

Plans of CALICE

Calorimeter for ILC

An outlook on the next few years

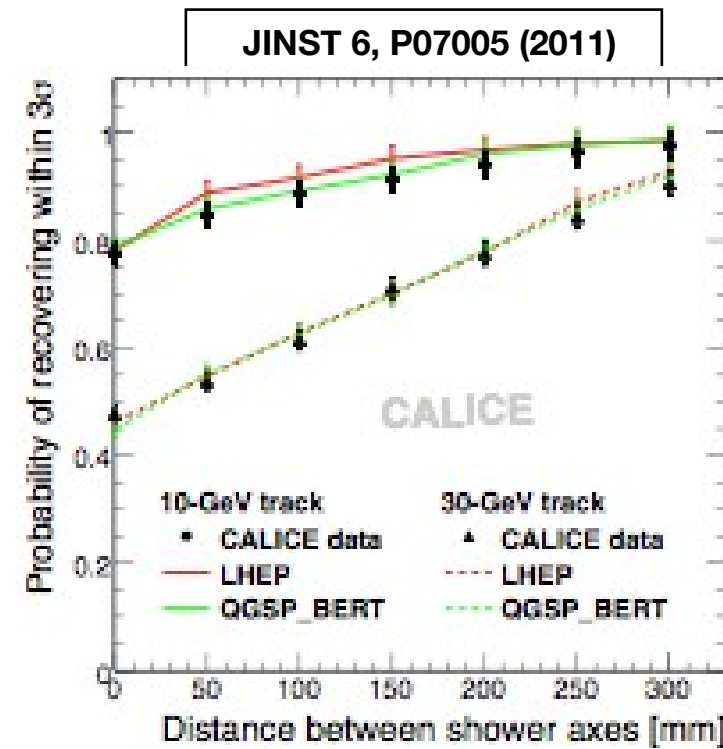
Roman Pöschl



LCWS 2021 – March 2021

Physics Prototypes

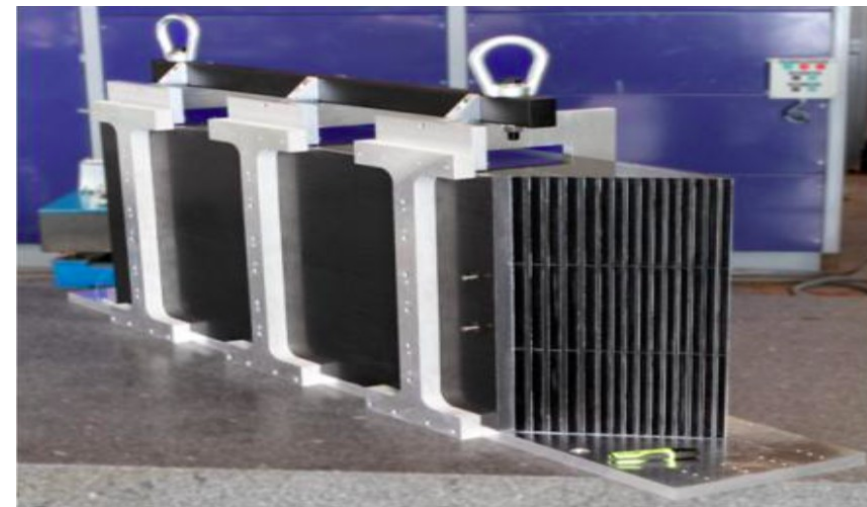
2003 - 2012



- Proof of principle of granular calorimeters
- Large scale combined beam tests
- Inspiration for CMS HGCAL

Technological Prototypes

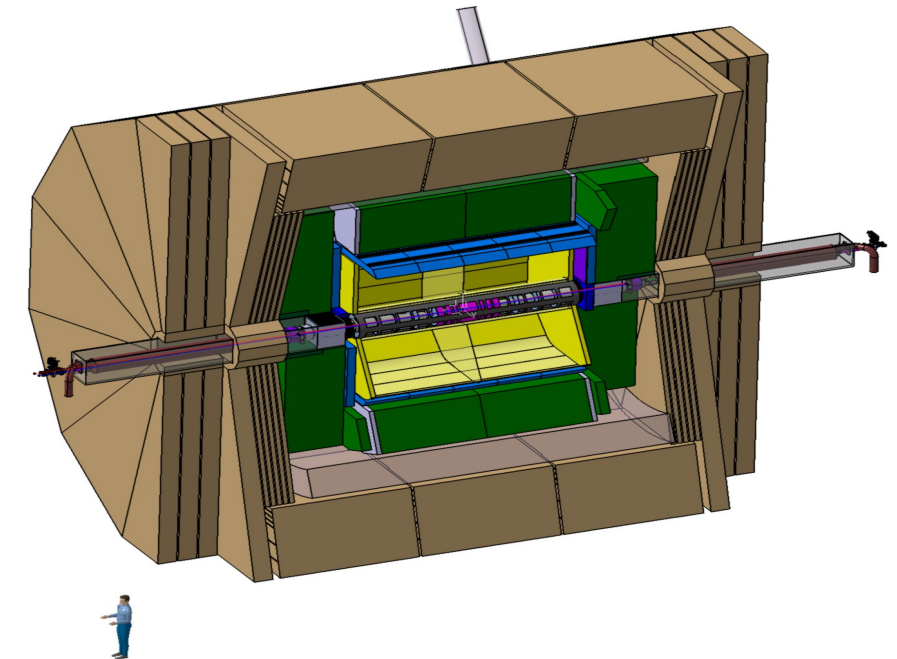
2010 - ...



- Engineering challenges
- Higher granularity
- Better sensitivity (lower noise)

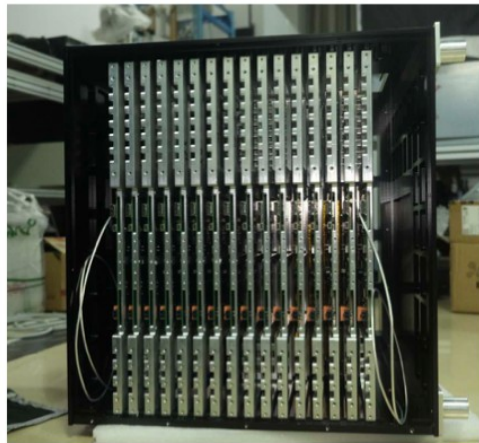
Current period

Higgs factory detector

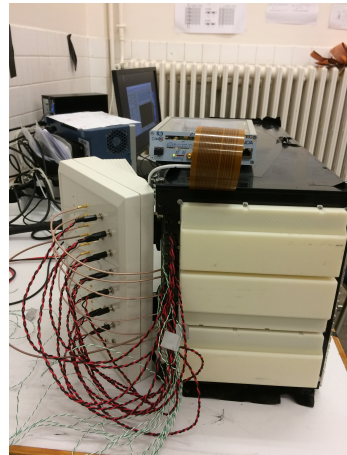


- The goal
 - Typically 10^8 calorimeter cells
- Compare:
 - ATLAS LAr $\sim 10^5$ cells
 - CMS HGCAL $\sim 10^7$ cells

- Complete beam test program with current technological prototype (size ~up to 1m³, details in backup)



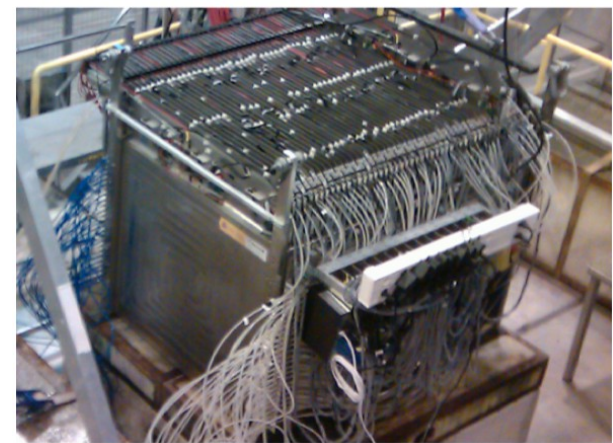
ScECAL



SiECAL

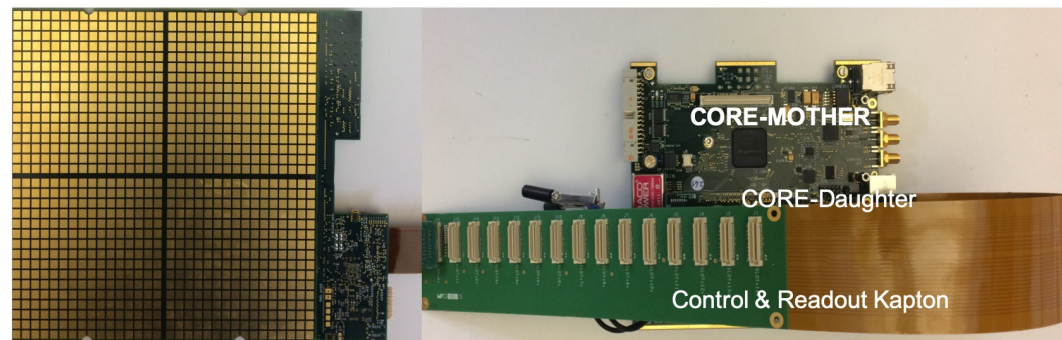
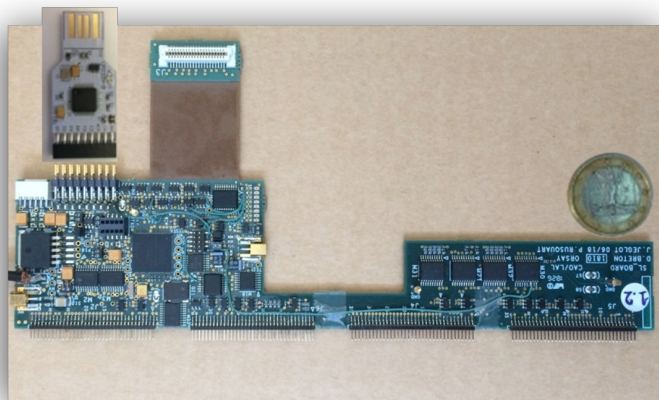


AHCAL



SDHCAL

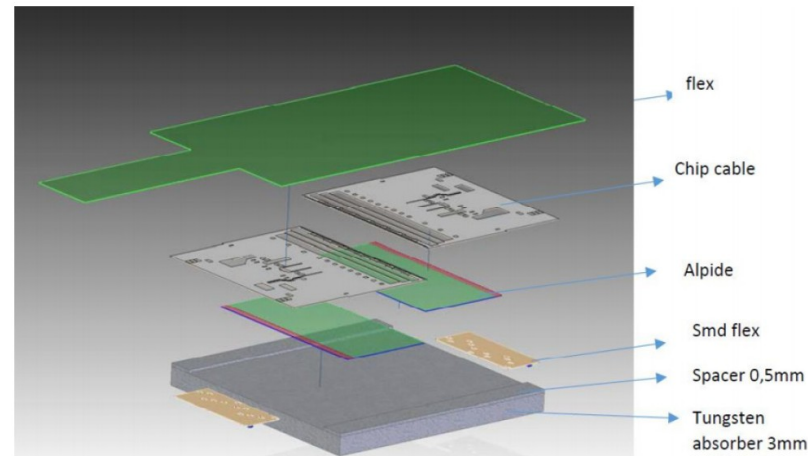
- Implies combined testbeams with high energetic electrons and hadrons of (more or less) **real size calorimeter prototypes** for PFA
- Develop and optimise hardware that meets tight space and power requirements in LC Detectors



- **First set of components are at hand for SiW ECAL**
- Scrutinisation and adaptation for other systems

Common hardware development and comparison of technologies under one roof is the big strength of CALICE

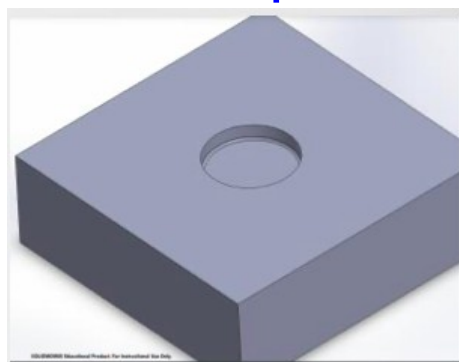
- Resuming the program of ultra high granularity (started in 2007 in CALICE)



- mTower Prototype MAPS based ALPIDE ASIC
 - See also Flash Talk by Fergus Wilson

- Dual Readout out goes highly granular

Next step:



3x3 cm² Glass tile



3x3 cm² Plastic Tile

- Dual Readout with “CALICE size tiles”
 - Additional information for PFA while preserving longitudinal granularity

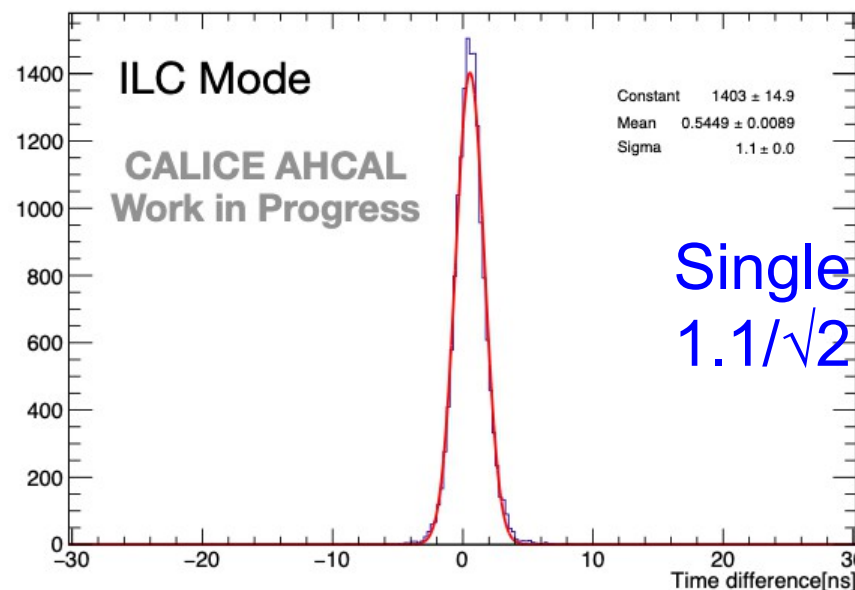
- C. Gatto, NIU
 Integration into beam test program described on previous page!?

Pioneered by LHC Experiments, timing detectors are/will be also under scrutiny by CALICE Groups

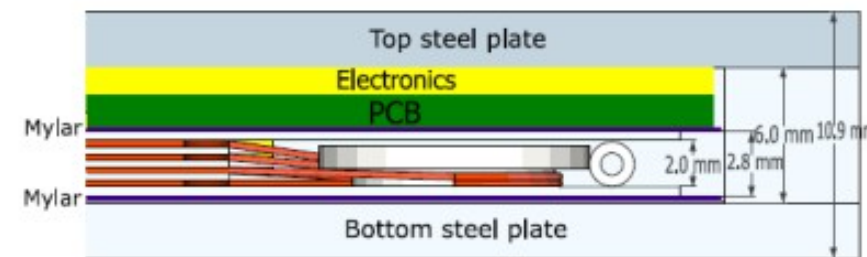
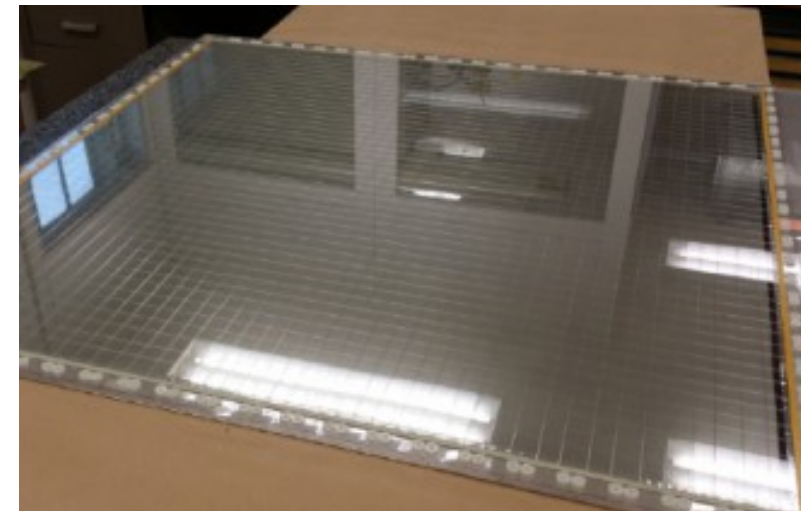
Hit time resolution:

Results from 2018 beam test of AHCAL with muons

Clock frequency 5 MHz, Powering pulsing



Single channel resolution
 $1.1/\sqrt{2} = 0.78\text{ns}$

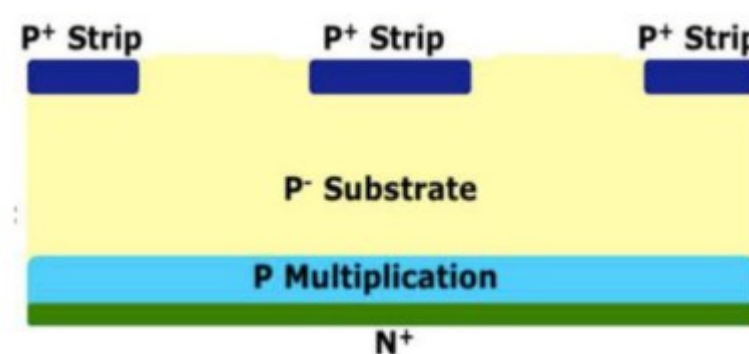


Under development:
 GRPC with PETIROC

- < 20ps time jitter
- Developed for CMS Muon upgrade

Inverse APD as LGAD?

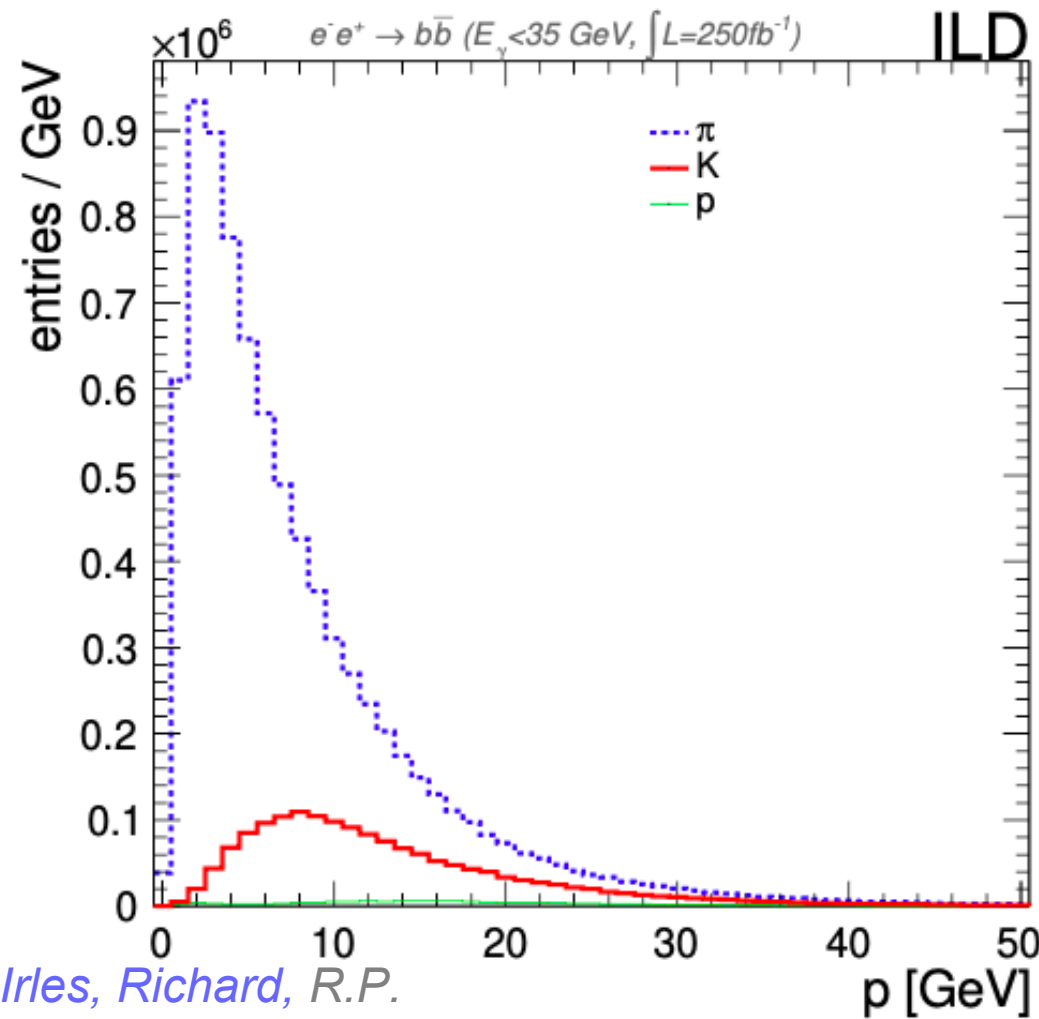
- We need to understand quickly how much “timing” is really needed
 - Average timing O(100ps) in all layers
 - Excellent timing O(30ps) or better in a few layers
- This drives the hardware development



Inverse APD
 by Hamamatsu

Gain ~ 50

Momenta and abundance of pi/K/p in ee->bb @ 250 GeV



ILD: Irlas, Richard, R.P.

Available time resolution with calos

Available "now"

Doable with Intensive R&D in 5-10 years

Requires a new breakthrough

Difference in ToA at ILD Calos

Barrel, R=1.6m, B=4T, cos θ =0

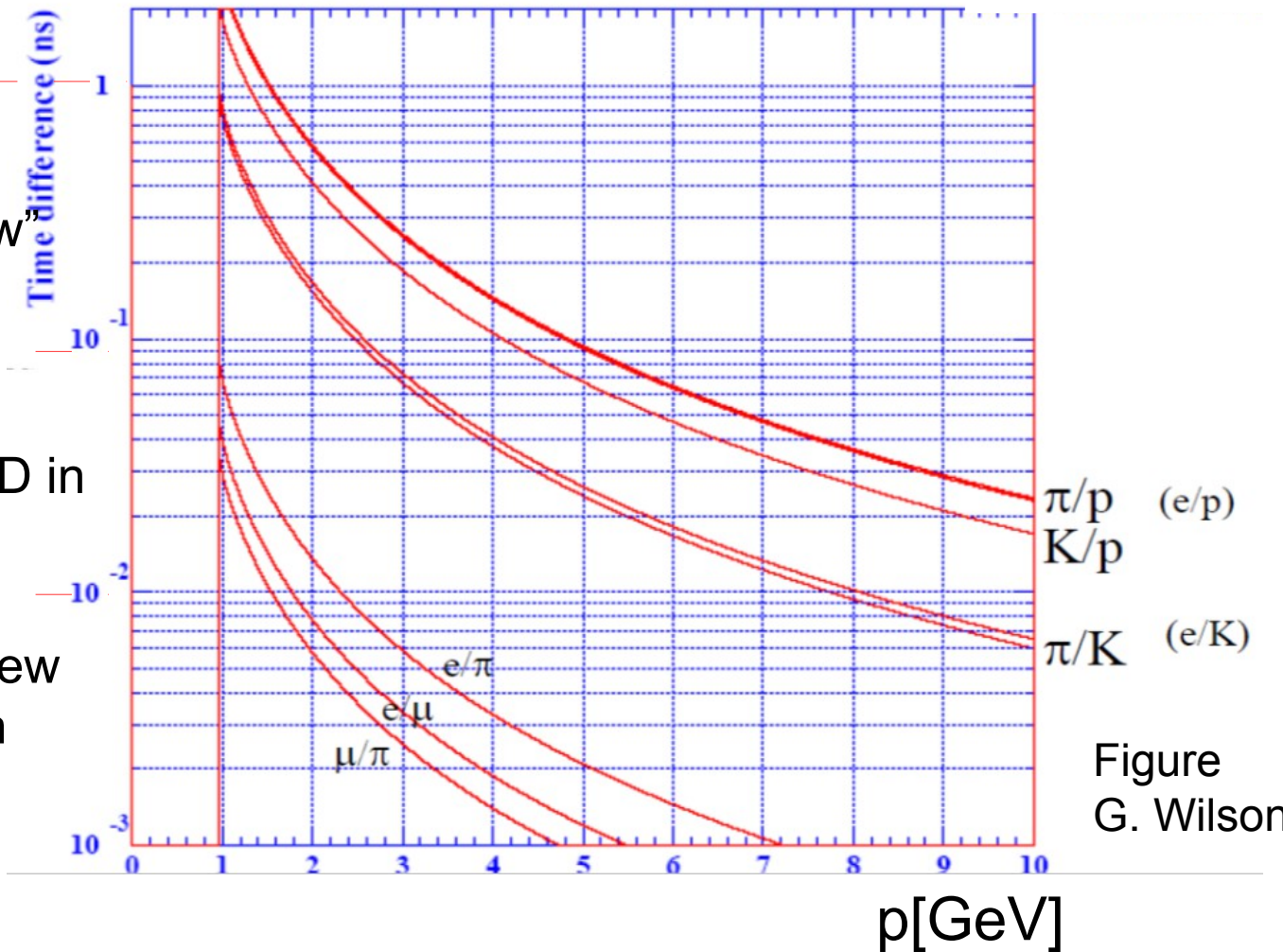


Figure G. Wilson

- Particle momenta (at 250 GeV) have peak below 10 GeV but long tail to higher energies
- Realistically ToF measurements will be (in foreseeable future) limited to particles below 10 GeV
 - Note that, apart from power consumption, in a final experiment one needs to control full system
- **Momenta above 10 GeV require a real breakthrough and maybe even radically new approaches**
- Mandatory if ToF should work at and well above 250 GeV i.e. at Linear Collider energies

- **CALICE pioneered R&D on highly granular calorimeters**
 - Main target Linear Collider Detectors
 - R&D since 2002 starting with “physics prototype” phase
 - Large scale prototypes with rich set of results obtained in combined beam tests
 - Successful R&D inspired CMS to opt for a highly granular calorimeter for the LHC Phase 2 Upgrade
 - Further Spin-offs ALICE FOCAL, DUNE ND, Belle II CLAWS
- **Technological prototypes address technological challenges of highly granular calorimeters**
 - High level integration => dense detector layers
 - Proven stable operation of prototypes
 - Power pulsing is established but may need further scrutiny
 - Versatile mechanics to avoid inactive detector zones (sorry for having been short on this)
 - Timing capabilities studied and will be exploited further
- **Ways forward (not mutually exclusive)**
 - Finalising R&D and accompany Linear Collider experiments during technology selection
 - Common beam tests
 - Addressing new challenges at Circular Colliders or the Electron Ion Collider
- **Precious feedback from LHC Upgrades**
 - System integration, timing, active cooling
- **CALICE federates many different proposals under one roof which facilitates comparison and technology evaluation**
 - It is this sense (nearly) unique in worldwide detector R&D

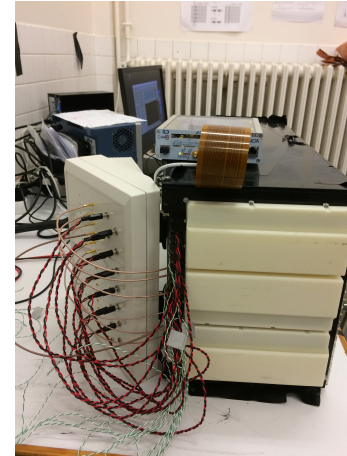
Backup

- Particle flow is driving concept for most of the detector designs for Higgs factories
- Introducing timing for Higgs factories may assist PFA but has implications for detector design
- What is better?
 - Excellent timing of the order of 10-30ps in a few layers at e.g. the beginning of a calorimeter or
 - Average timing of the order of 100-200ps in the entire detector
- Guidance has to come from GEANT4 simulations that implement properly the time structure of hadronic showers
- The specific needs for timing would trigger dedicated hardware developments
- Given current hardware constraints CALICE will be able to validate G4 physics list at the 500ps - 1ns level
 - With large prototypes
 - Maybe better with smaller dedicated setups

(Main) Technological prototypes



ScECAL



SiECAL



AHCAL



SDHCAL

Name	Sensitive Material	Absorber Material	Resolution	Pixel size/mm ³	~Layer size ^{**} /cm ³	~Layer depth/X ₀	~Layer depth/λ _r	# of Pixels/layer	# of layers	Comment
ScECAL	Scintillator	W-Cu Alloy	Analogue, 12bit	5x45x2	23x22x0.5	0.73	0.03	210	32	2x16 x and y strips
SiECAL	Si	W	Analogue, 12bit	5.5x5.5x0.3 (0.5, 0.65)	18x18x0.24 (-0.63)	0.6-1.6	0.02-0.06	1024	≥22	Can be run in different configs.
AHCAL	Scintillator	Fe*/W	Analogue, 12bit	30x30x3	72x72x2/1.4	1/2.9	0.11	576	38	Running with Fe and W
SDHCAL	Gas	Fe*	Semi-digital 2bit	10x10x6	100x100x2.6	1.1	0.12	9216	48	

*Stainless Steel

**Only absorber + sensitive material for z direction, air gaps, electronics discarded here (would add 5-10%)