

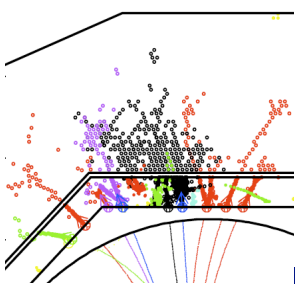
Overview and plans



Felix Sefkow



ILD meeting at LAL
Orsay, May 23-25, 2011



IDAG

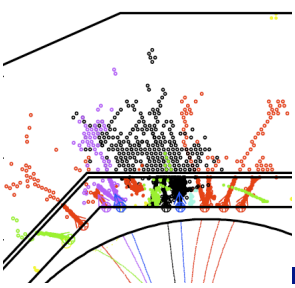
5. EVALUATION OF THE THREE CONCEPTS

5.1 ILD

The ILD Collaboration has presented a LOI which documents the impressive quantity and quality of work performed. A particular strength of the LOI is the very extensive R&D effort made in test beams with full-size prototypes of the calorimeter having been constructed and operated at DESY, CERN and Fermilab. Indeed, alternative technologies for the calorimetry are also being explored in the test beam program. Integrated with these calorimeter tests their data have been taken with a "tail catcher" for one of the possible muon system options. This large data set will allow ILD to validate the PF strategy which is central to their design. The

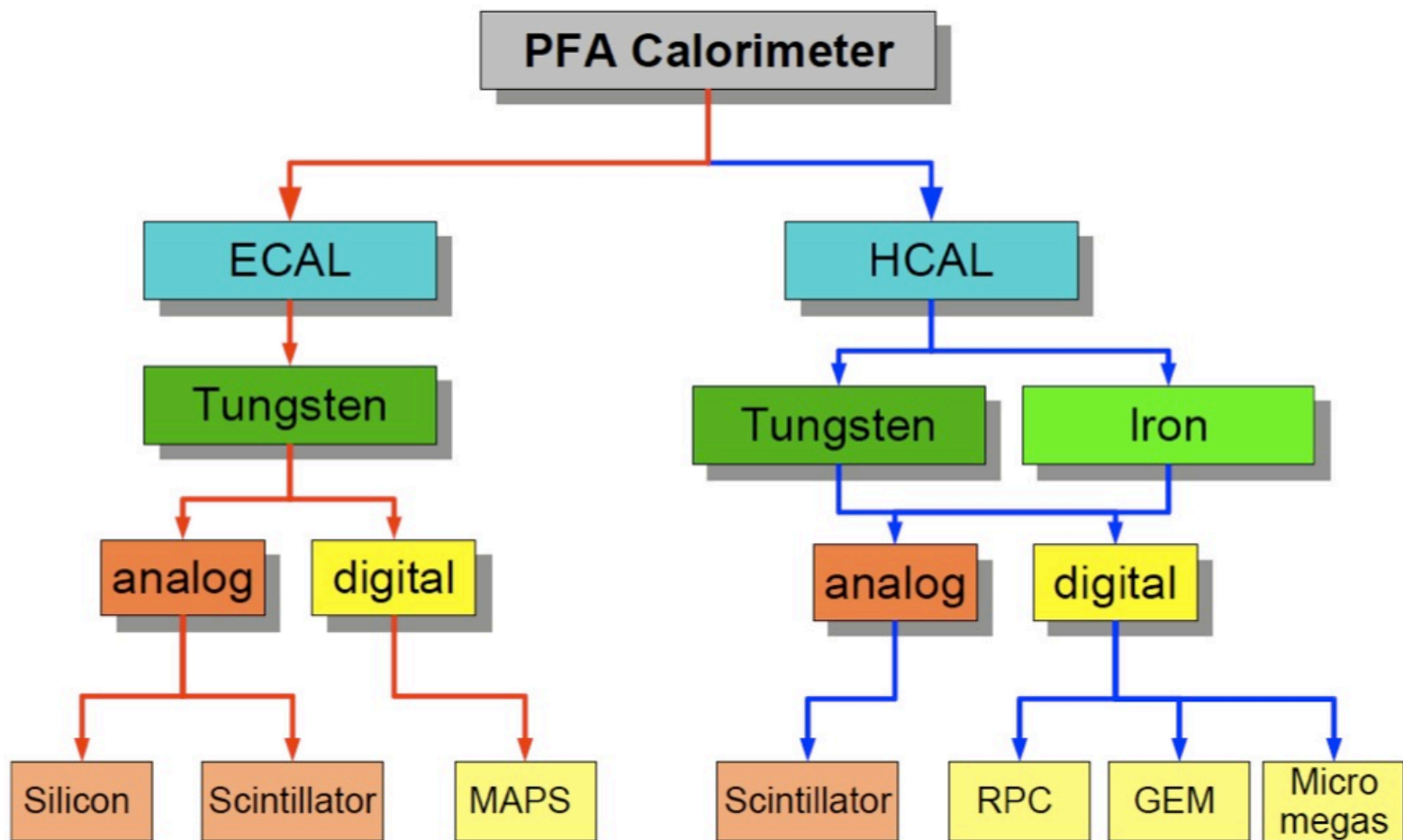
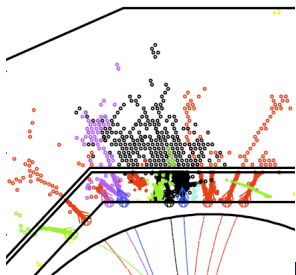
- Calorimeter test beam is highly appreciated
- And will also be the key in the future

Outline

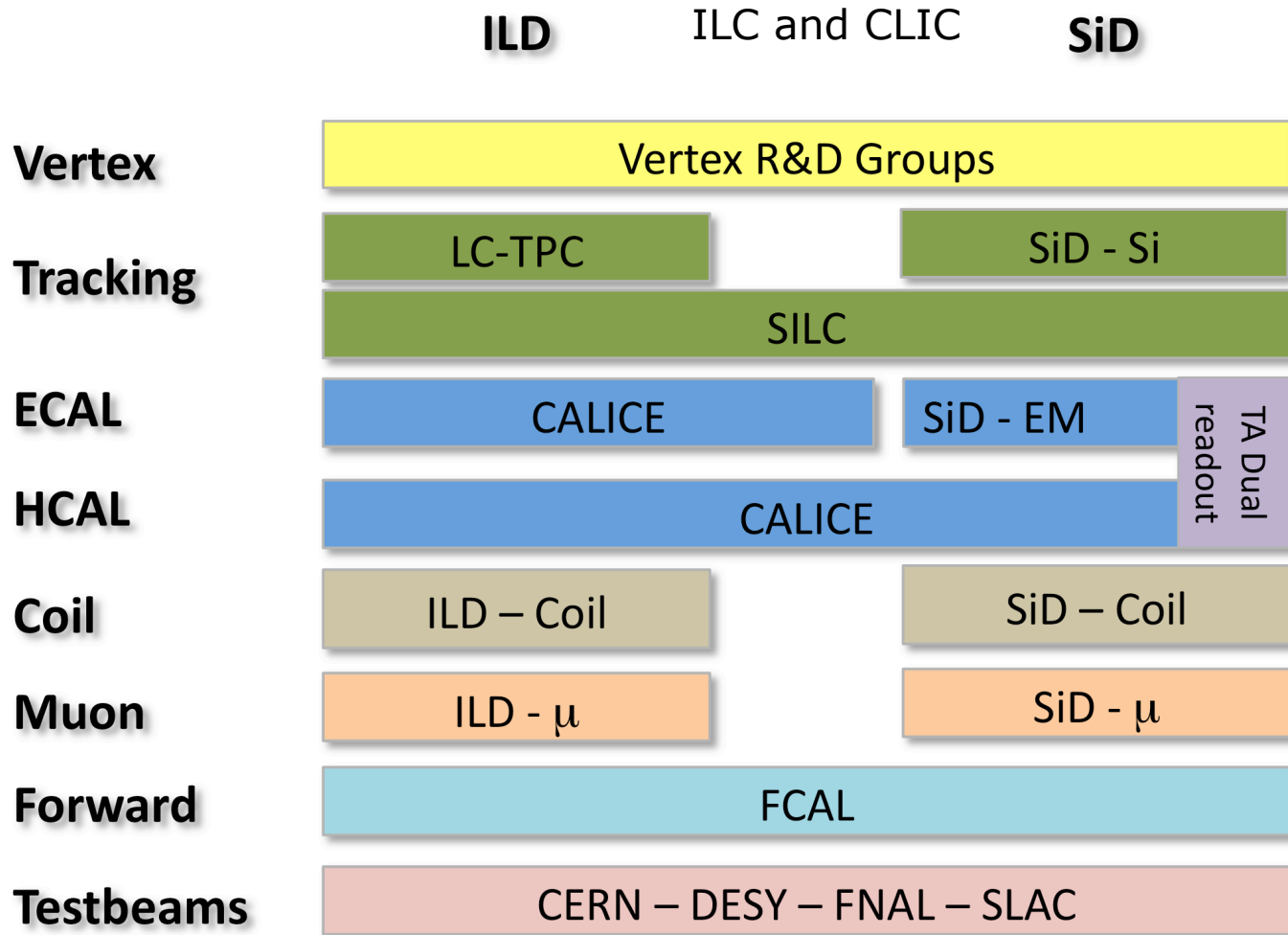
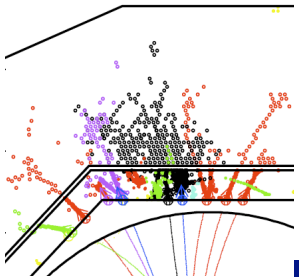


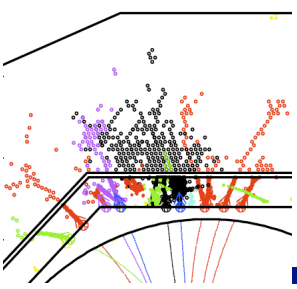
- Status of prototype beam tests
- Goals for 2012, Interdependencies
- Report from ongoing beam tests

Technologies



Activities

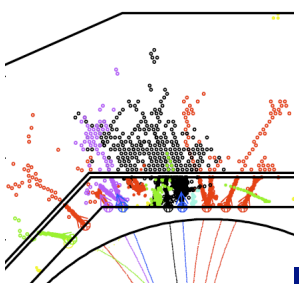




Last week's CALICE meeting



- most recent addition: Kyushu university



Score card

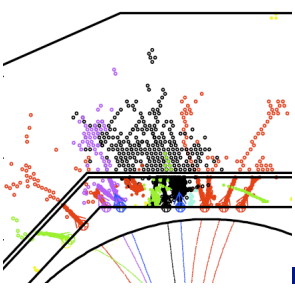
- Completed:
 - SiW ECAL, Scint W ECAL, Scint Fe AHCAL
- Ongoing:
 - Scint W AHCAL, RPC Fe DHCAL
- On the way:
 - CALICE RPC Fe SDHCAL, W DHCAL
 - SiW ECAL, Scint W ECAL, Scint AHCAL demonstrators
- Future:
 - CALICE 2nd generation Si/Scint W ECAL, Scint W/Fe HCAL
- Ongoing, on the way and in future:
 - individual or few layer tests with alternative technologies
 - GEMs, micromegas, MAPS
 - funding driven

Publications, talks etc.

- ❖ Since the start of 2010:
 - ❖ 6 papers submitted for publication
 - ❖ **Study of the interactions of pions in the CALICE silicon-tungsten calorimeter prototype** [2010 JINST 5 P05007](#)
 - ❖ **Effects of high-energy particle showers on the embedded front-end electronics of an electromagnetic calorimeter for a future lepton collider** Submitted to NIM ; e-print [arXiv:1102.3454](#)
 - ❖ **Construction and Commissioning of the CALICE Analog Hadron Calorimeter Prototype** [2010 JINST 5 P05004](#)
 - ❖ **Electromagnetic response of a highly granular hadronic calorimeter** [2011 JINST 6 P04003](#)
 - ❖ **Environmental Dependence of the Performance of Resistive Plate Chambers** [JINST 5 \(2010\) P02007](#)
 - ❖ **Beam test of a small MICROMEGAS DHCAL prototype** [2010 JINST 5 P01013](#)
 - ❖ + 2 more imminently.
 - ❖ 11 new Calice Analysis Notes (preliminary results)
 - ❖ >100 Conference talks given
- ❖ See <https://twiki.cern.ch/twiki/bin/view/CALICE/SpeakersBureau>

Summary of publications etc.

- ❖ Currently ~20 [Papers](#)
- ❖ + two very close to submission (PFA tests, TCMT paper)
- ❖ ~30 analysis notes [Analysis Notes](#) (approved preliminary results for conferences); at least 10 should turn into papers, possibly in suitable combinations. Two more currently under collaboration review.
- ❖ 15 [theses](#) listed ; almost certainly more; our records are not complete.
- ❖ Many [Conference talks](#) and [posters](#)



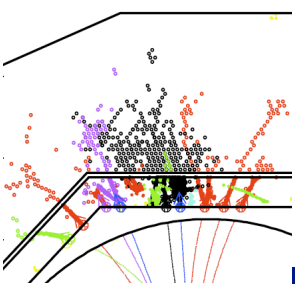
PRC recommendations

- **CALICE**

The PRC **congratulates** the CALICE collaboration for the successful **development** of future PFA (particle flow algorithm) calorimeters with an extensive **variety of approaches and options**. The PRC also congratulates the collaboration on its **effective test beam campaigns at CERN and Fermilab so far** and is very happy to see some of the important outcomes have been **published as recommended** in previous PRC meetings. The further efforts with the test beam, to improve **prototypes as realistic components** of future ILC detectors to be presented in the ILC **DBDs in 2012**, are highly supported.

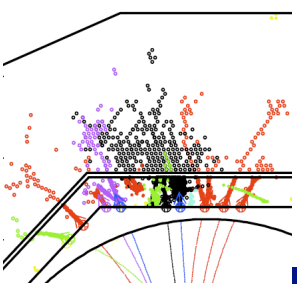
The PRC notes the challenges associated with the provision of **adequate test beam time**, and the **funding** necessary to carry out the proposed program. The PRC recommends that **DESY continues support** for necessary modifications to test beam fixtures, test beam campaigns at CERN and Fermilab, continuation of electronics integration development, mechanical and electrical engineering, and provision of computing resources.

Since the PRC believes that the coherent effort in the **shower simulation model development** with the test beam results are extremely important to maximize the CALICE contribution to the field, it is **requested CALICE to make a report at the next PRC meeting about their collaborative activities with the relevant group** in this direction in conjunction with the current **status of the shower simulations in general**.



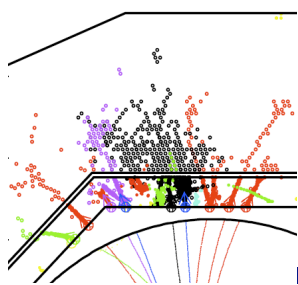
ILD, SiD concepts; DBD

- Our scope, and our obligation to the community, are broader
- Still, concepts guide R&D prioritization
- Without technology demonstration of high granularity calorimeters, the particle flow revolution is stuck half-way
- We are expected to provide input to ILD and SiD DBDs in a well organized and coherent way
 - discussions with concepts at previous CALICE meetings
- Next Steps on ILD side
 - software baseline summer 2011
 - technology baseline options 2nd quarter 2012

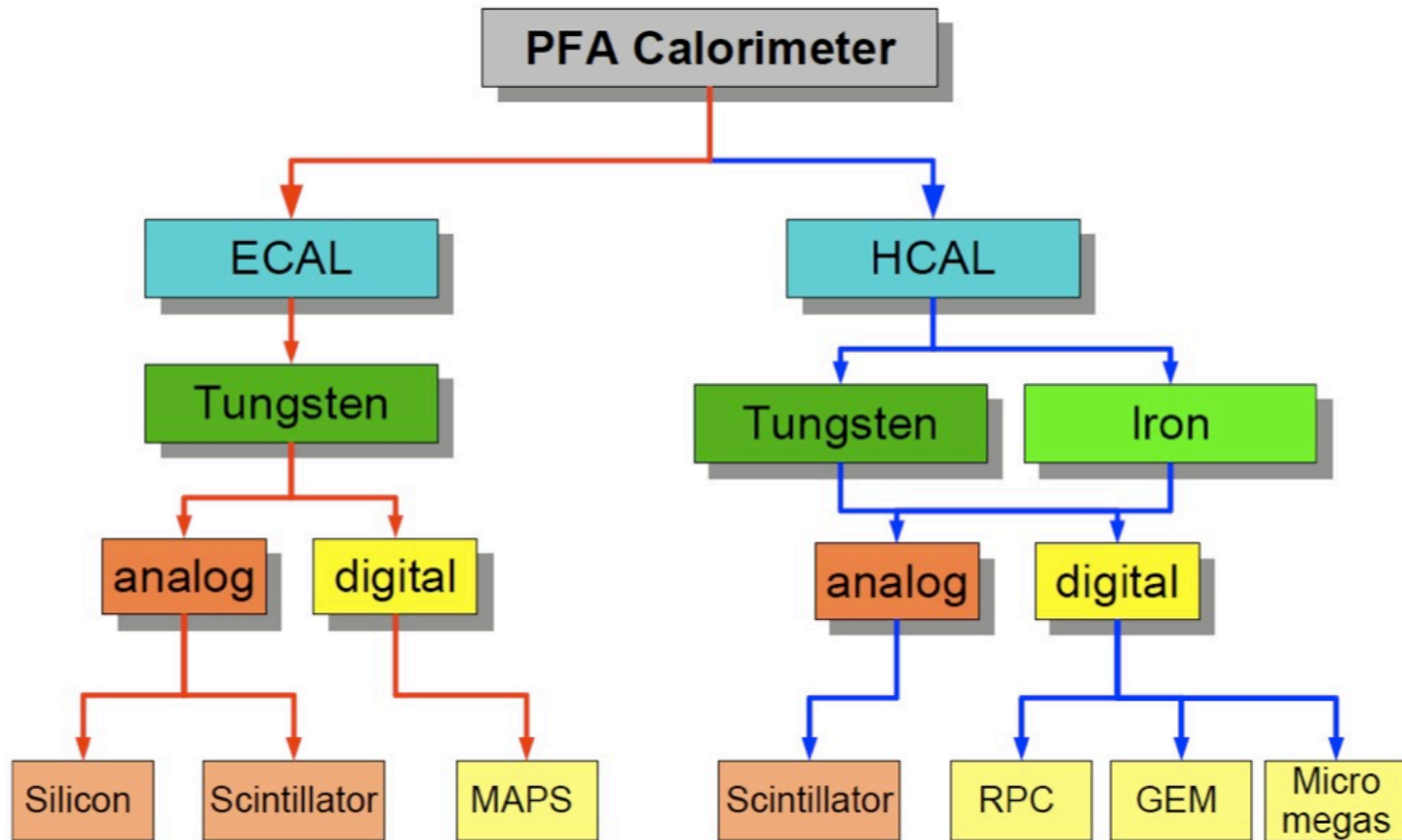


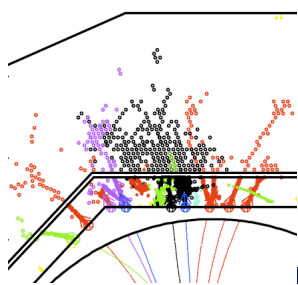
Technology criteria 2012

- From the PRC report:
 - **Established performance:** energy resolution, linearity, uniformity, two particle separation
 - **Validated simulation:** longitudinal and transverse shower profiles, response, linearity and resolution, for electrons and hadrons
 - **Operational experience:** dead channels, noise, stability, monitoring and calibration
 - **Scalable technology solutions:** power and heat reduction, low volume interfaces, data reduction, mechanical structures, dead spaces, services and supplies
 - **Open R&D issues:** analysis and R&D to be completed before a first pre/production prototype can be built, cost reduction and industrialization issues
- On us to review and report in 2012



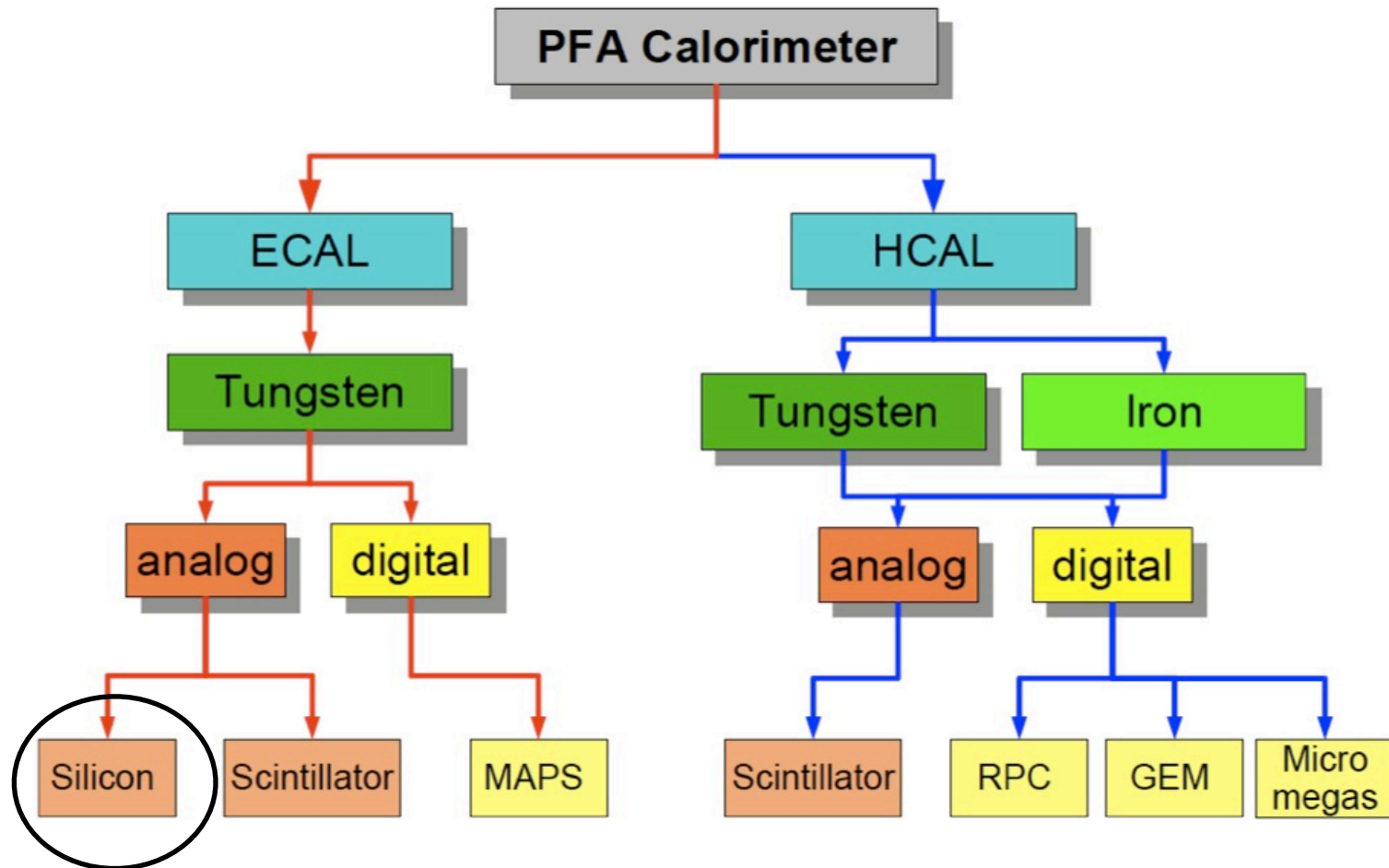
Status

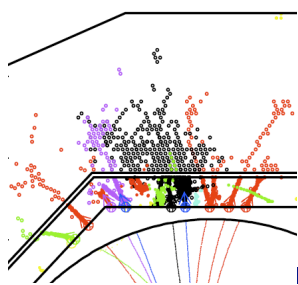




Status

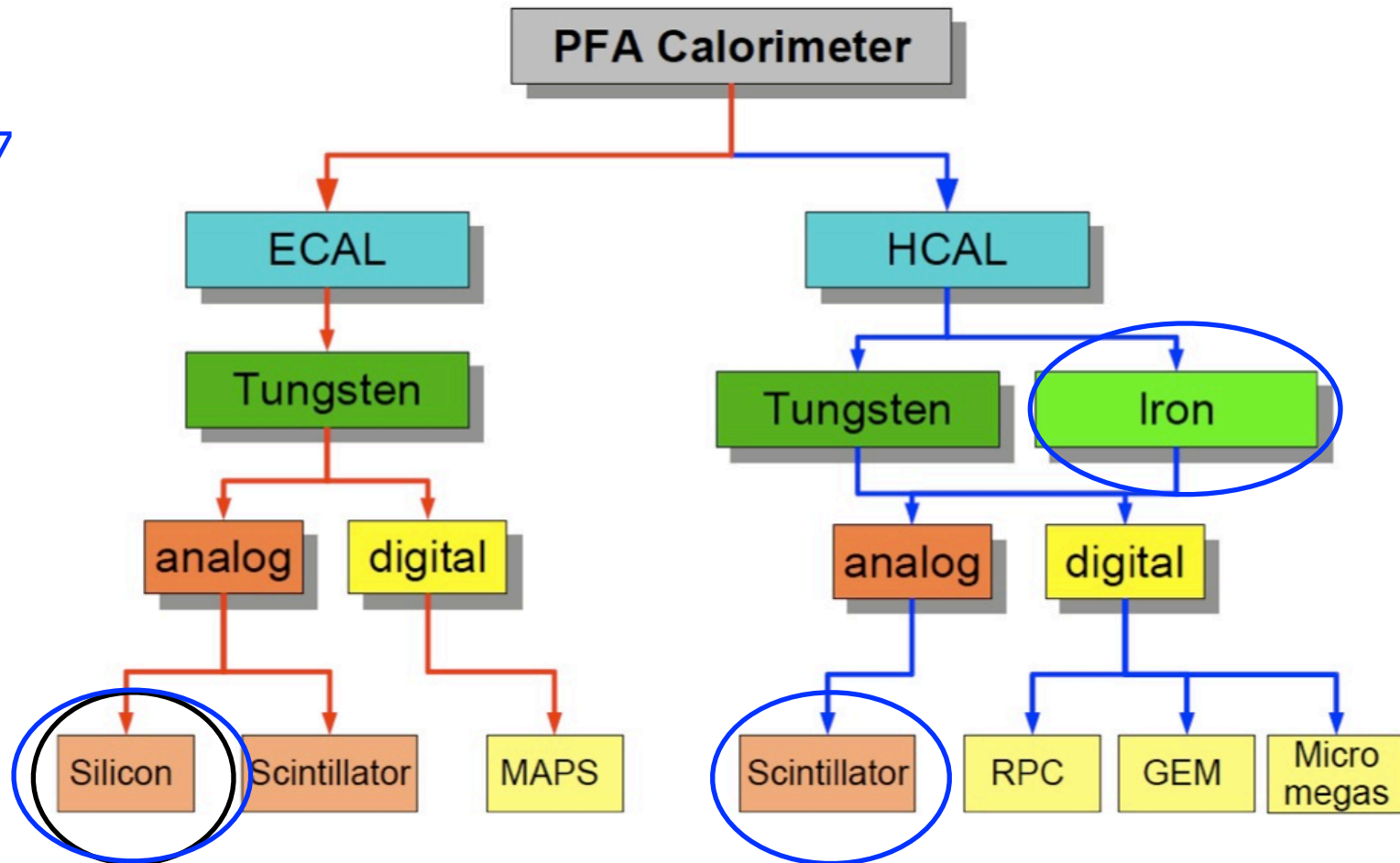
- 2005

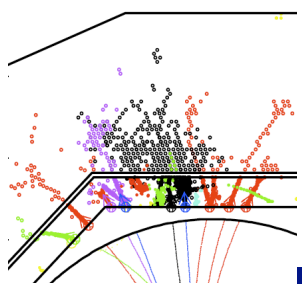




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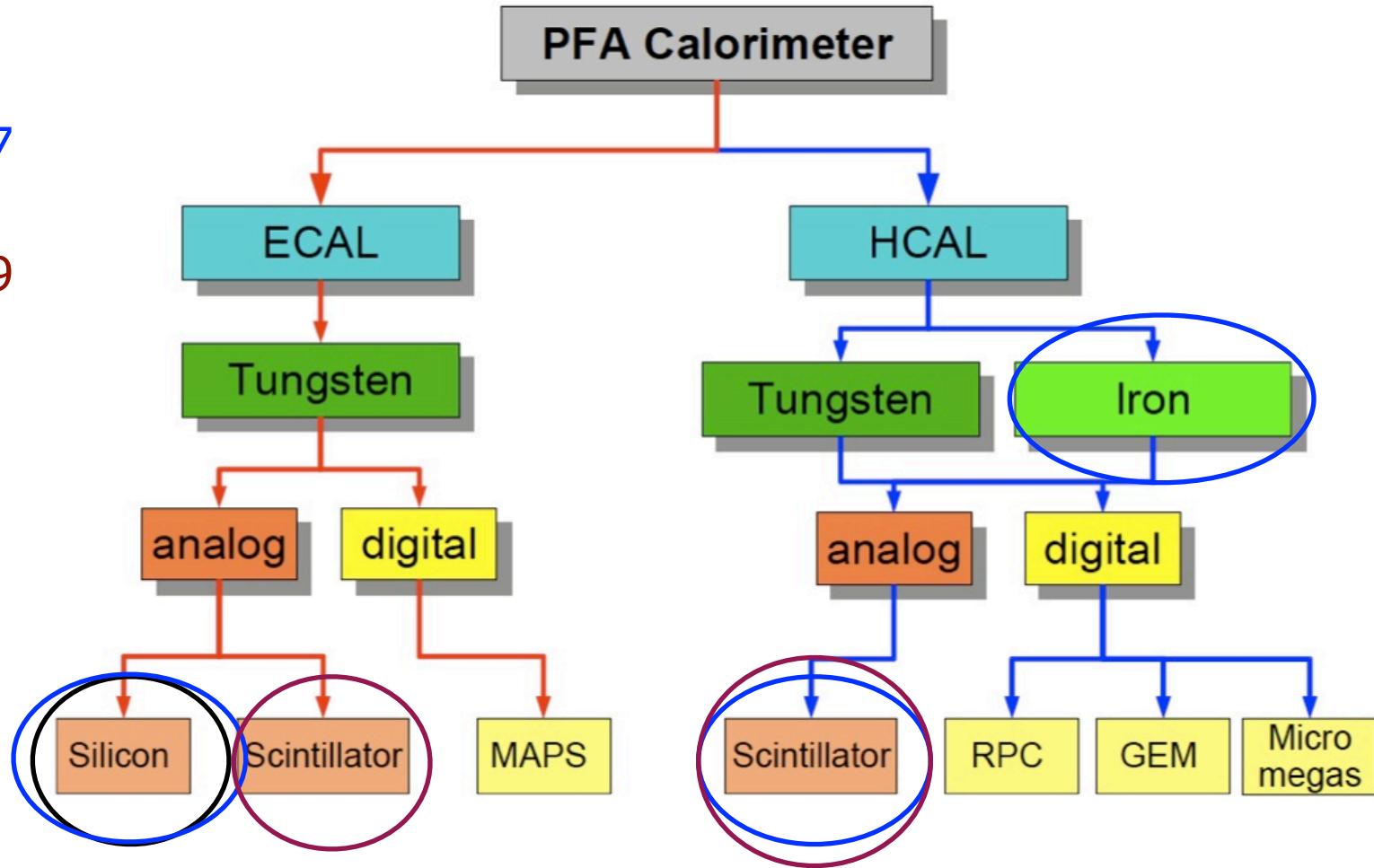
- 2005
- 2006-07

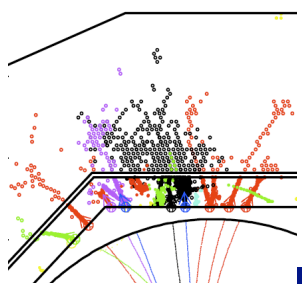




Status

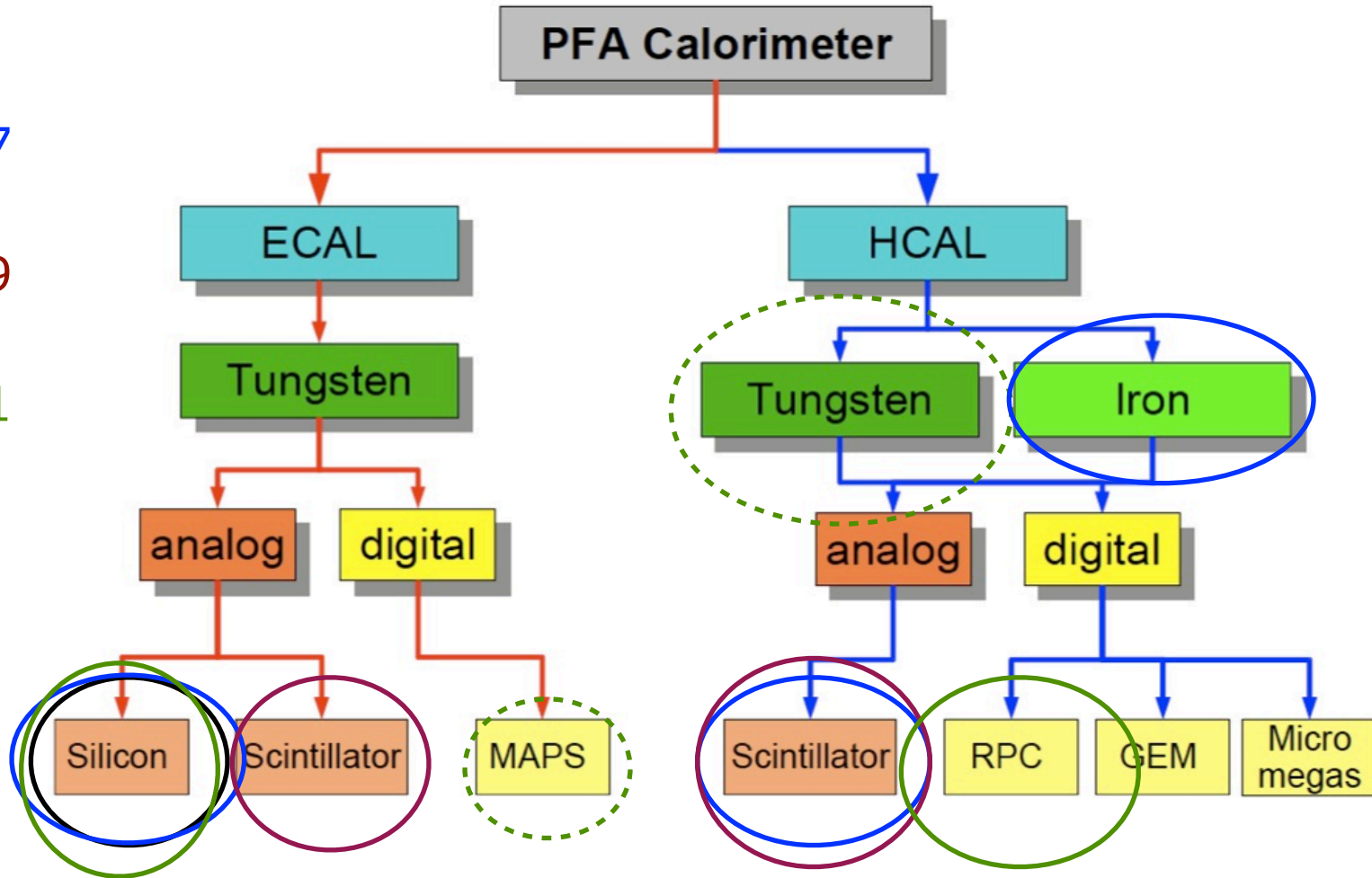
- 2005
- 2006-07
- 2008-09

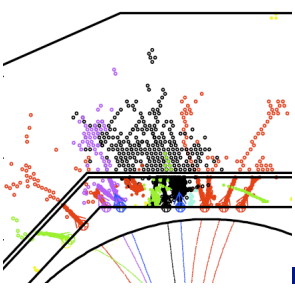




Status

- 2005
- 2006-07
- 2008-09
- 2010-11





Software validation

- Validation with data at different levels
 - single cell level, e.g. charge spectrum
 - active layer level, e.g. technology demonstrators
 - particle level, e.g. energy resolution
 - combined tests
 - particle flow performance
- reflecting the different status of projects
 - funding driven
- recently intensified activities on DHCAL frontier
 - detector modeling
 - topological reconstruction, beautiful new ideas
 - **looking forward to try on real data**

Digital Hadron Calorimeter DHCAL

José Repond

Argonne National Laboratory

The DHCAL

Description

38 (DHCAL) + 14 (TCMT) layers of Resistive Plate Chambers (RPCs)

96 x 96 readout pads/layer, each with a 1 x 1 cm² area

Readout based on DCAL III chip with 64-channels and a single threshold (= digital readout)

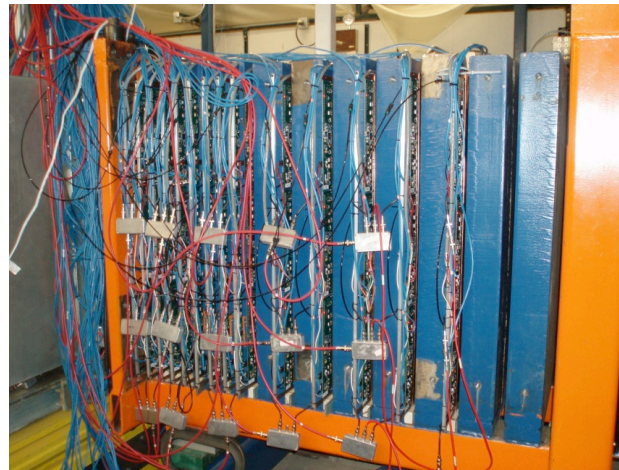
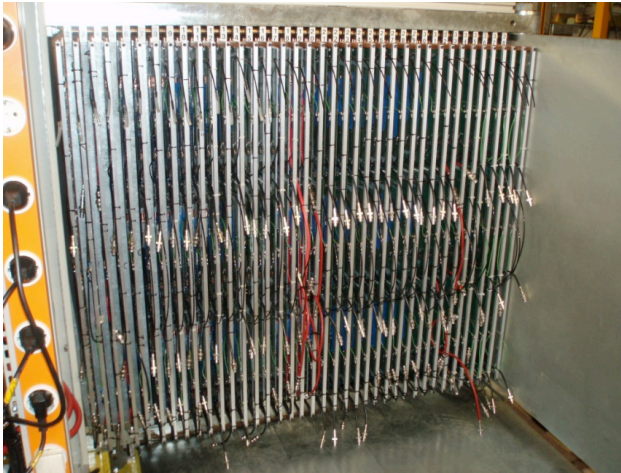
Front-end readout electronics embedded inside the stack

Active layers interleaved with 20 mm thick absorber (Fe + Cu) plates

➤ **380,000 readout channels** (more than the 4 LHC calorimeters combined)

Status

Construction **completed** in February 2011



Construction of the DHCAL

Time frame

Started in September 2008
DHCAL completed in September 2010
TCMT completed in February 2011

Quality assurance

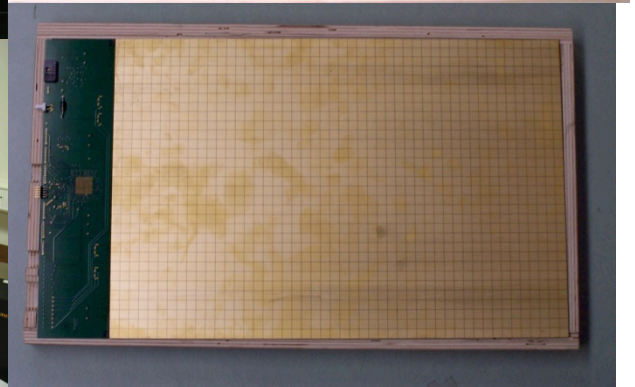
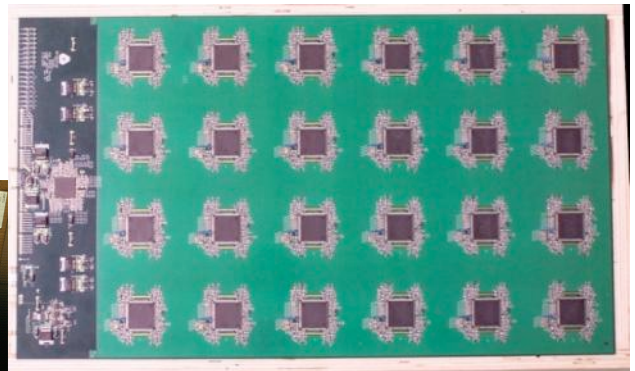
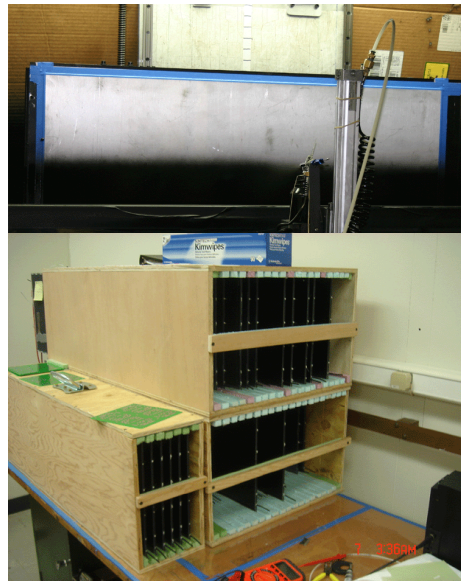
Tests and measurements at every step
Quick feedback

RPC assembly

Spraying of glass plates with resistive paint ← **Careful measurement of surface resistivity**
Assembly of chambers with precision fixtures (tolerances at 50 – 100 μm level) ← **Measurement of thickness**
Assembly of HV connection ← **Tests at 7.0 kV**

Construction of electronics readout system

Production of 10,000+ DCAL III ASICs ← **Tests using clamshell and robot (FNAL)**
Production of 300+ front-end boards and pad-boards with 1536 pads each ← **Bench tests 3 – 6 hours/board**
Connection with drops of conductive glue ← **Every so often measurement of resistivity ($\sim 0 \Omega$)**

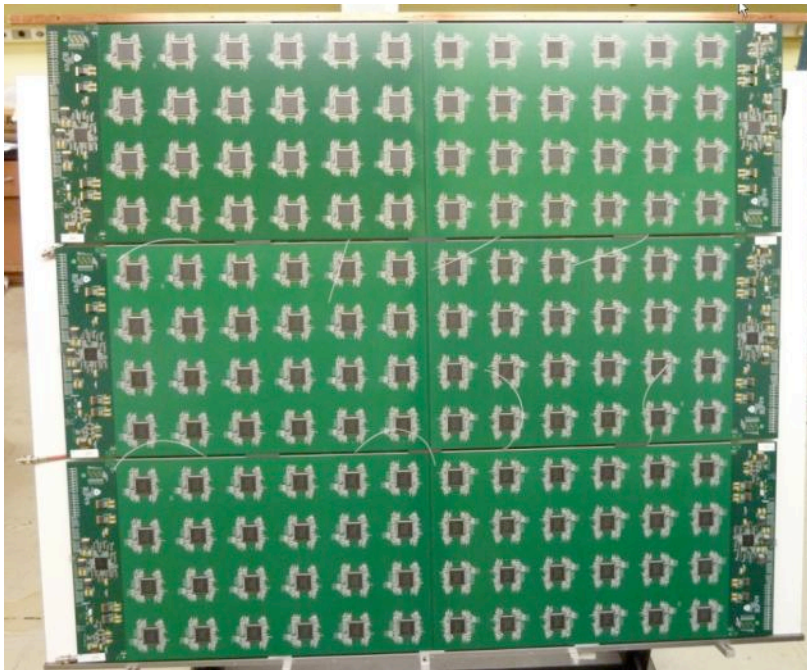


Assembly of cassettes

- 1 x 1 m and 9216 readout channels
- 2 mm Copper front-plate
- 2 mm Fe back-plane

Transportation to Fermilab

- Specifically designed transport structure
- Insertion into CALICE HCAL structure



Some cute muon events

Note: Consecutive events (not selected)
Look for random noise hits

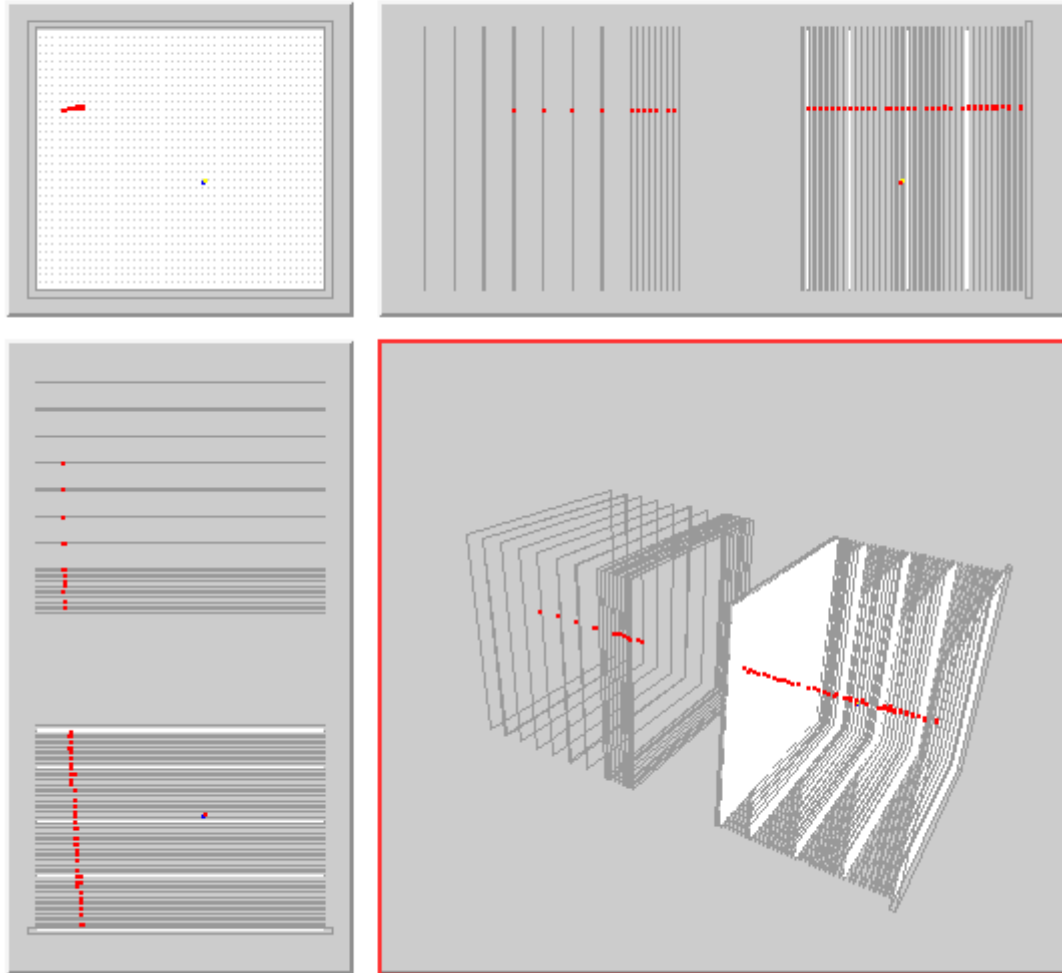


Some cute muon events

Note: Consecutive events (not selected)
Look for random noise hits

Run 998:0 Event 1202

Time: 549533
Hits: 65 Energy: xxx mips

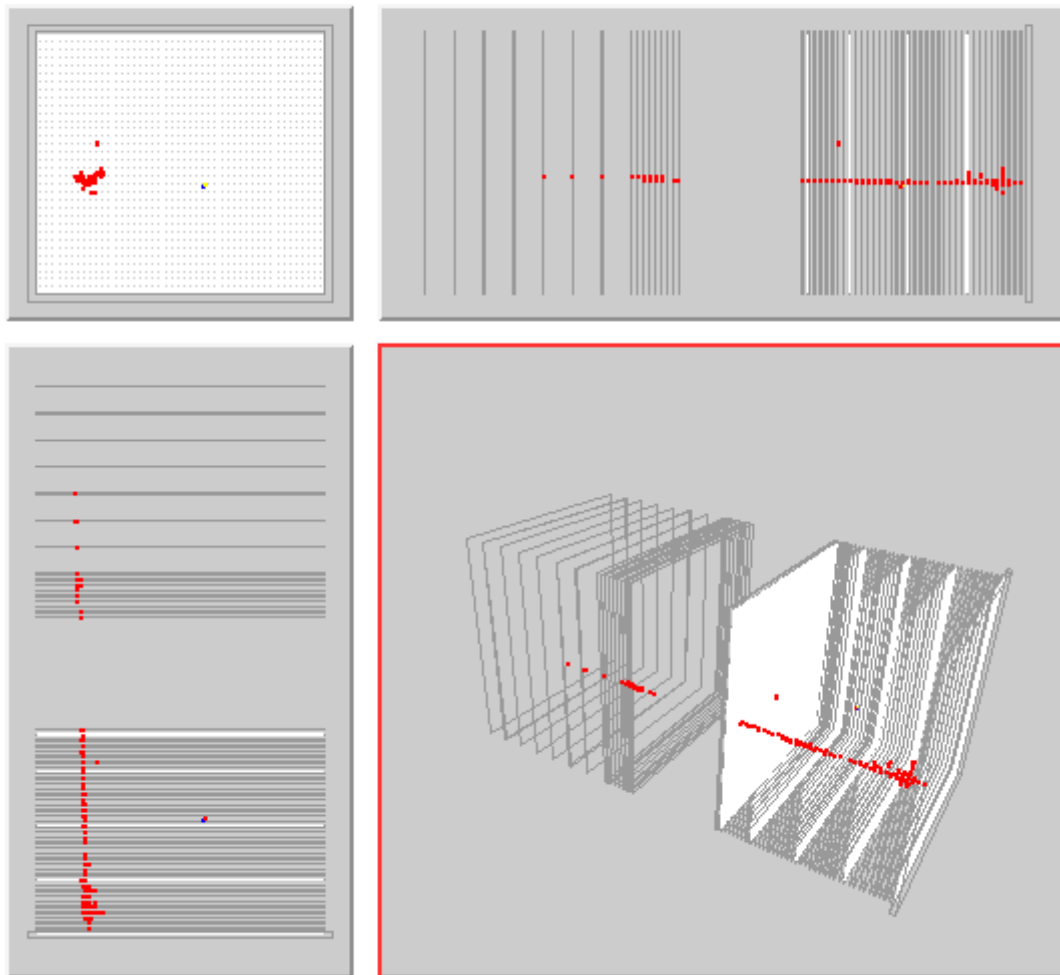


Some cute muon events

Note: Consecutive events (not selected)
Look for random noise hits

Run 998:0 Event 1203

Time: 709088
Hits: 139 Energy: xxx mips

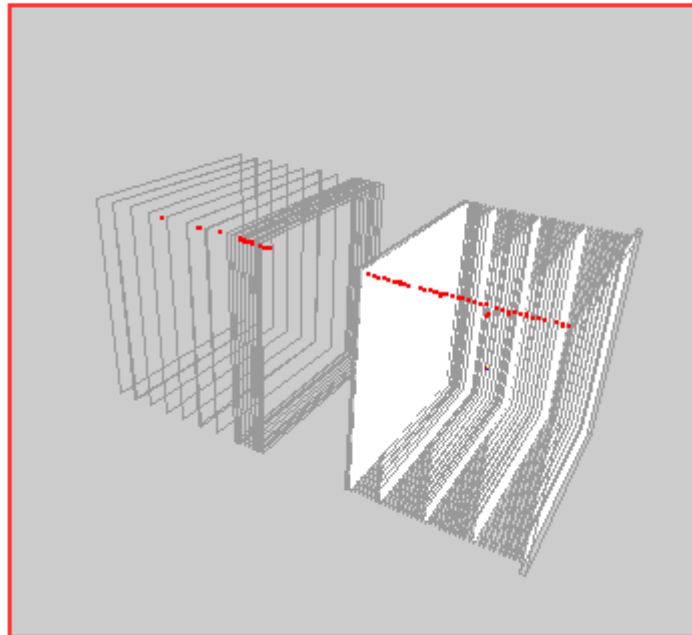
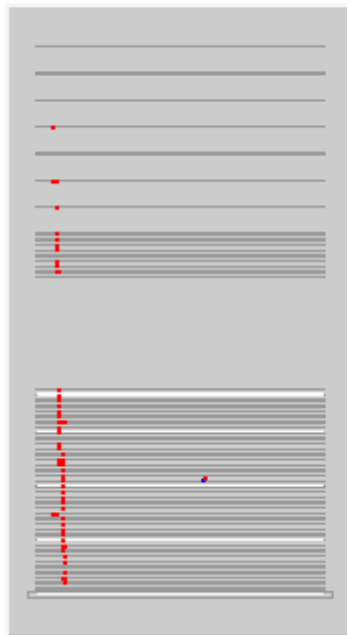
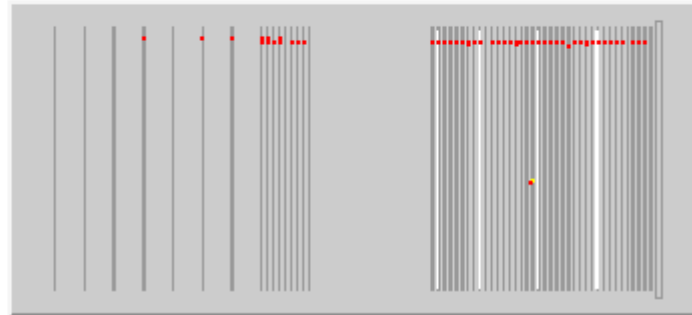
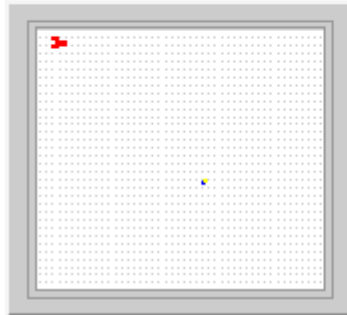


Some cute muon events

Note: Consecutive events (not selected)
Look for random noise hits

Run 998:0 Event 1204

Time: 775524
Hits: 60 Energy: xxx mips

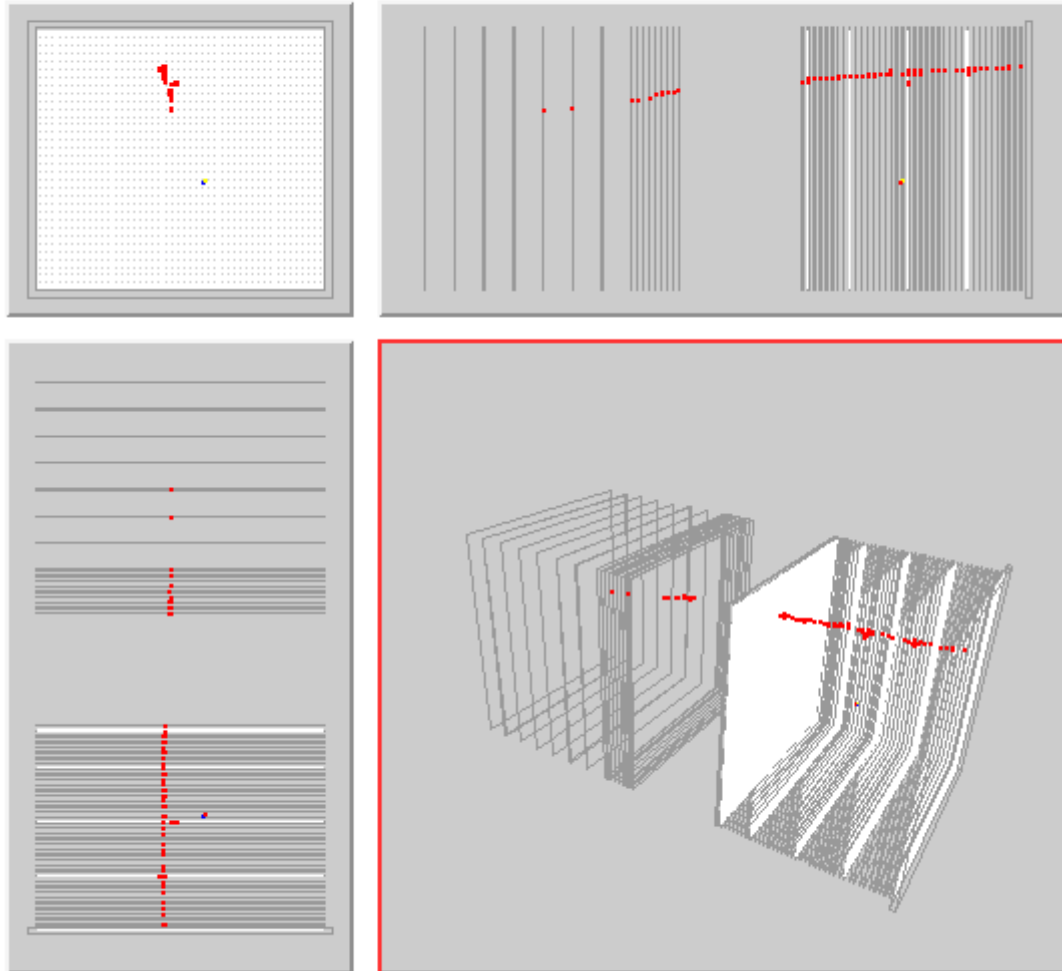


Some cute muon events

Note: Consecutive events (not selected)
Look for random noise hits

Run 998:0 Event 1206

Time: 910276
Hits: 78 Energy: xxx mips

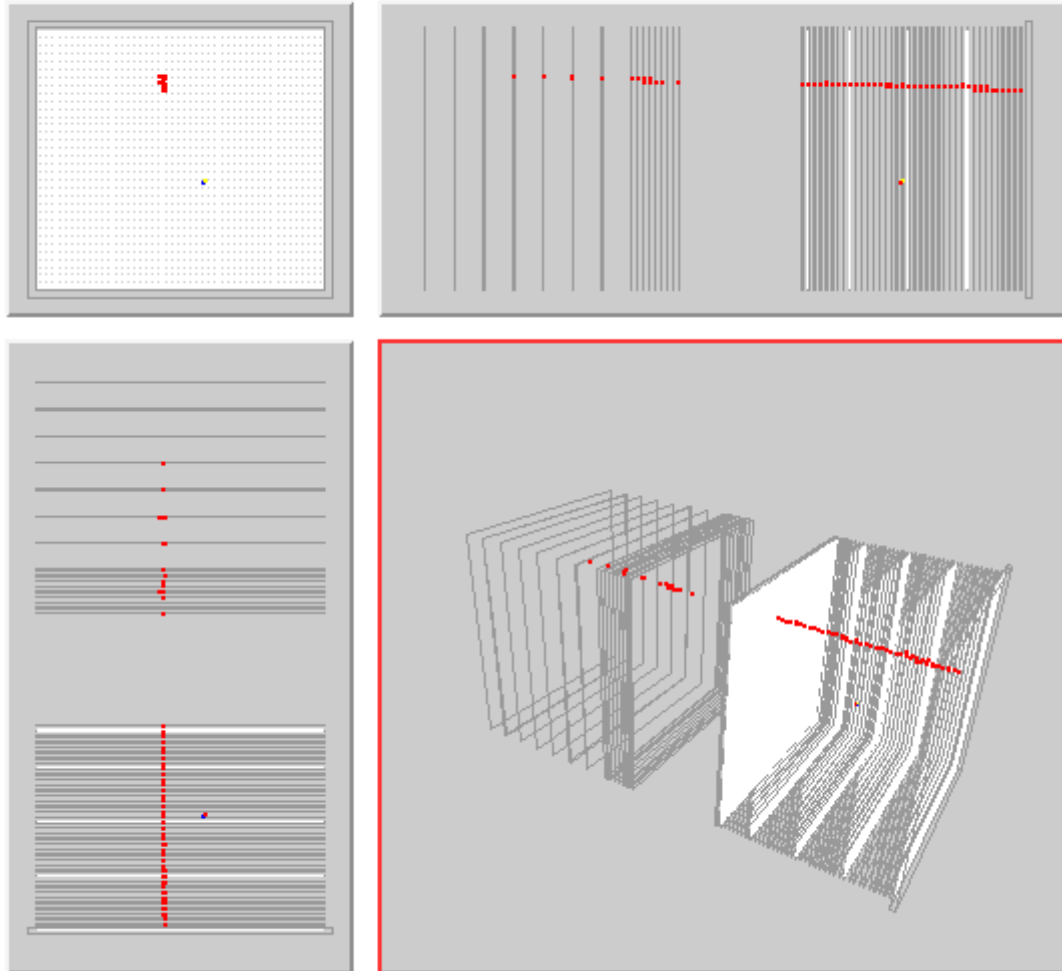


Some cute muon events

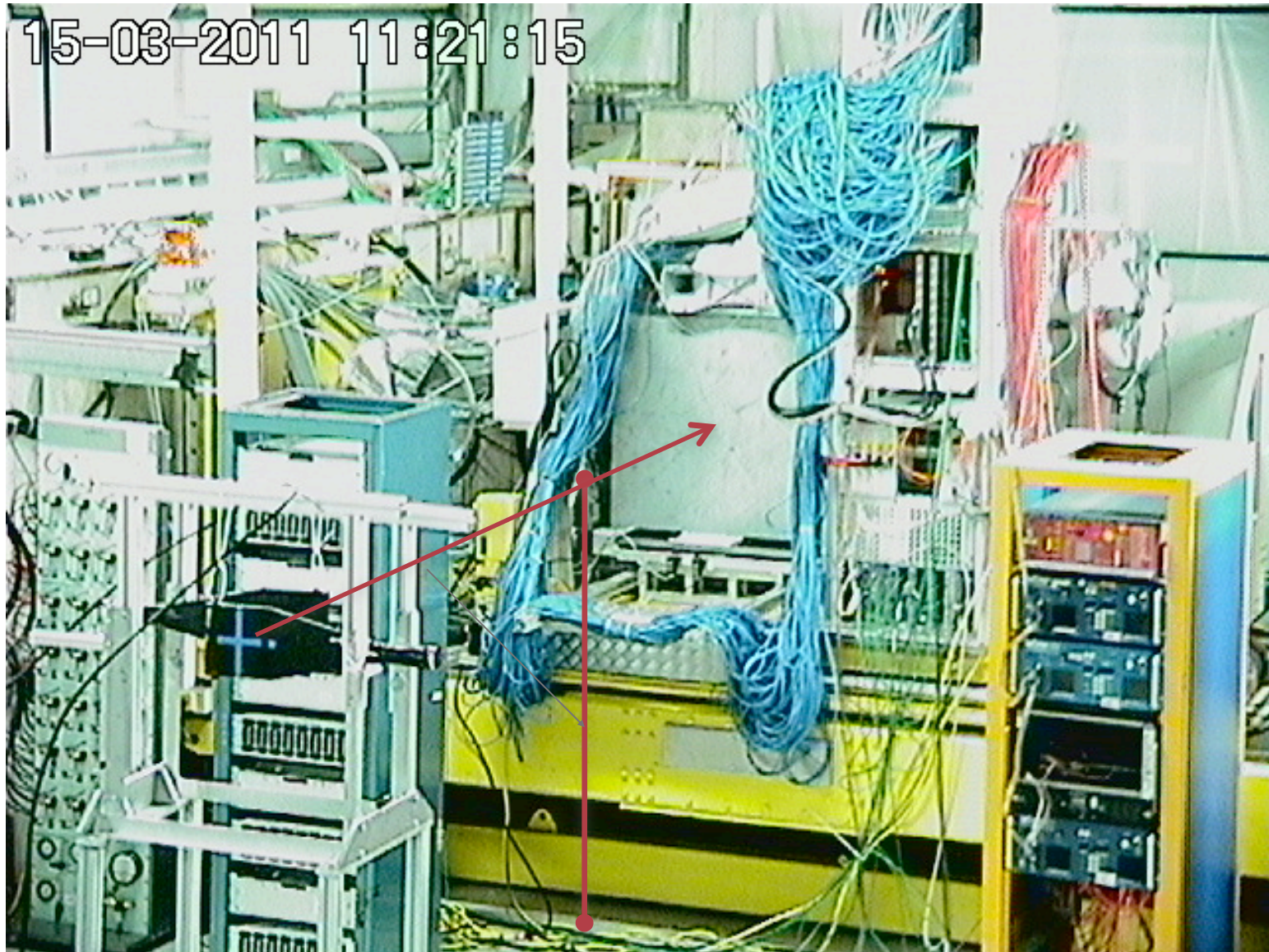
Note: Consecutive events (not selected)
Look for random noise hits

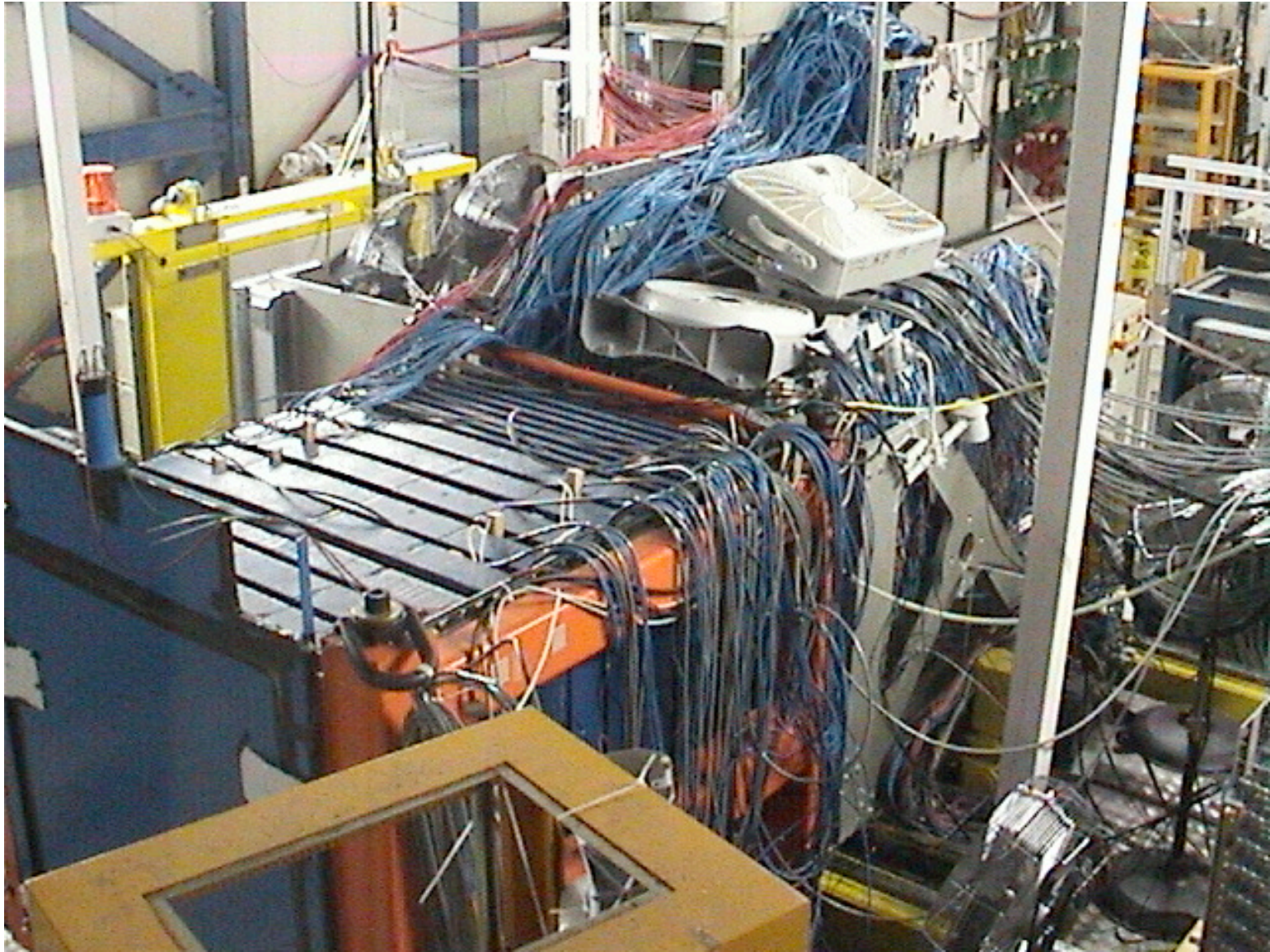
Run 998:0 Event 1208

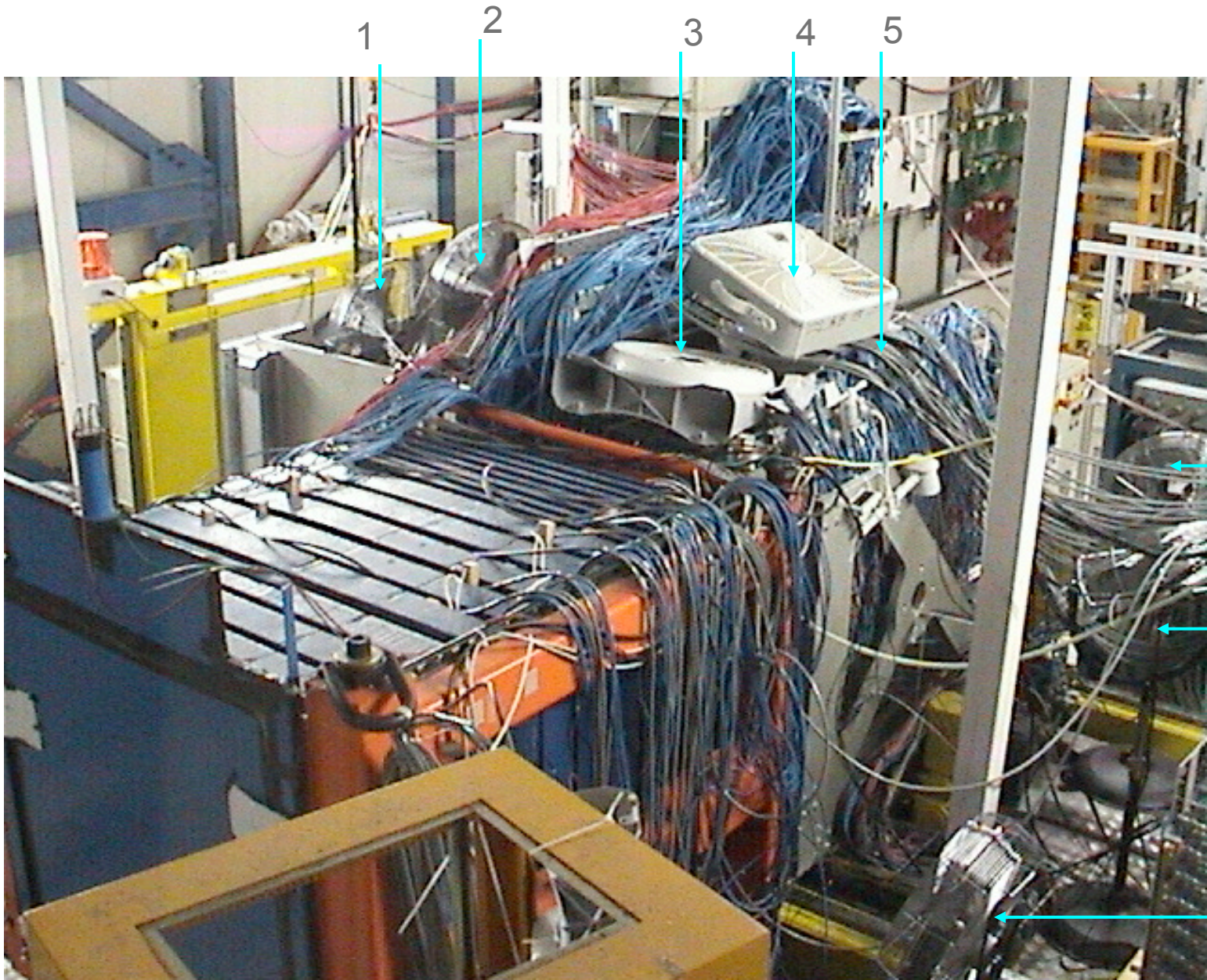
Time: 1099507
Hits: 74 Energy: xxx mips



At Fermilab

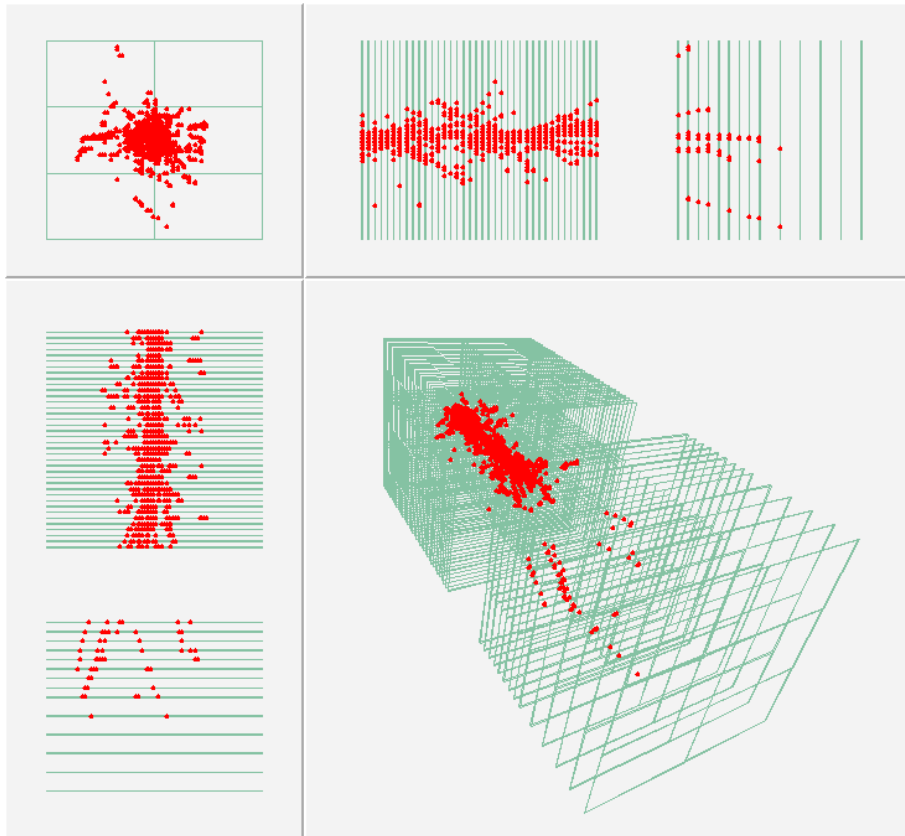






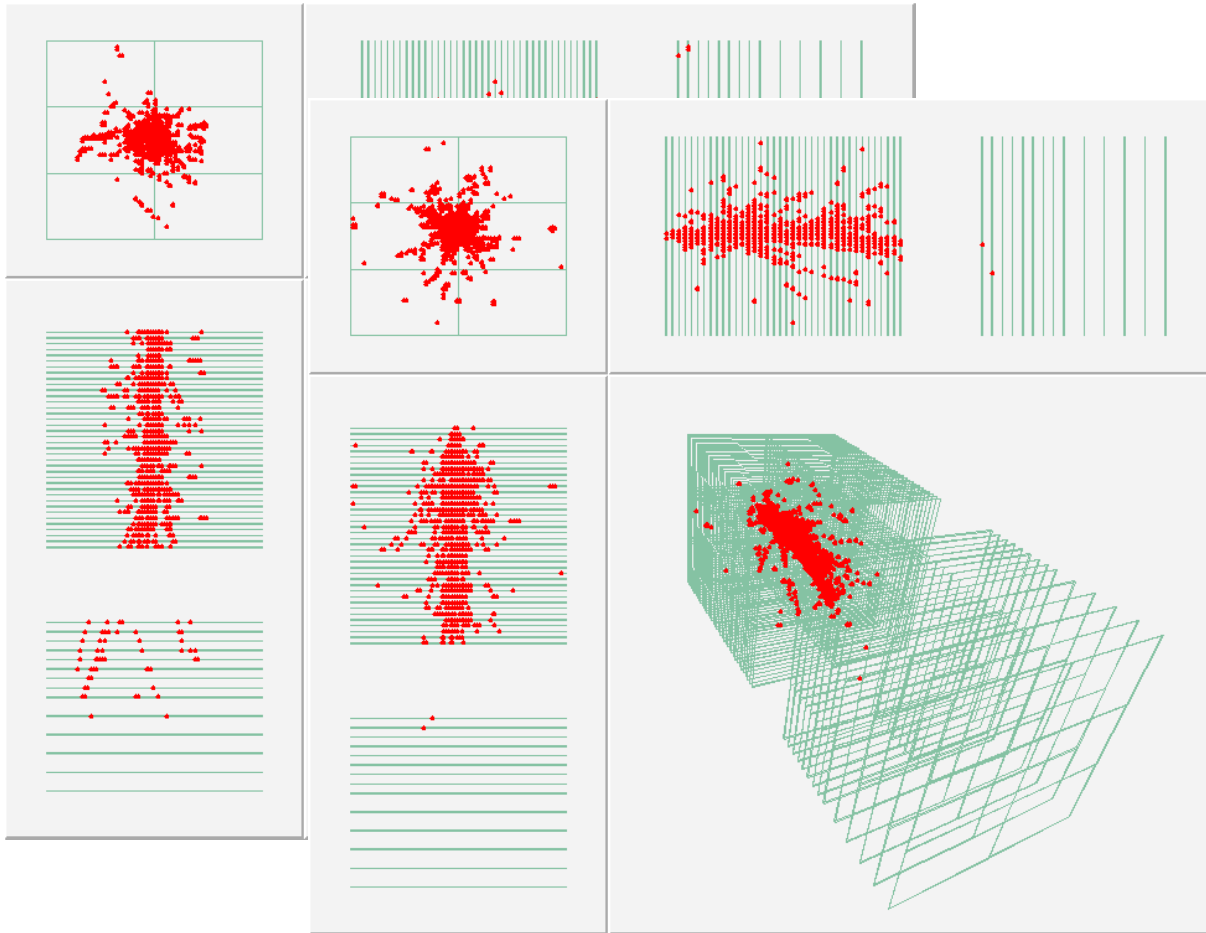
The DHCAL at 120 GeV

In average ~1400 hits



The DHCAL at 120 GeV

In average ~1400 hits



The DHCAL at 120 GeV

In average ~1400 hits



The DHCAL at 120 GeV

In average ~1400 hits

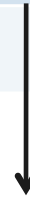


Test Beam Activities

Run period	Date	Configuration	Muon events [10 ⁶]	Secondary beam events	Secondary beam momenta [GeV/c]
1	Oct 2010	DHCAL	1.4	1.5	2,4,8,10,12,16, 20,25,32
2	Jan 2011	DHCAL + partial TCMT	1.6	3.6	2,4,6,8,10,60
3	Apr 2011	ECAL + DHCAL + TCMT	3.5	4.8	4,8,12,16,20,25,32,40,50,60,120
4	Jun 2011	DHCAL + TCMT			32,40,50,60,120, rotation
5	Fall 2011	DHCAL with Tungsten + TCMT			4,8,12,16,20,25,32,40,50,60,120
6	Later	DHCAL w/o absorber			0.50,0.75,1.00, 1.25,1.50,2.00
TOTAL			6.5	+ 9.9	= 16.4M



Only cassette covers (2mm Cu + 2 mm Fe)
Corresponds to ~ 1.23 interaction lengths



Tertiary beam as built for
the Minerva test beam



General DHCAL Analysis Strategy

Noise measurement

- Determine noise rate (correlated and not-correlated)
- Identify (and possibly mask) noisy channels
- Provide random trigger events for overlay with MC events

Measurements with muons

- Geometrically align layers in x and y
- Determine efficiency and multiplicity in 'clean' areas
- Simulate response with GEANT4 + RPCSIM (requires tuning 3-6 parameters)
- Determine efficiency and multiplicity over the whole $1 \times 1 \text{ m}^2$
- Compare to simulation and tuned MC
- Perform additional measurements, such as scan over pads, etc...

Measurement with positrons

- Determine response
- Compare to MC and tune 4th (d_{cut}) parameter of RPCSIM
- Perform additional studies, e.g. software compensation...

Measurement with pions

- Determine response
- Compare to MC (no more tuning) with different hadronic shower models
- Perform additional studies, e.g. software compensation, leakage correction...

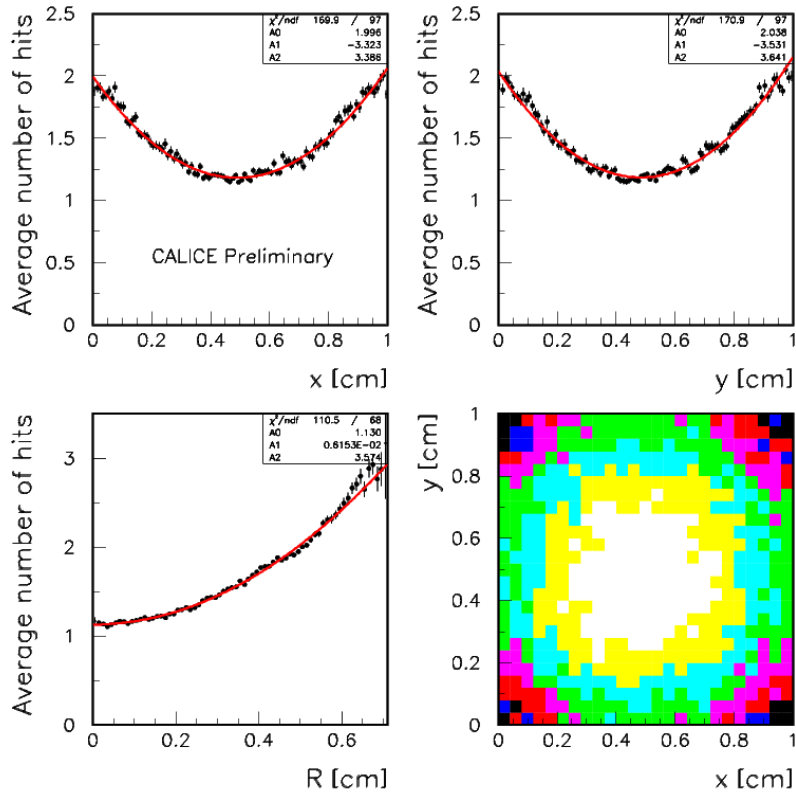


Scan across pad using muons

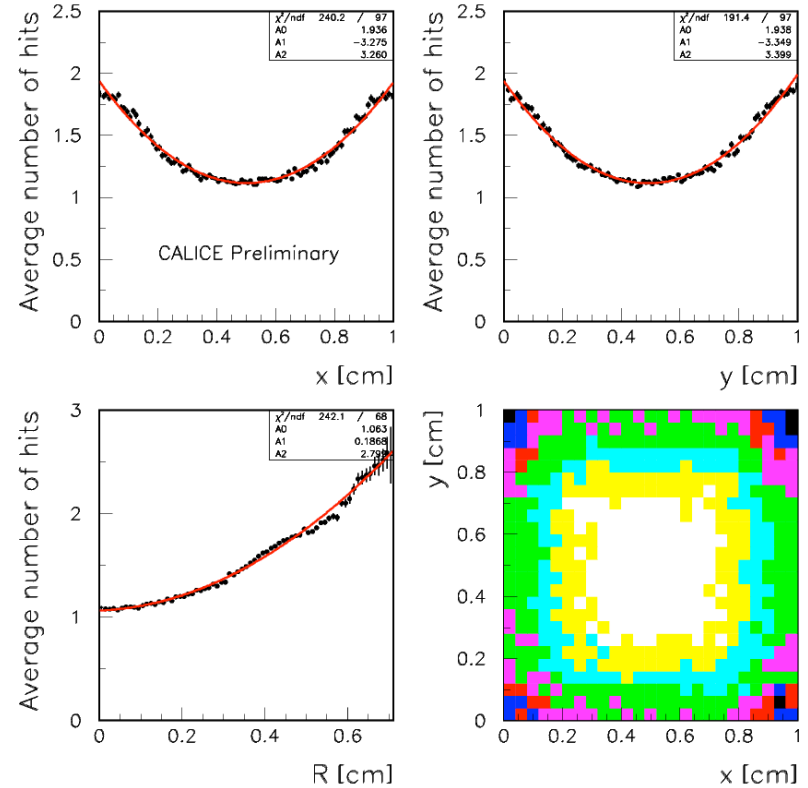
$$x = \text{Mod}(x_{\text{track}} + 0.5, 1.) \text{ for } 0.25 < y < 0.75$$

$$y = \text{Mod}(y_{\text{track}} - 0.03, 1.) \text{ for } 0.25 < x < 0.75$$

Data 630011



Simulation

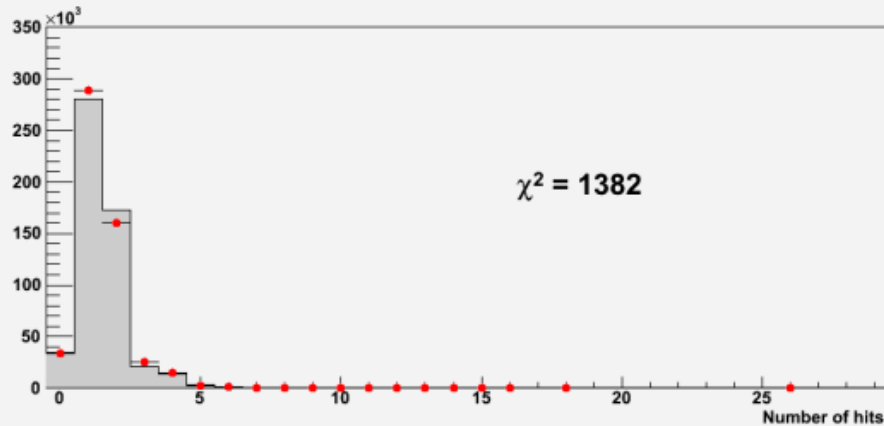


Note

These features **not** implemented explicitly into simulation
Simulation distributes charge onto plane of pads...



Average MIP response in 'clean' areas



Beam

+32 GeV/c beam with beam blocker

Tracks

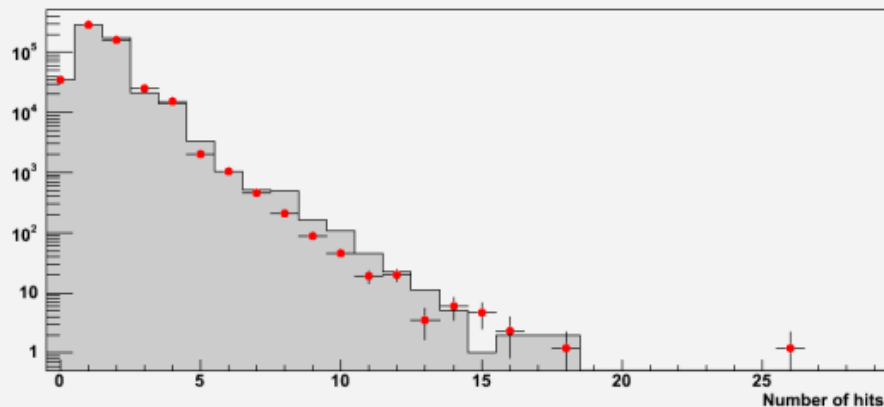
Reconstruction using all layers
except one layer (layer i)

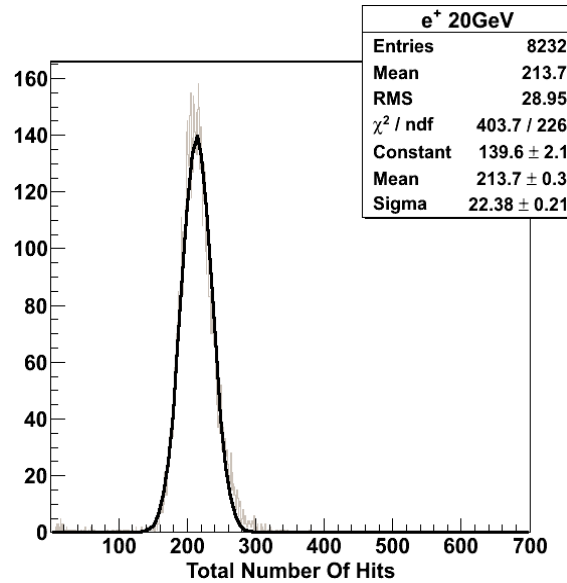
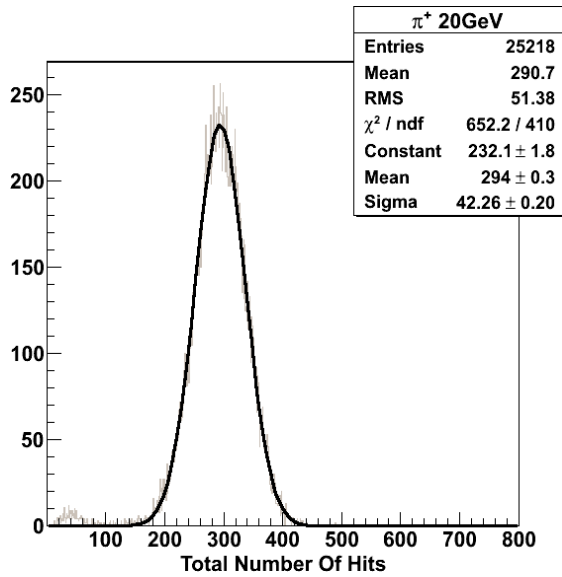
Measurement

Look for cluster in layer i close to track
Count hits in cluster

Histogram = **data**

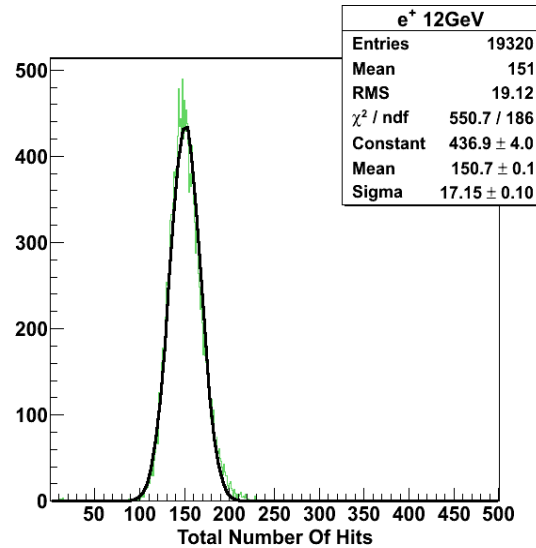
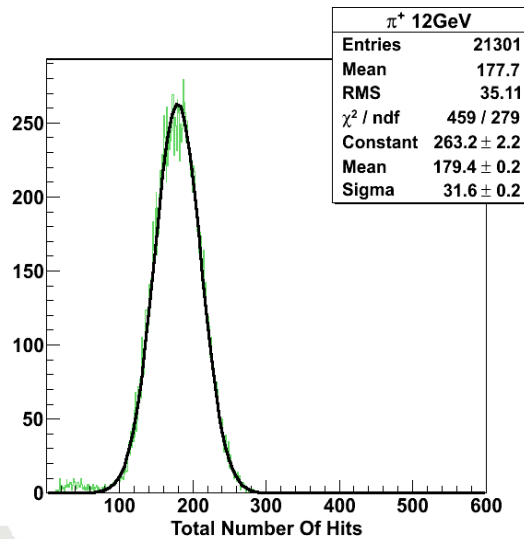
Data points = **simulation** (tuning still ongoing)





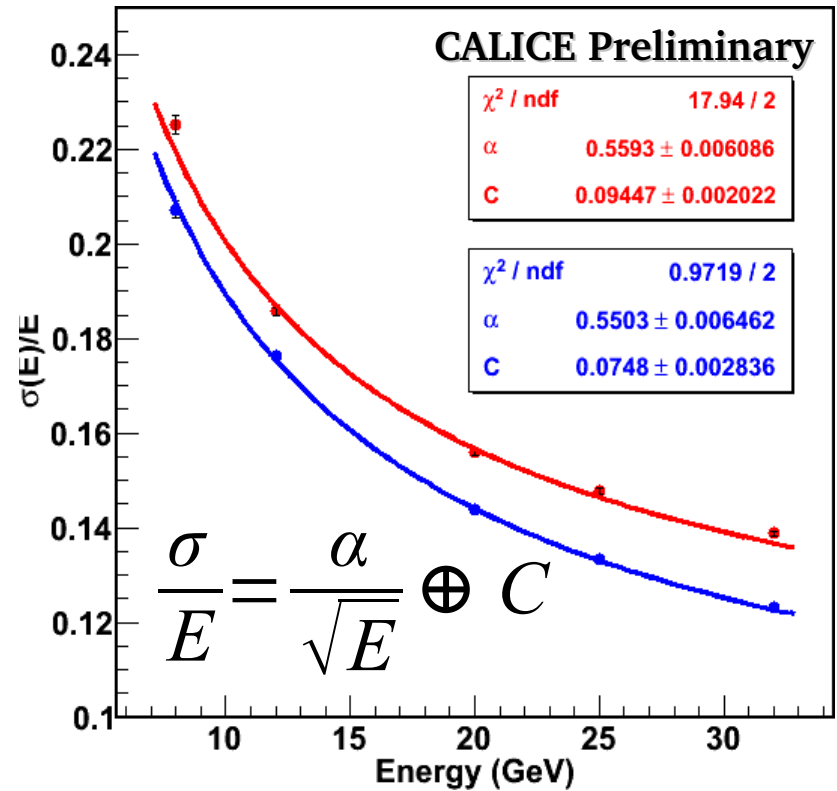
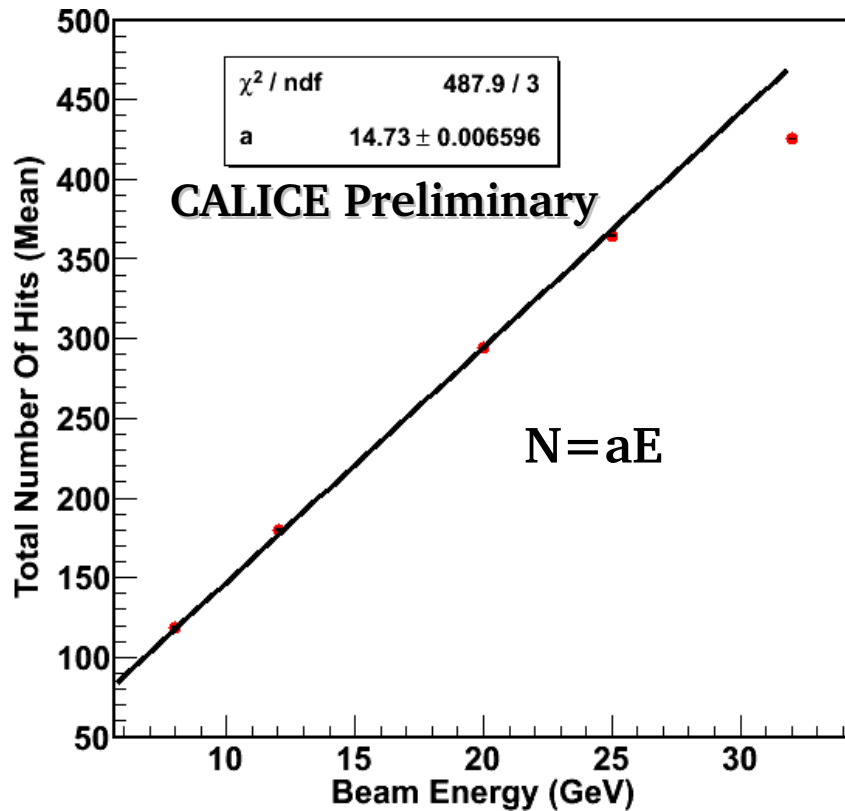
First look at data

Preliminary particle ID



Response to pions

Results after preliminary calibration using track segments



Linearity

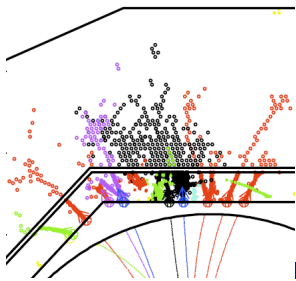
As expected

Saturation effects expected to become noticeable at $p > 30 \text{ GeV}/c$

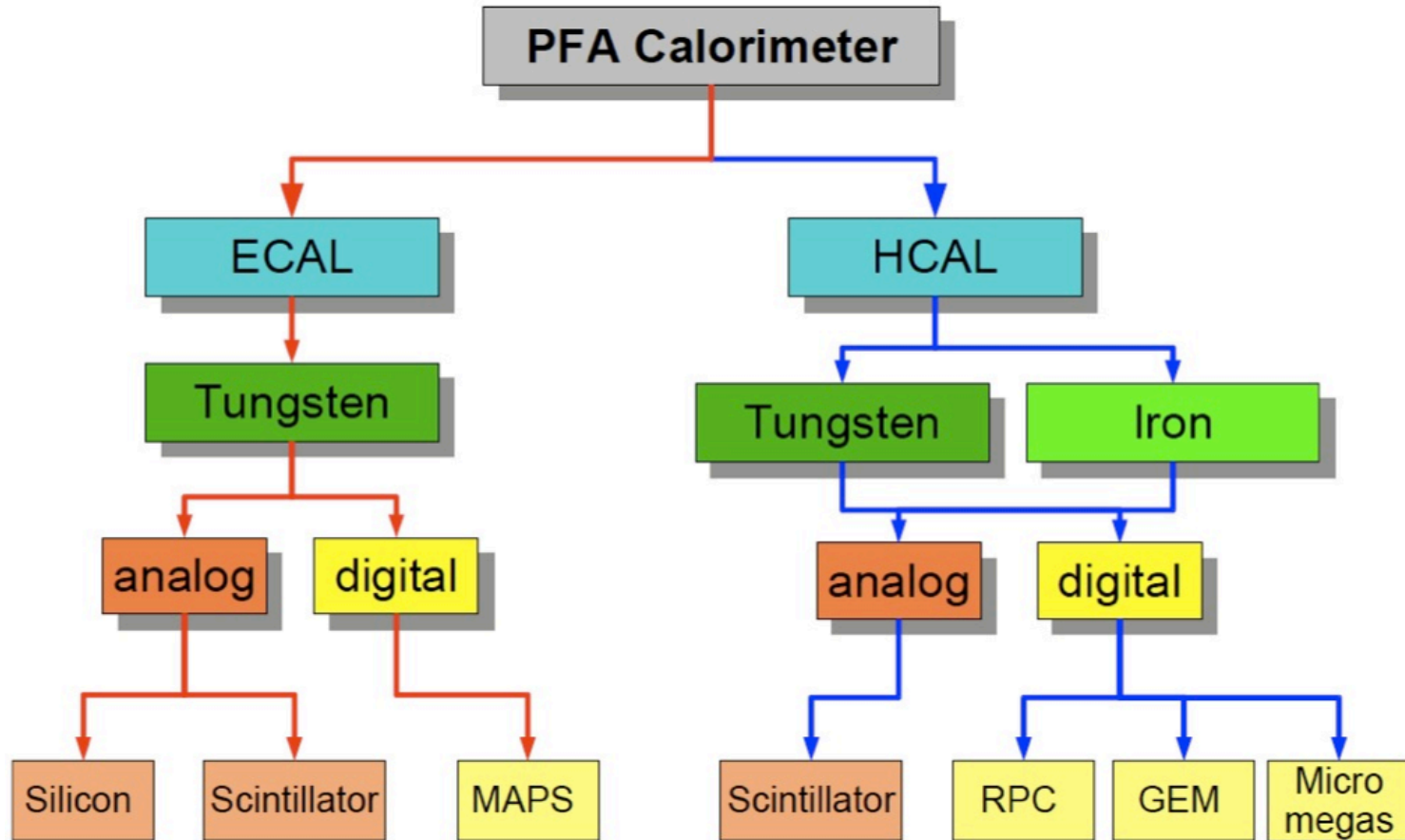
Resolution

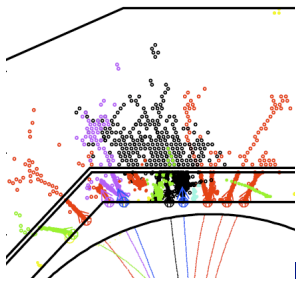
Monte Carlo predicted $58\%/\sqrt{E}$





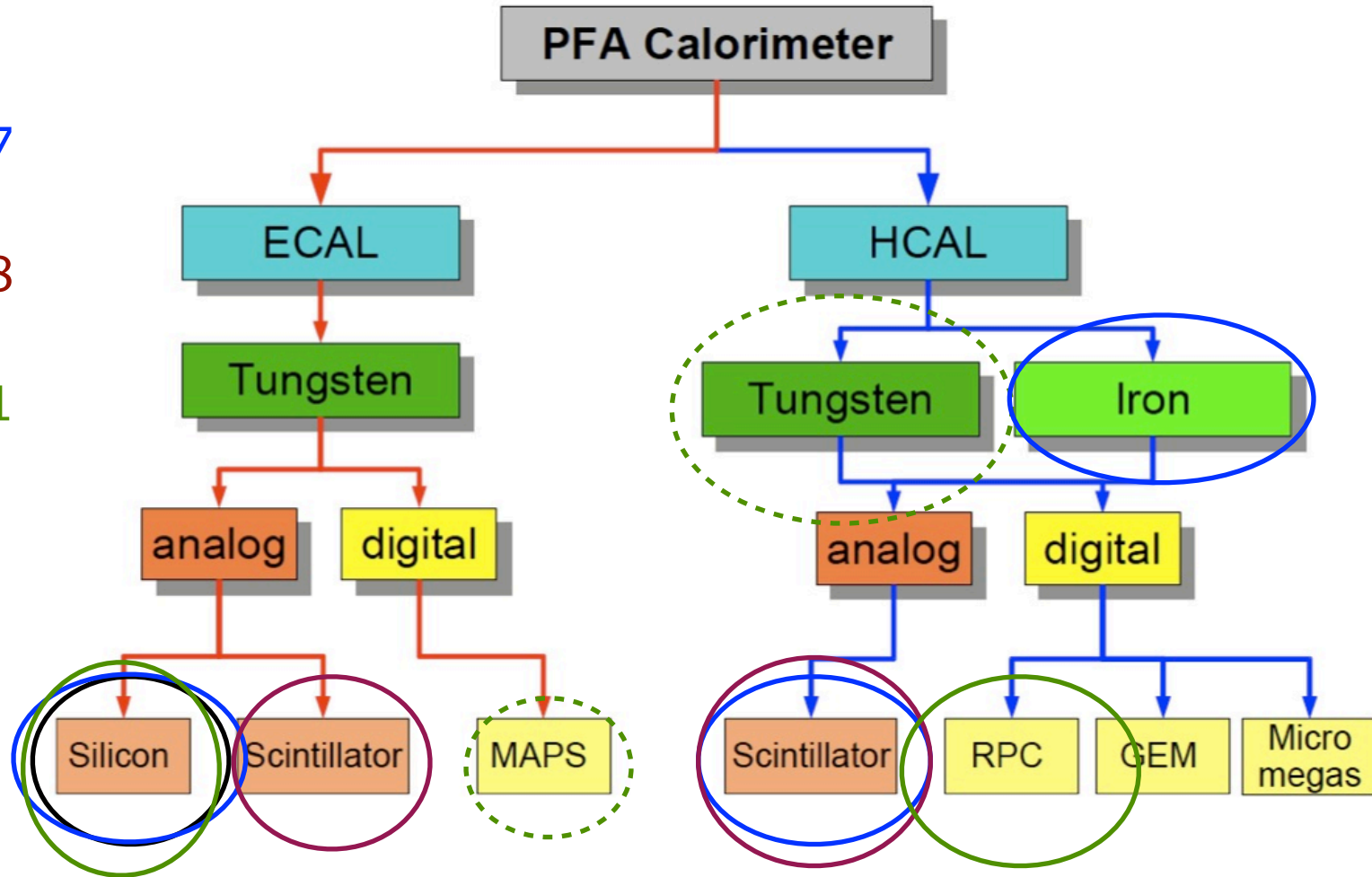
Goals 2012

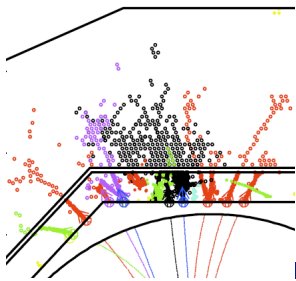




Goals 2012

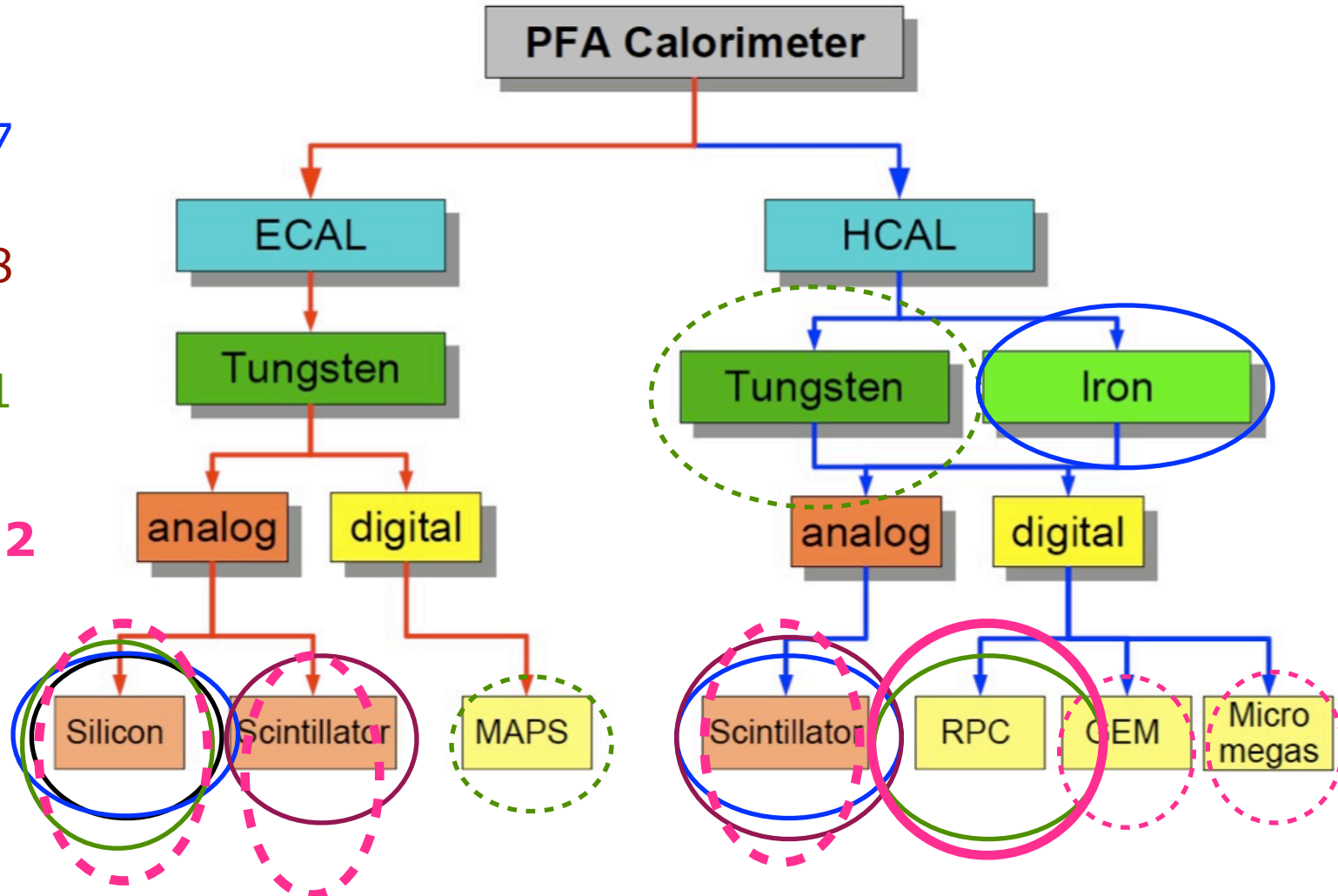
- 2005
- 2006-07
- 2007-08
- 2010-11



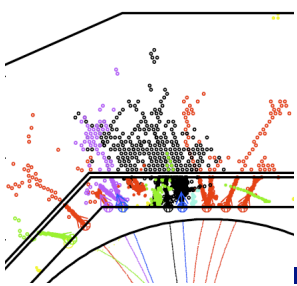


Goals 2012

- 2005
- 2006-07
- 2007-08
- 2010-11
- **2011-12**



Test beams

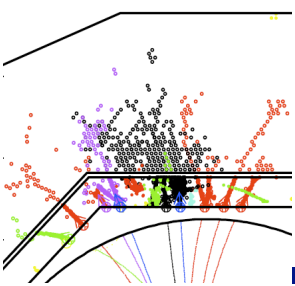


- Requested 20 weeks for 2011 at CERN
- Got less than half

- 2012 data essential for DBD
- Should agree on deadlines for test beam results fall 2012



Outlook



- We foresee to propose 2 ECAL and 2 HCAL baseline options
- The sDHCAL is expected to be the only full size second generation prototype exposed to test beams
 - data taking and analysis schedules are ambitious
 - build validation on DHCAL results, too, combined runs
- The Si W ECAL, Scint W ECAL and Scint AHCAL have physics prototype test beam results and prepare technical prototype demonstrators
 - Si ECal and Sci E/HCal: common chip development
 - Sci E/HCal: common boards, Si/Sci ECAL common W mechanics
 - will rely on sDHCAL for proof of system aspects
- Combined data: SiW E + A/D HCAL, Si/Sci E + AHCAL only
- Alternatives: proof of principle for MAPS, GEMs, μ -megas

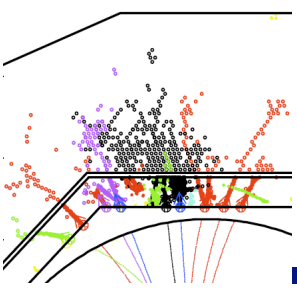
Outlook



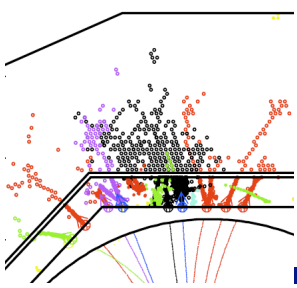
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Back-up slides

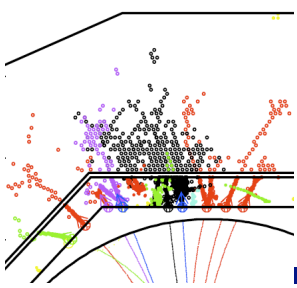
Test beams



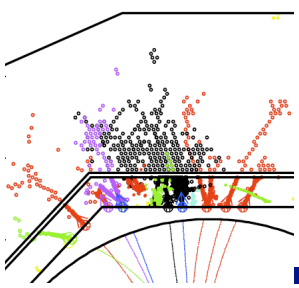
Test beams



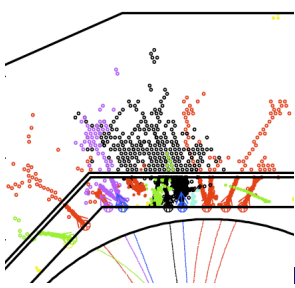
Test beams



Test beams



Test beams



Test beams

