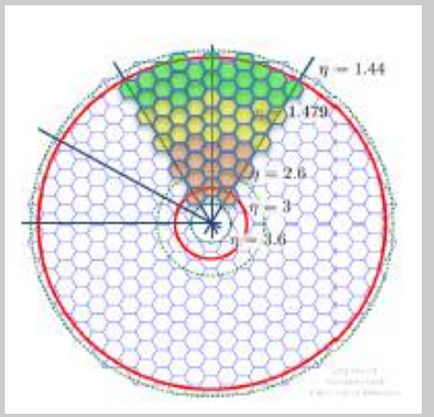


CMS endcap ECAL/HCAL option

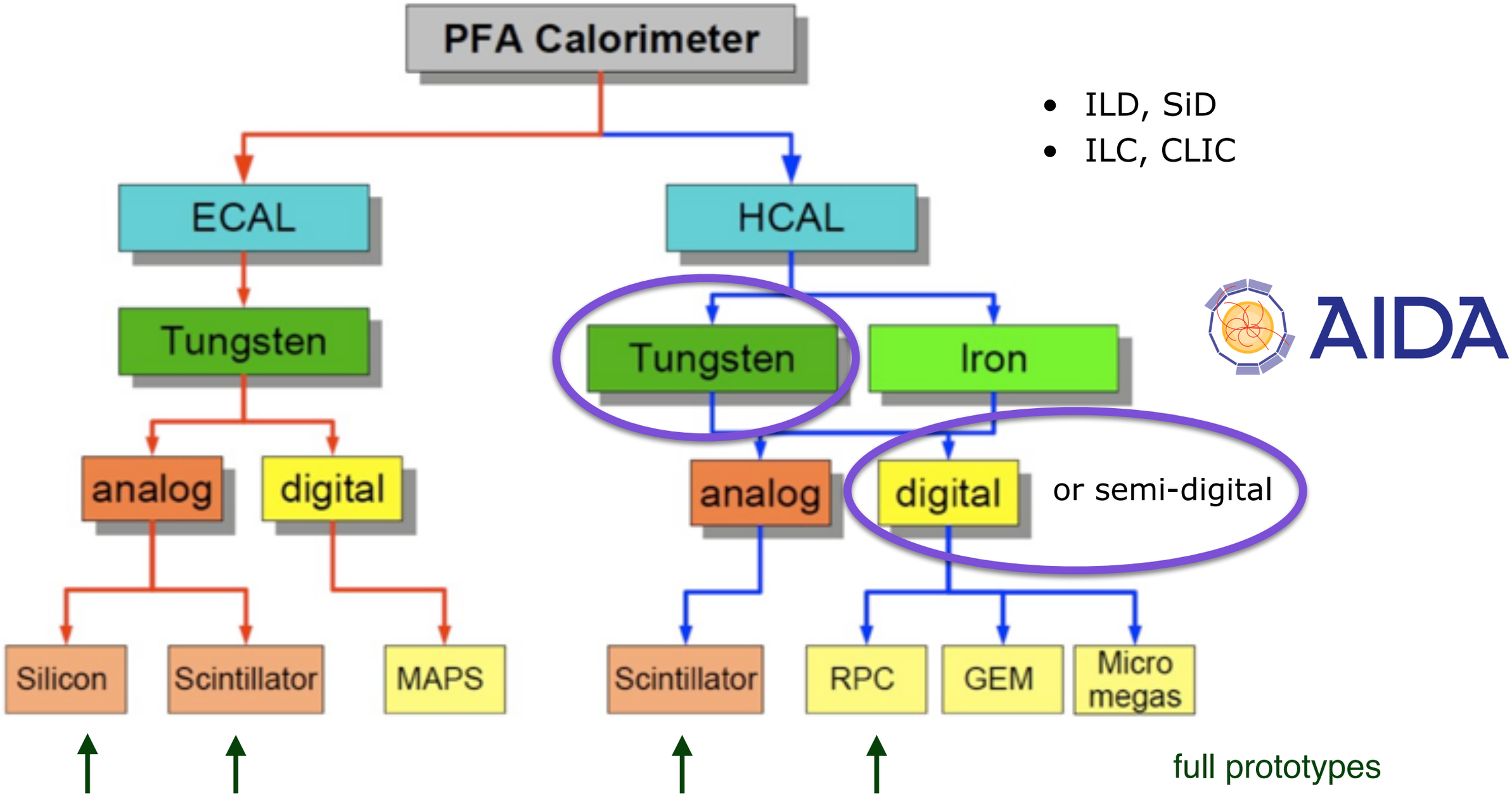
Silicon + Scintillator backing calorimeter

- EM: Silicon-lead/copper
- Hadr: Silicon-brass
- Scintillator-brass backing calorimeter
- 700 m² silicon pads 0.5-1 cm²





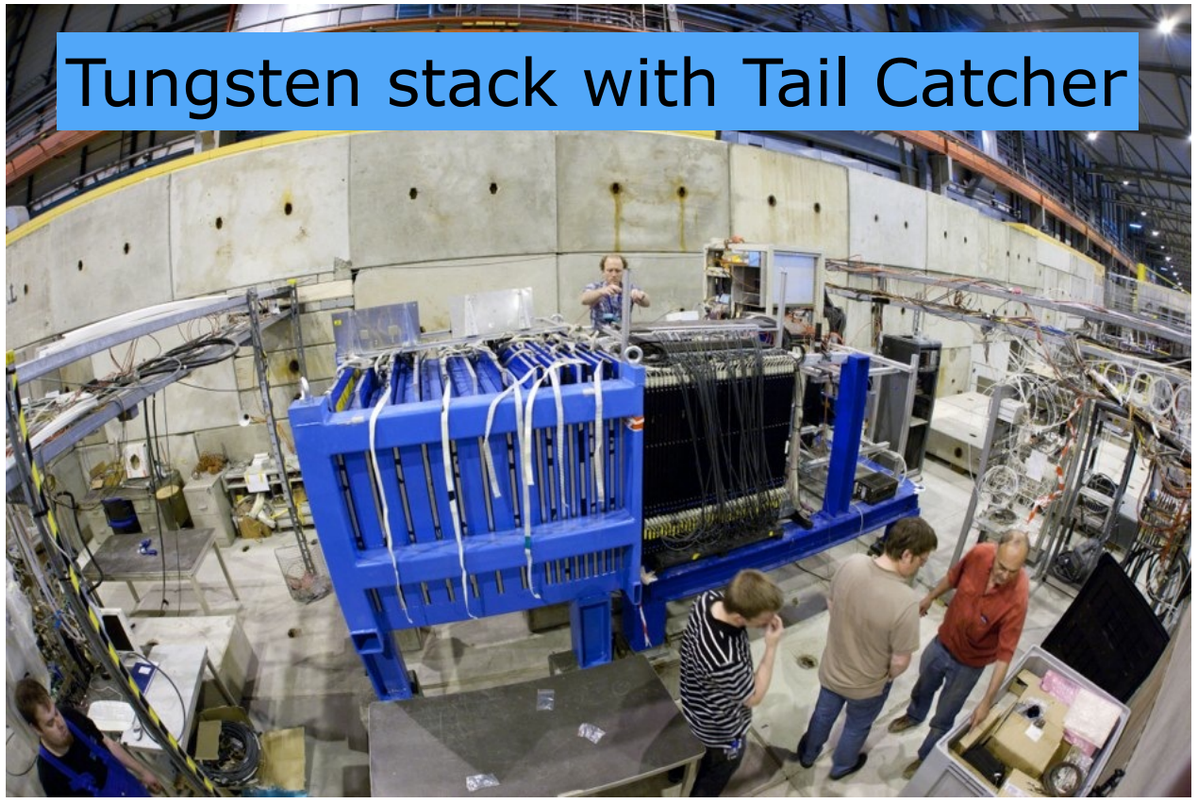
CALICE technologies and test beam

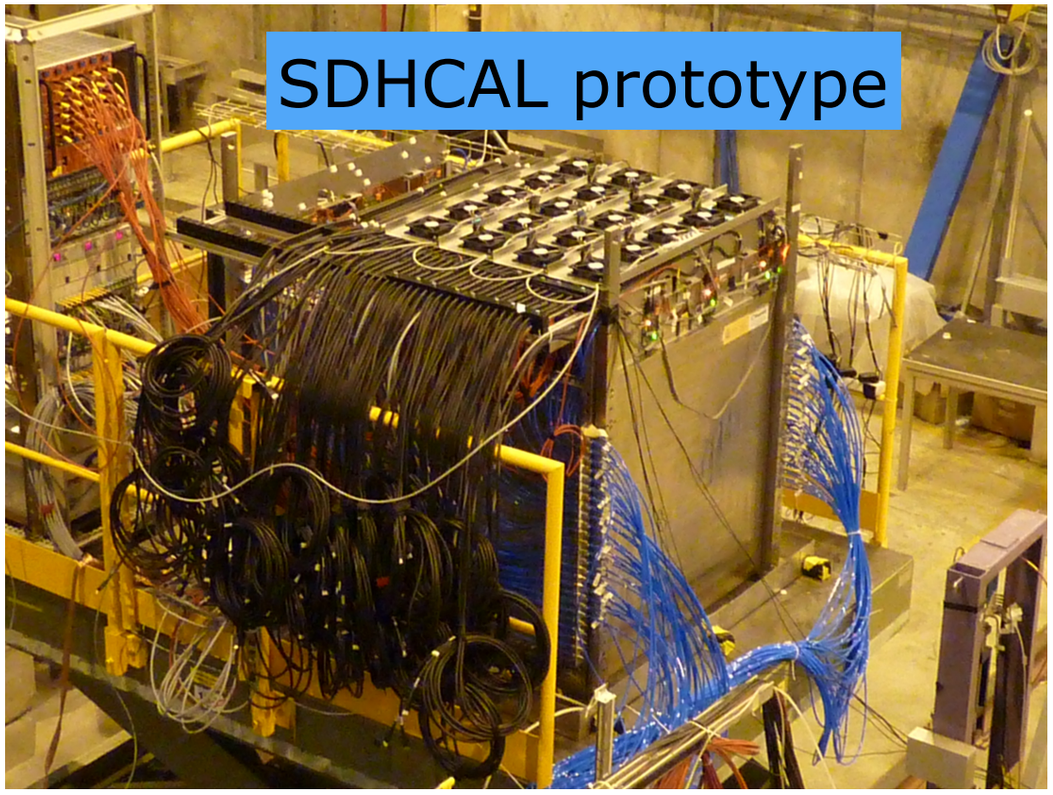


- ILD, SiD
- ILC, CLIC

AIDA contributions - indirect

- The direct support of Geant 4 development in EUDET was not continued in AIDA
- However, test beam data analysis in CALICE benefits from AIDA-supported **software and analysis** framework
- **Transnational Access** supported participation at CERN campaigns (and preparation runs at DESY)

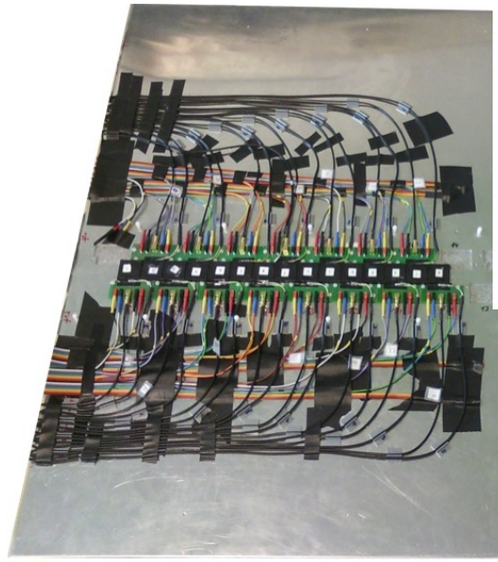


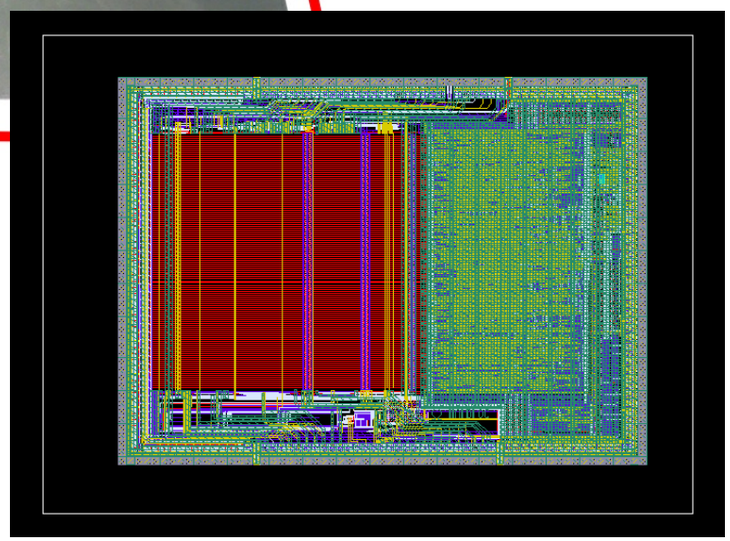


AIDA direct contributions

- **Mechanical infrastructure** for tests of **tungsten** absorber structure with analogue scintillator and digital RPC readout
- Support of a dedicated **tungsten timing** set-up **T3B**
- HARDROC **ASIC** from OMEGA for the RPC-based **SDHCAL** (EUDET)
- **SDHCAL** Peripherals: **gas system, DAQ**

- For details see Roman's talk





Results: pre-AIDA data

- AIDA 2011-2014 was harvesting season in CALICE
  - List here only results that contain comparisons with Geant 4 hadron shower simulations

Journal papers:

- **Hadronic energy resolution of a highly granular scintillator-steel calorimeter using software compensation techniques** ; 2012_JINST_7_P09017; e-Print: arXiv:1207.4210
- **Track segments in hadronic showers in a highly granular scintillator-steel hadron calorimeter** ; 2013_JINST_8_P09001; e-Print: arXiv:1305.7027
- **Validation of GEANT4 Monte Carlo Models with a Highly Granular Scintillator-Steel Hadron Calorimeter**; 2013_JINST_8_P07005; e-Print:arXiv:1306.3037
- **Shower development of particles with momenta from 1 to 10 GeV in the CALICE Scintillator-Tungsten HCAL**; 2014_JINST_9_P01004; e-Print:arXiv:1311.3505
- **Testing Hadronic Interaction Models using a Highly Granular Silicon-Tungsten Calorimeter** e-Print: arXiv:1411:7215, submitted to NIM
- **Pion and proton showers in the CALICE scintillator-steel analogue hadron calorimeter;** e-Print: arXiv: 1412.2653 submitted to JINST

CALICE Analysis notes (conference papers):

- **CAN-048.pdf** : Parametrisation of hadron shower profiles in the CALICE Sc-Fe AHCAL
- **CAN-049.pdf** : Analogue, Digital and Semi-Digital Energy Reconstruction in the CALICE AHCAL
- **CAN-051.pdf** : Extraction of h/e and calorimeter response from fits to the longitudinal shower profiles in the CALICE Sc-Fe AHCAL

Results: data from the AIDA years

- AIDA 2011-2014 was seeding season in CALICE
  - continued tungsten data with scintillator (and added RPC read-out)*
  - added SDHCAL data with RPCs ($1m^3$) (and micromegas (4 planes))*
  - added T3B (and FastRPC)*

Journal paper:

- **The Time Structure of Hadronic Showers in Highly Granular Calorimeters with Tungsten and Steel Absorbers, C**. Adloff et al. ; JINST 9 (2014) P07022;; e-Print: arXiv:1404.6454

CALICE Analysis notes (conference papers):

- **CAN-044.pdf** : Shower development of particles with momenta from 10 to 100 GeV in the CALICE scintillator-tungsten HCAL
- **CAN-047.pdf** : Tracking within Hadronic Showers in the SDHCAL prototype using Hough Transform Technique

* results published, but papers/notes not included, since no gaseous detector simulation yet

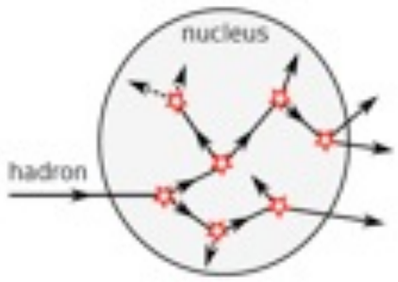
Instead of flashing one plot per paper

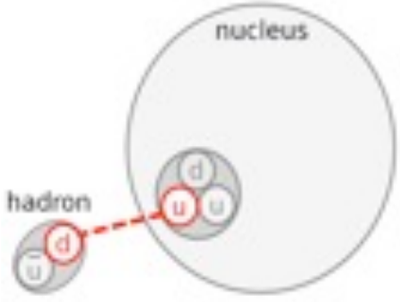
- Some highlights:

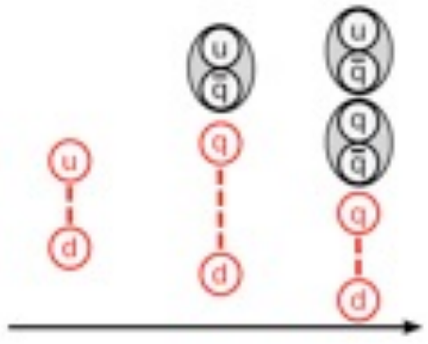
- Recent progress in shower shapes
- New observables

Shower simulation in Geant 4

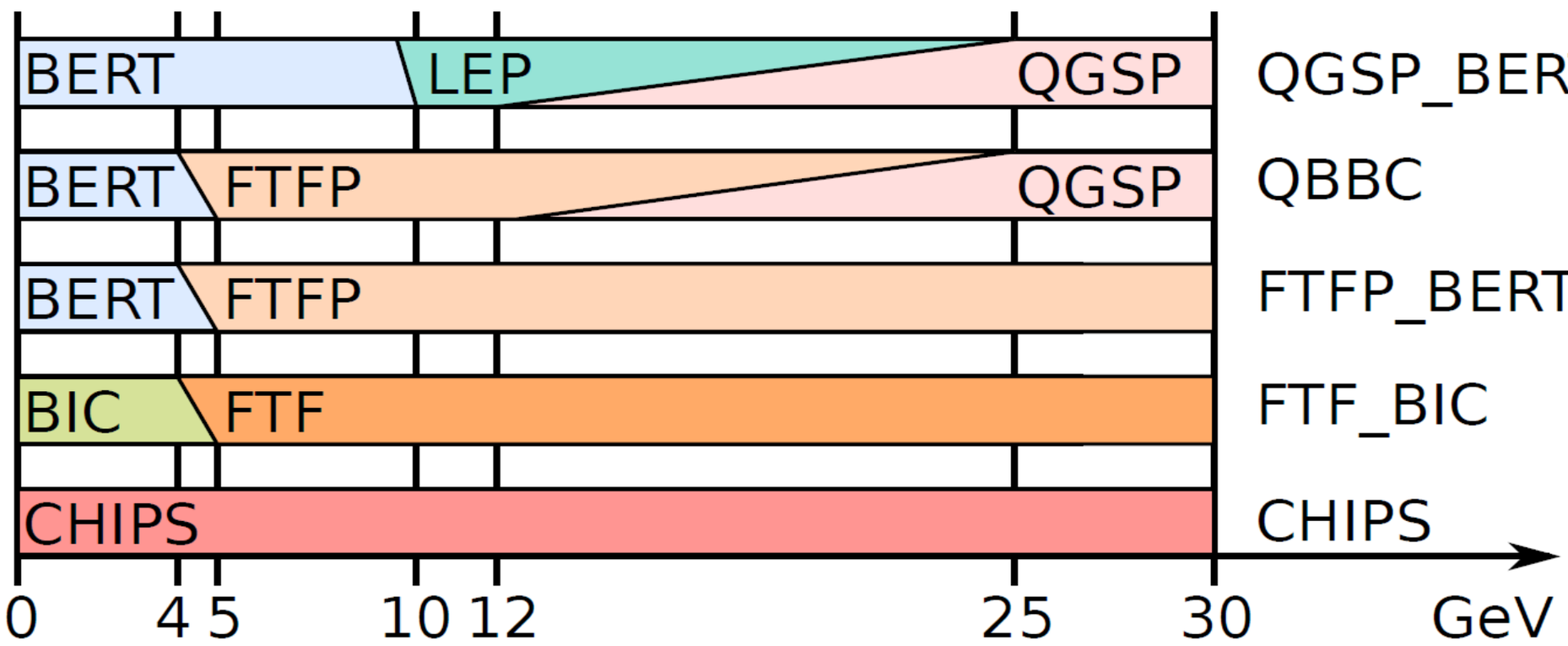
- Low energy: cascade models
- High energy: partonic models





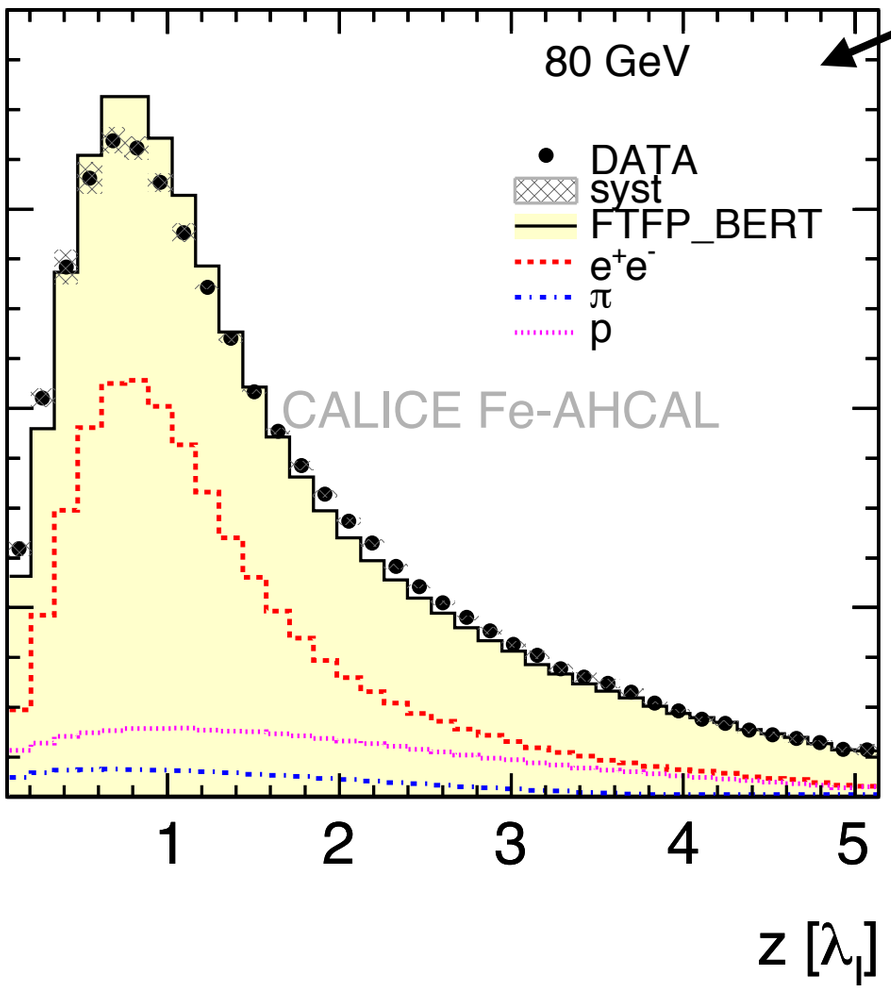


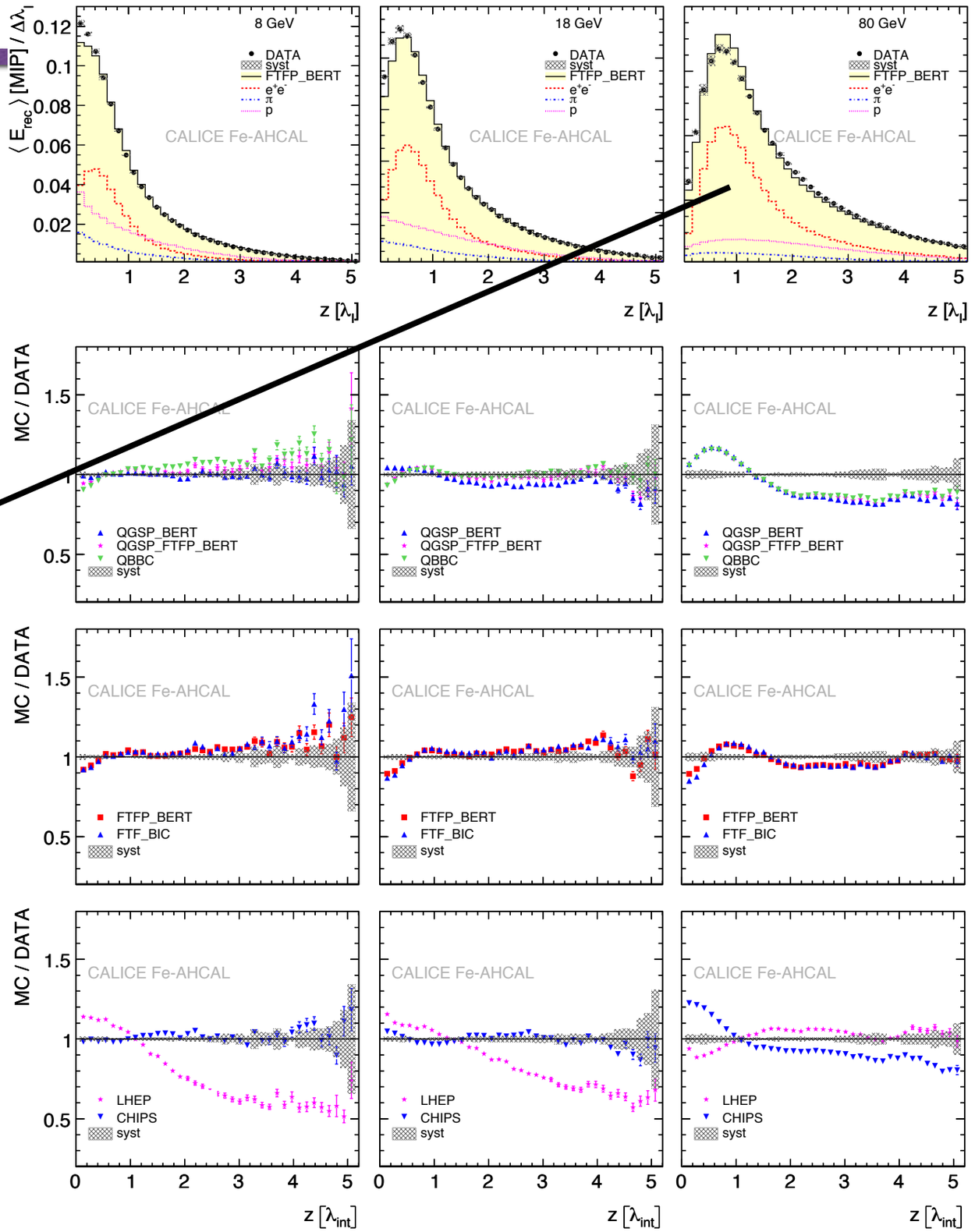
minimize use of phenomenological parameterization



Longitudinal profiles

- Measured from the shower start reconstructed event by event
- Core overestimated at higher energies

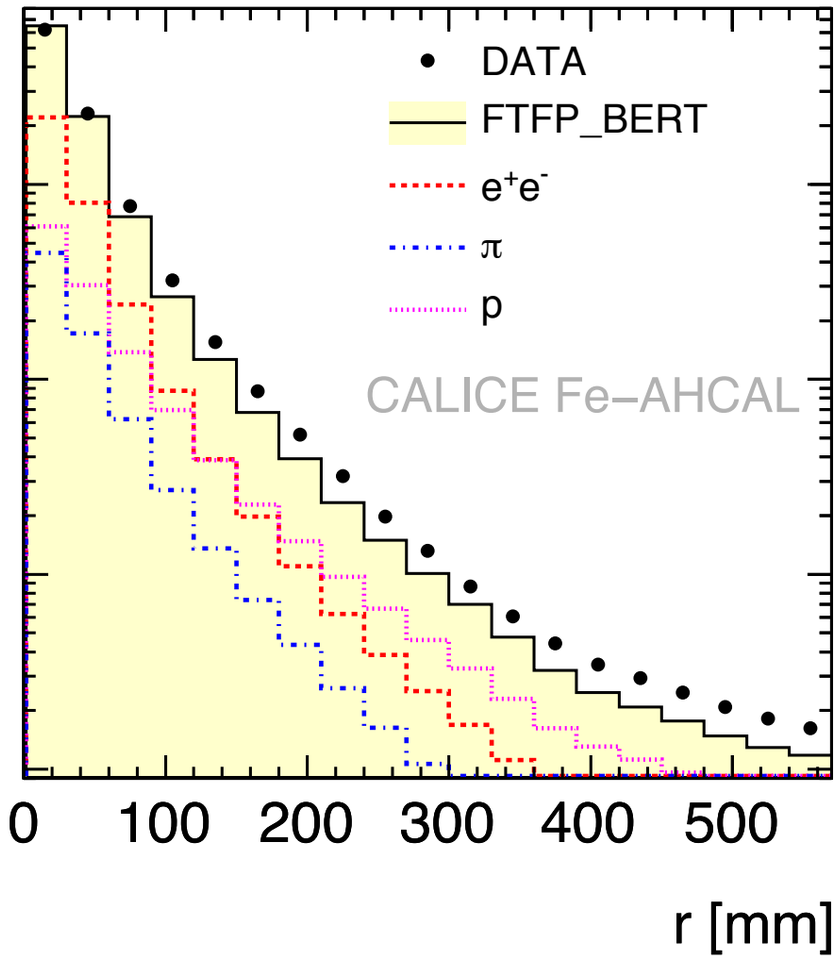




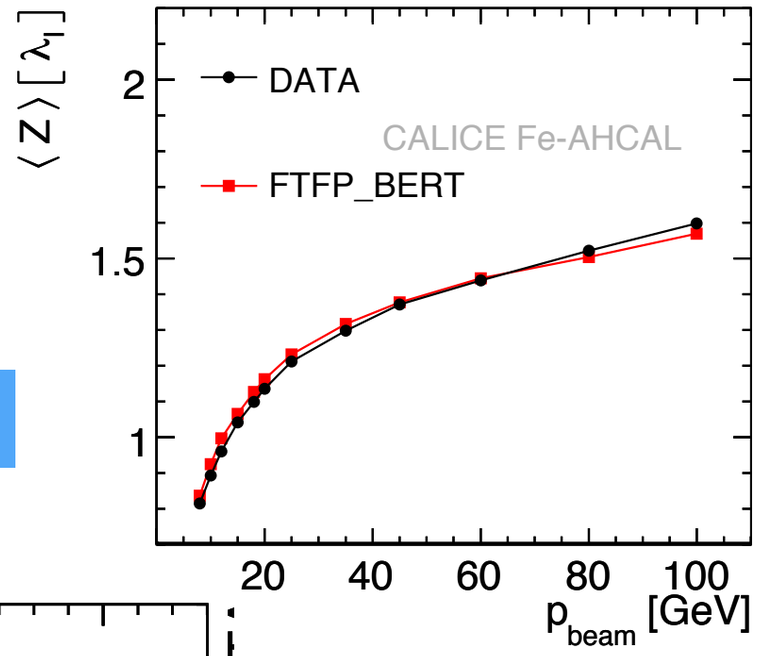
2013 JINST 8 P07005

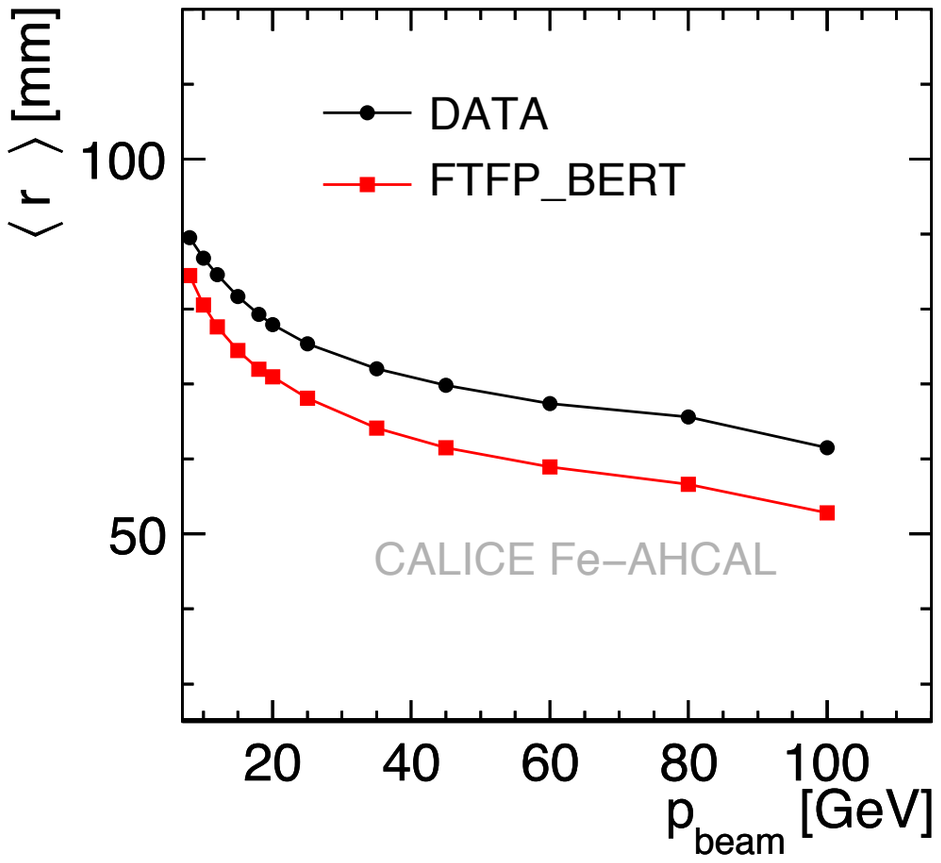
Radial profiles, means

- Mean longitudinal depth OK
- Mean radial extension not



Geant 4 v 9.4 p02

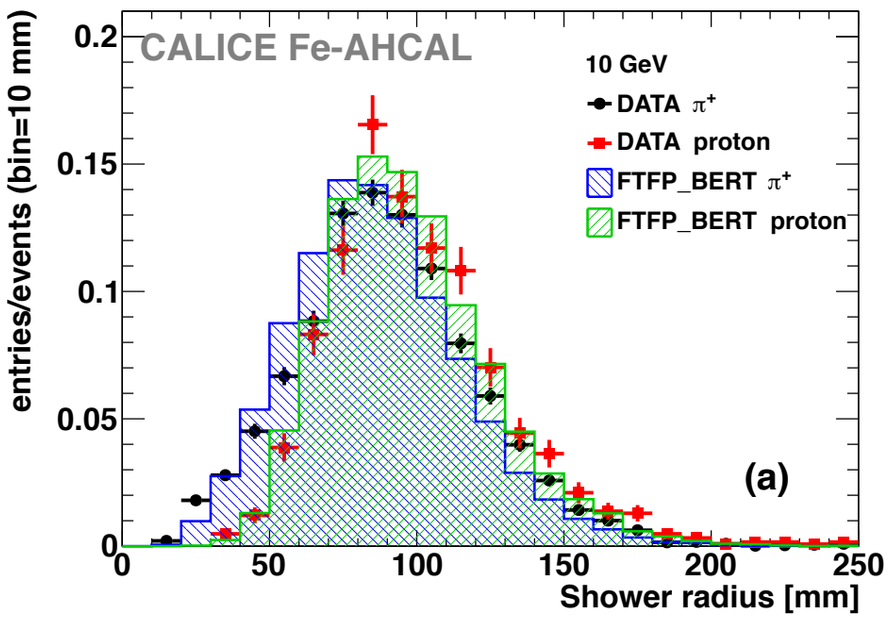


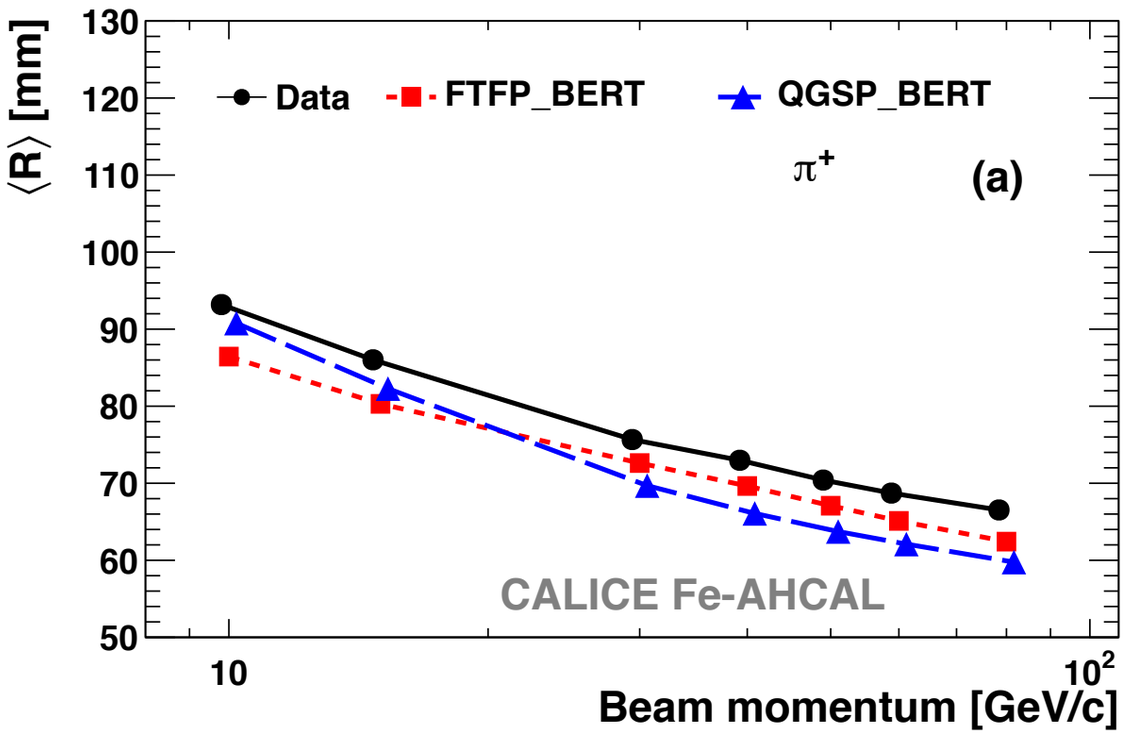


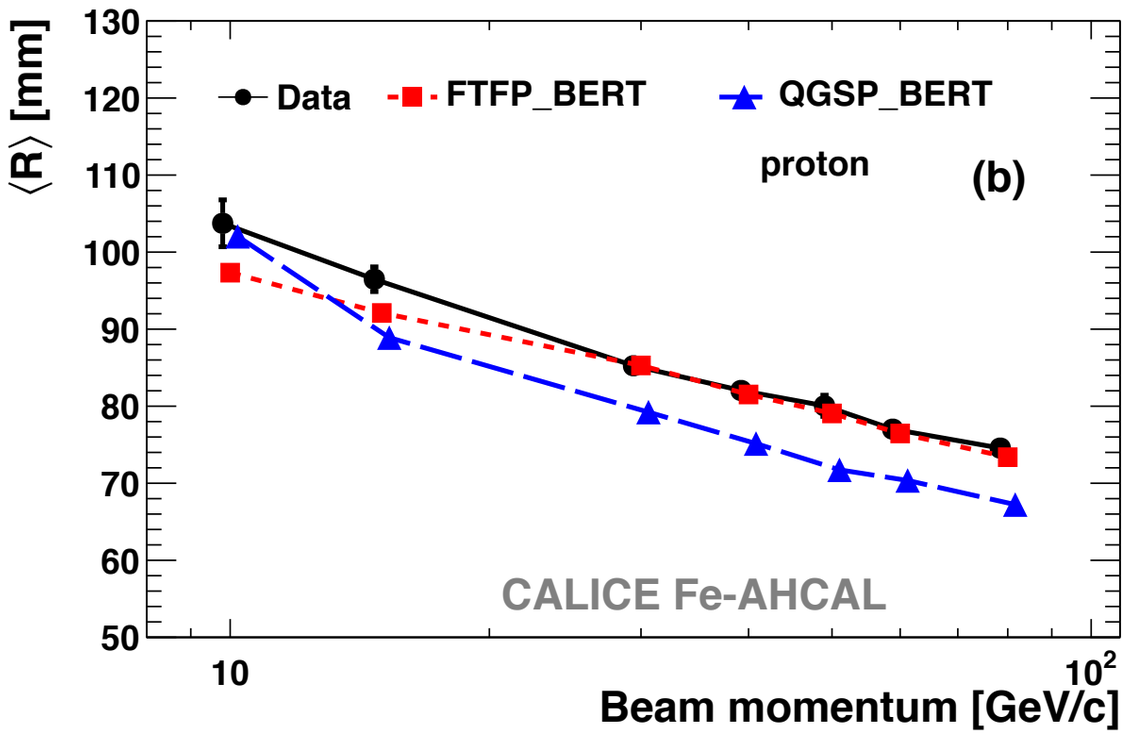
More recent version: Geant 4 v9.6

- CALICE paper submitted this week
- Agreement up to 5% or better
- over large energy range

- Event-to-event fluctuations also well described

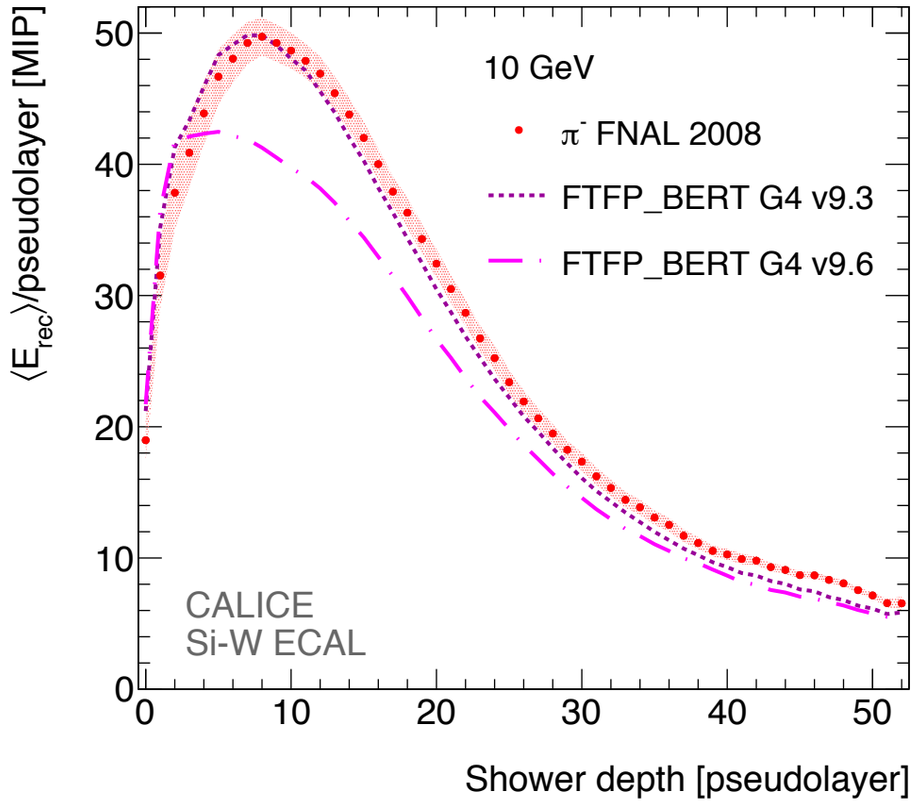




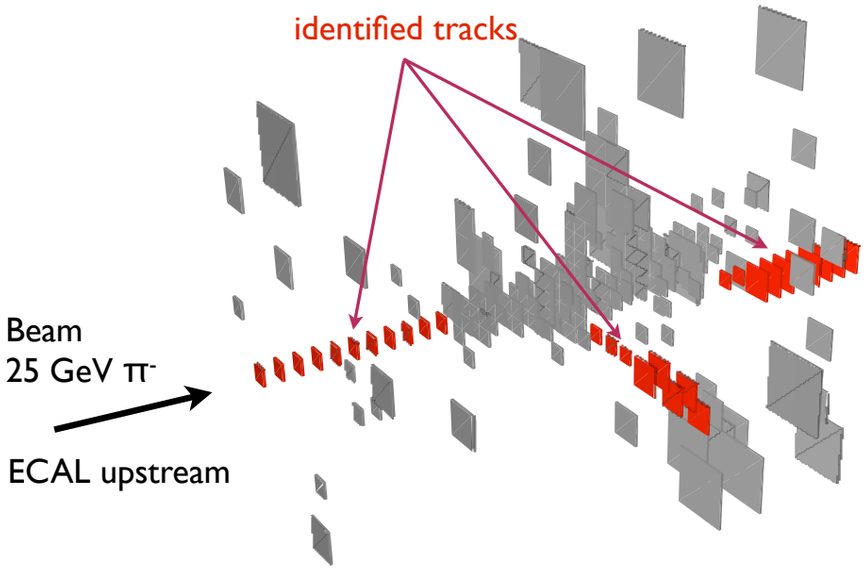


But…

- … sometimes things also go in the wrong direction
- Validation with highly granular **SiW ECAL**
- Discrepancy not visible in QGSP
- Bug in Fritiof identified, will be fixed in G4 v 10

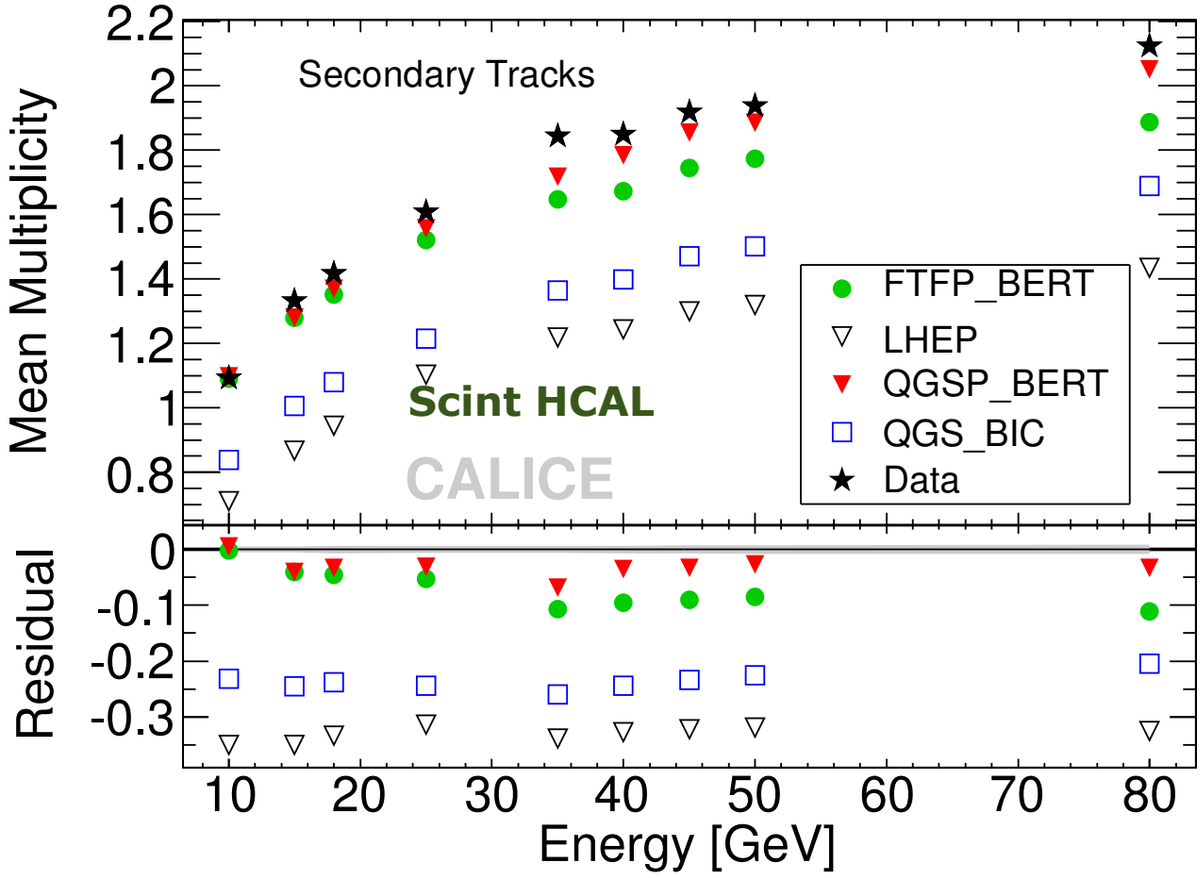


Shower fine structure: track segments



- Could have had the same global parameters with “clouds” or “trees”
- Powerful tool to check models
- Surprisingly good agreement already - for more recent models

- Gas HCAL: sparse region of shower already well described by detector simulation tuned to hadron data



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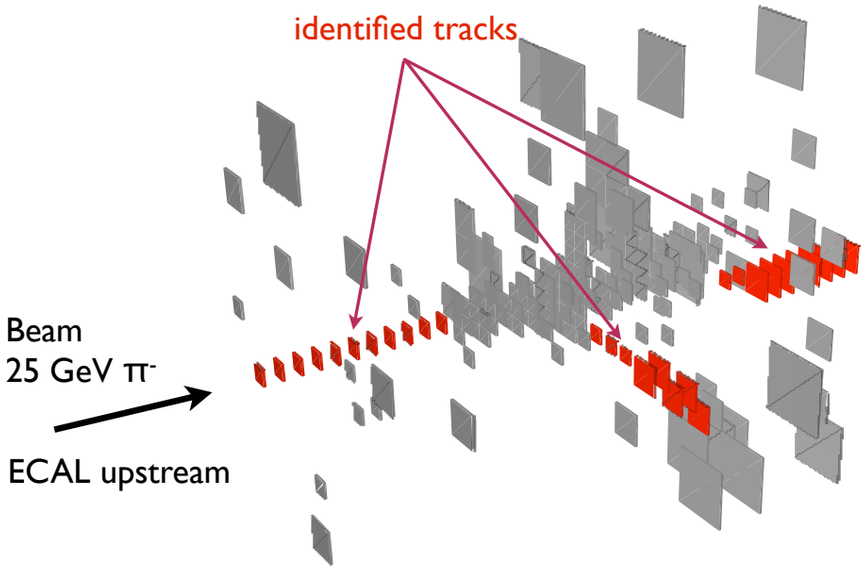

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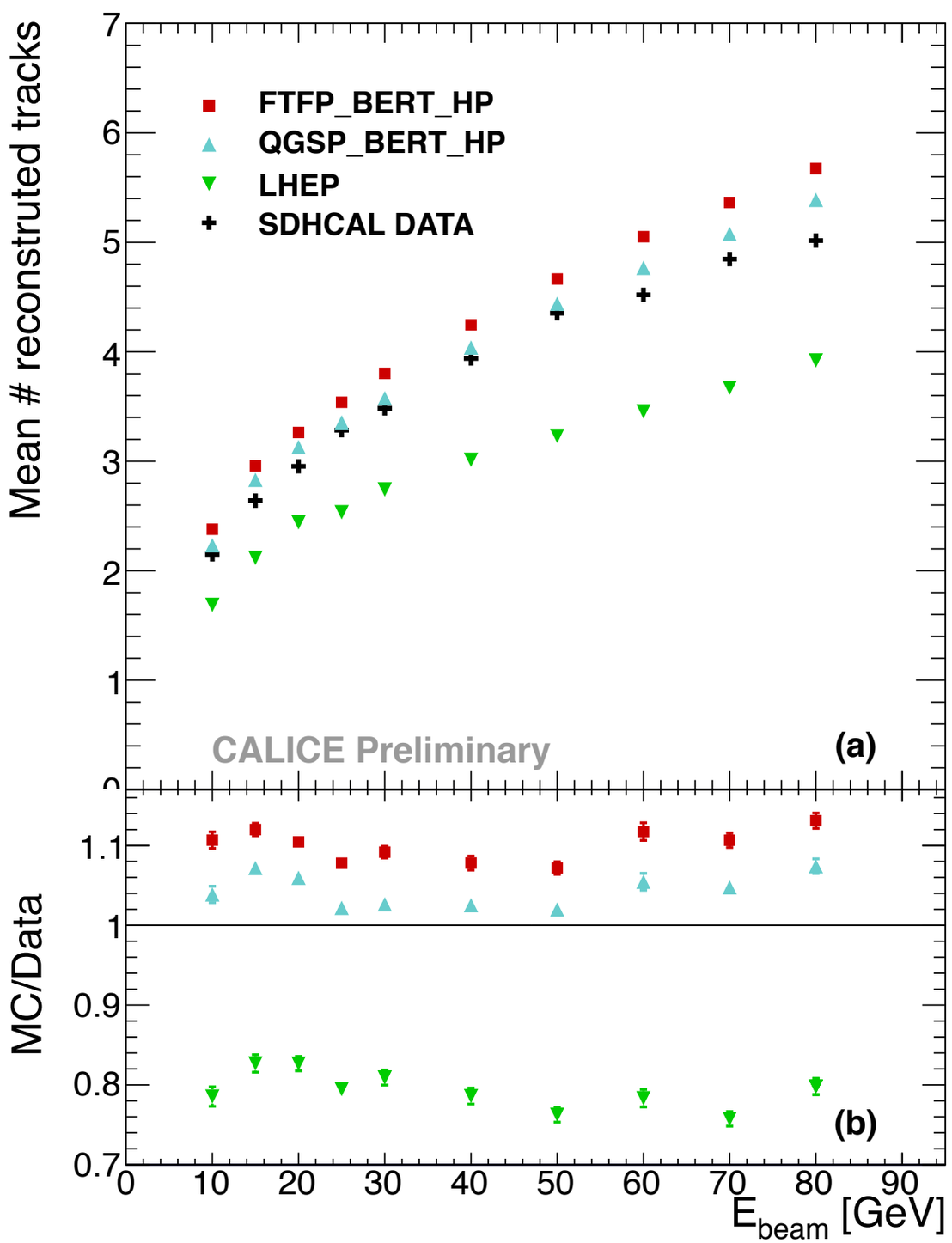
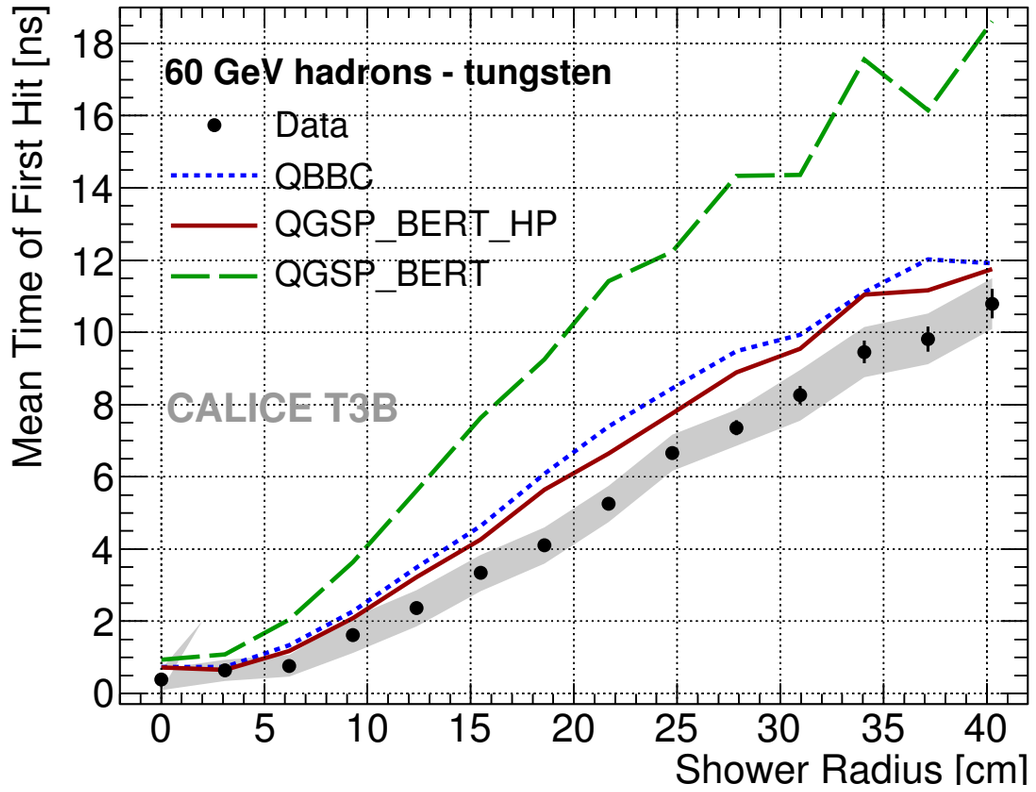
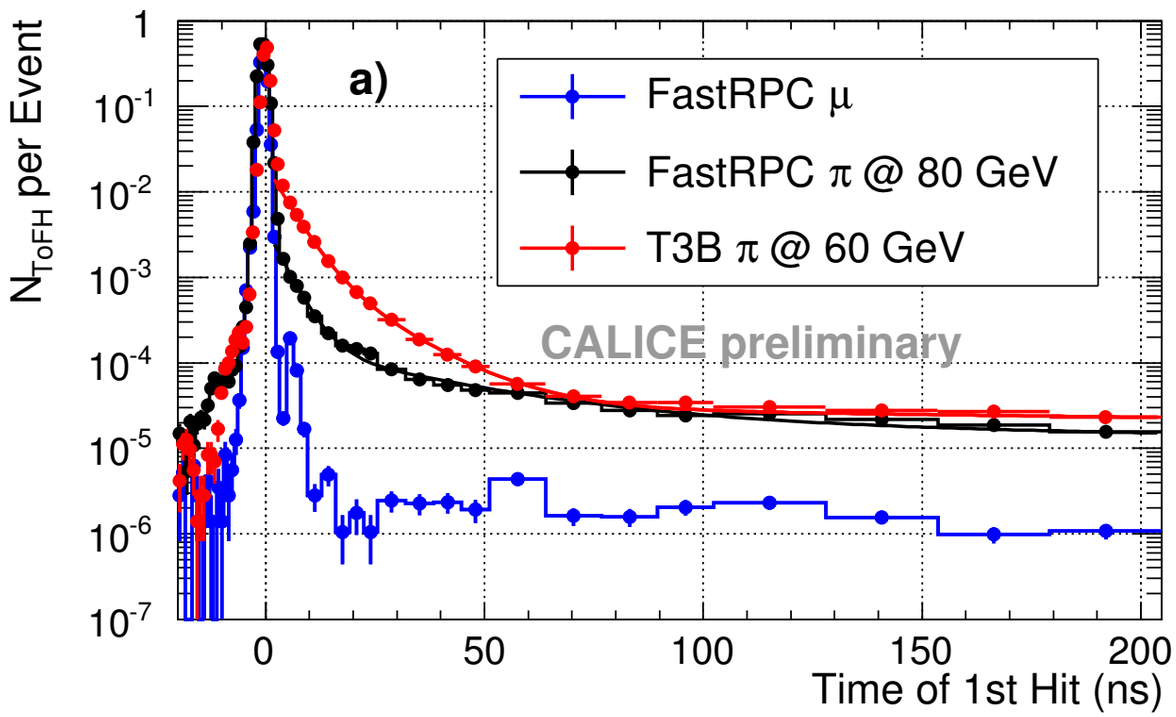
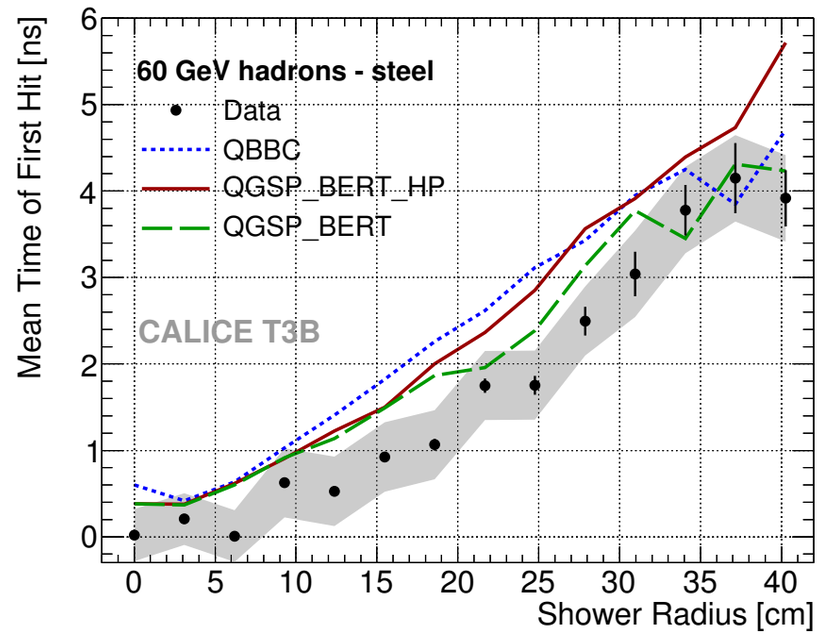


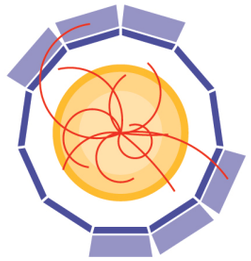
Shower timing

- For neutron-rich materials like tungsten, need to include detailed simulation of neutron absorption
- Not an issue for steel
- Depends on active material, too
- More timing studies to come with 2nd generation prototypes









Summary

- Significant progress in modelling accuracy: calorimetry matures from voodoo to physics
- High granularity amplifies the challenge - at LHC and LC

- Validation remains important; offers new observables - in 4D
- AIDA made important contributions: hardware, software, TA

- Crossing fingers for AIDA-2020 - to continue an exciting story
- Lots of gaseous HCAL analyses still to come

- Deliverable report on the way

Grant Agreement No: 262025

AIDA

Advanced European Infrastructures for Detectors at Accelerators

Seventh Framework Programme, Capacities Specific Programme, Research Infrastructures, Combination of Collaborative Project and Coordination and Support Action

DELIVERABLE REPORT

ADEQUATENESS OF GEANT 4 SHOWER SIMULATION MODELS

DELIVERABLE: D9.8

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Due date of deliverable:	End of Month 46 (November 2014)
Report release date:	24/12/14
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Lead beneficiary:	DESY
Document status:	Draft [Final when fully approved]

Abstract:

AIDA has contributed to the validation and further development of Geant 4 shower simulation models through the provision of mechanical and electronics as well as software infrastructure to support carrying large test beam campaigns and analysing the recorded data. The report gives a brief account of the measures, highlights some results and guides to more detailed documentation.

TABLE OF CONTENTS

Delivery Slip

	Name	Partner	Date
Authored by	I. Laktineh, W. Klempt, K. Krüger, F. Sefkow, R.Pöschl, N. Seguin	IPNL CERN DESY LAL OMEGA	24/12/2014
Edited by	F. Sefkow	DESY	24/12/2014
Reviewed by	R. Pöschl [Task coordinator] V. Boudry [WP coordinator] L. Serin [Scientific coordinator]	LAL LLR LAL	10/01/2015
Approved by	Steering Committee		30/01/2015

Backup