Test beam simulations for physics validation

Status report, 30.10.2018

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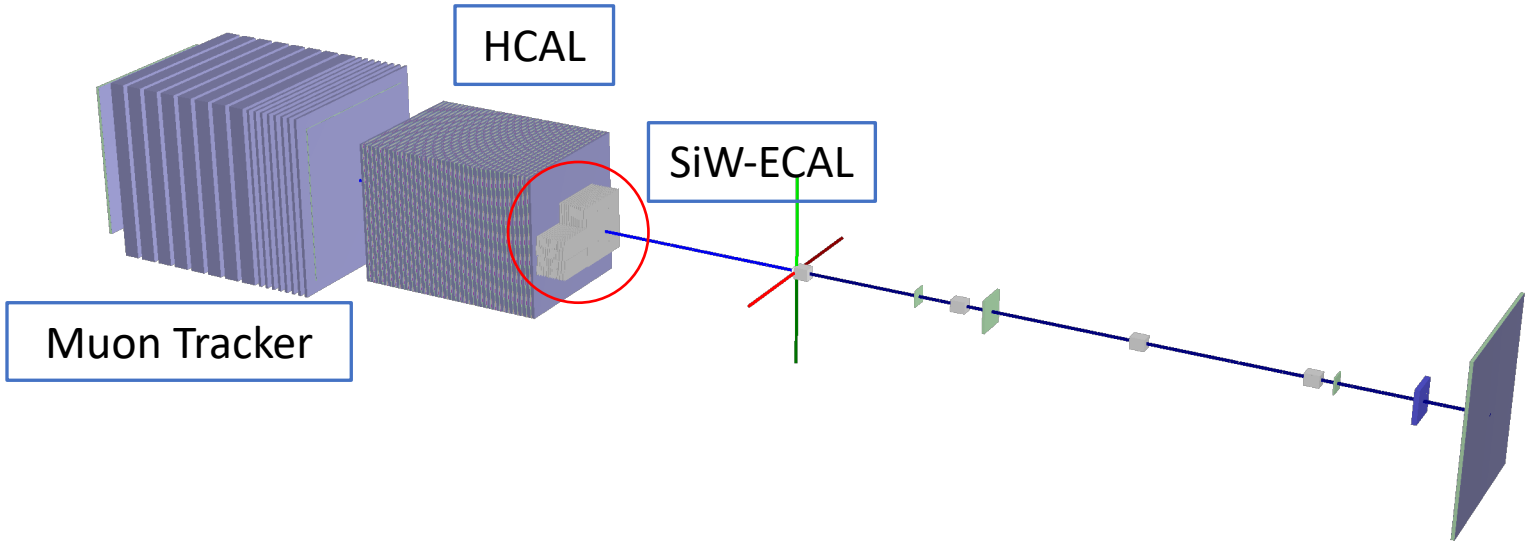
Overview/Reminder

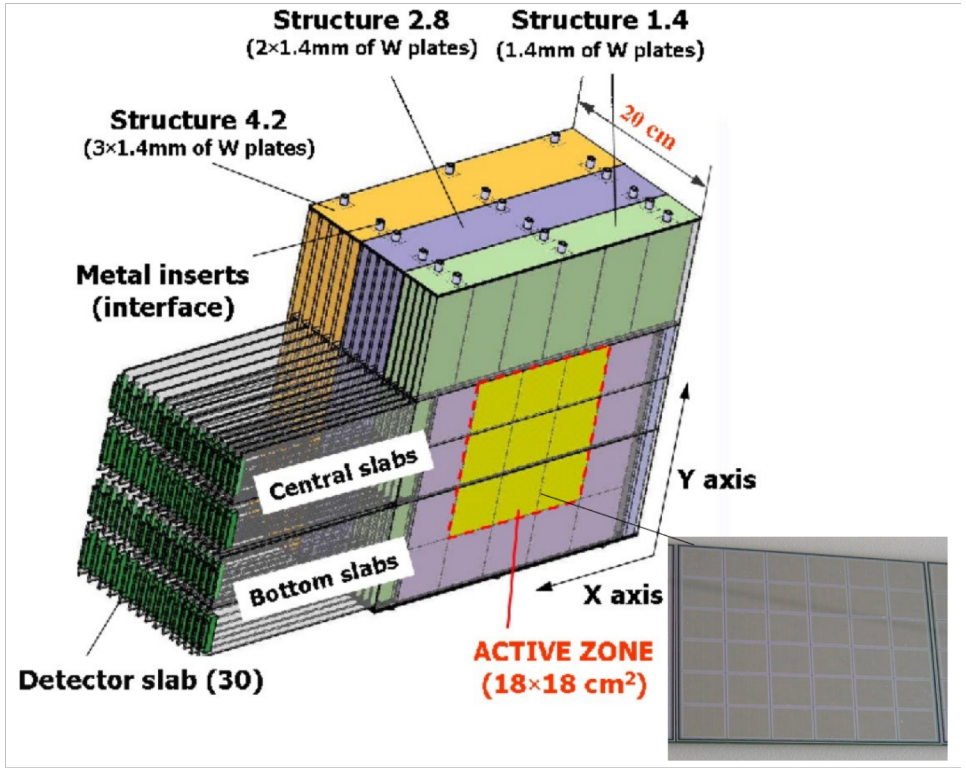
- Goal: **standalone test beam simulations** to be run on a regular basis
- **Calorimeter test beams** of interest covering a wide range of energy
  - CALICE
  - ATLAS Hadronic Endcap Calorimeter (HEC) & Tile Calorimeter (TileCal)
- **Challenge**: get access to data and simulation tools or retrieve TB setup geometry information ➡ efficient communication with collaborations is key!

CALICE Calorimeter Prototypes

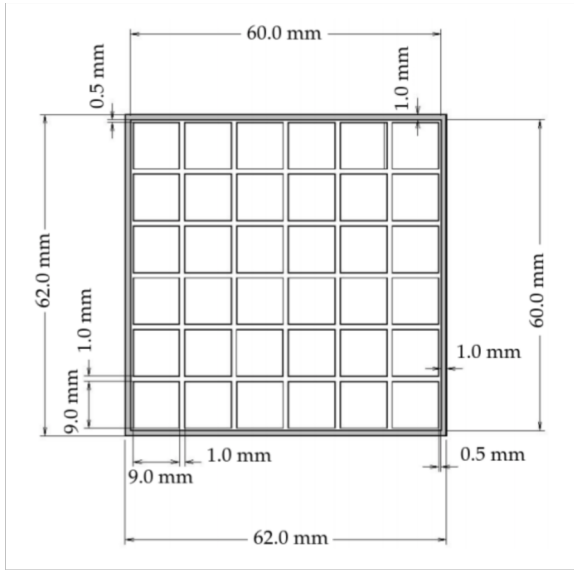
- This work: **Si-W ECAL** calorimeter prototype to **test first hadronic interactions & hadronic interactions @ low energies**



TB geometry representation from gdml output of MOKKA simulation software



The CALICE SiW-ECAL

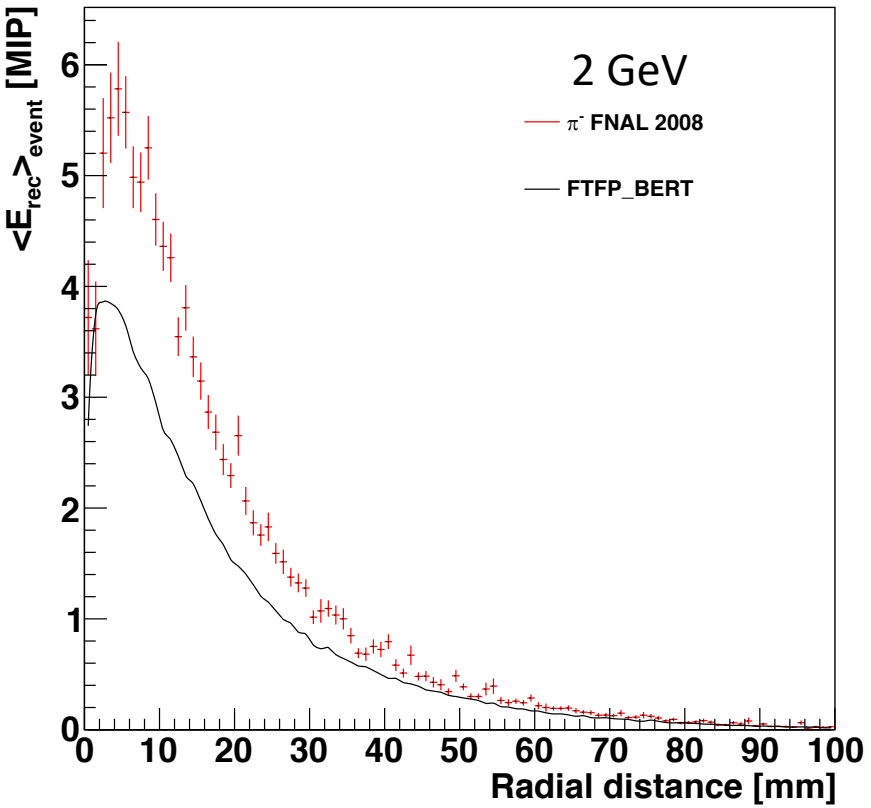


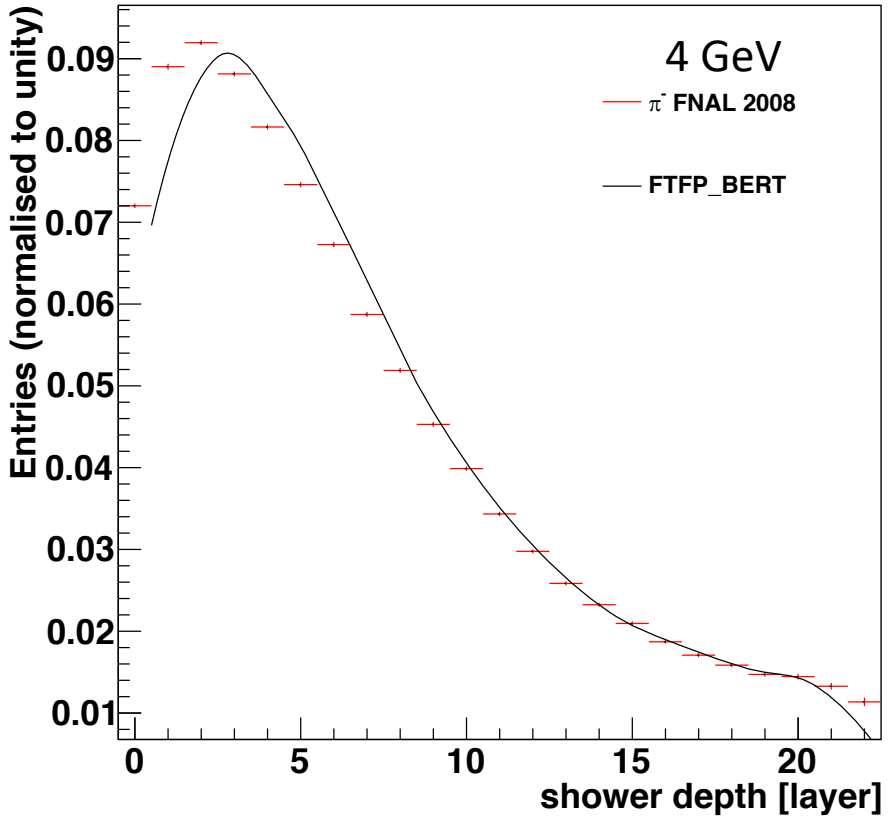
- Active material: 525µm Si P-I-N diodes
- 3 Modules with different absorber thickness: W plates 1.4 mm, 2.8 mm & 4.2 mm, total thickness 24.6 X_0 = 1 λ_{Int}
- 30 layers with 1 x 1 cm^2 granularity: total active area → 9720 pixels

- π- test beam @ Fermilab in 2008: 2 – 10 GeV, published in B. Bilki et al., NIM A794 (2015) 240-254; access to data via some pre-analysed ROOT files
- Standalone simulation of test beam setup exists on gitlab: ep-sft/calice-siw-ecal-tb, contains information on observables (hit position, energy) via hits in sensitive detector volume with pixel precision; analysis scripts to obtain physical observables
- Currently being integrated in the validation framework (thanks Dmitri)

CALICE – Existing Observables

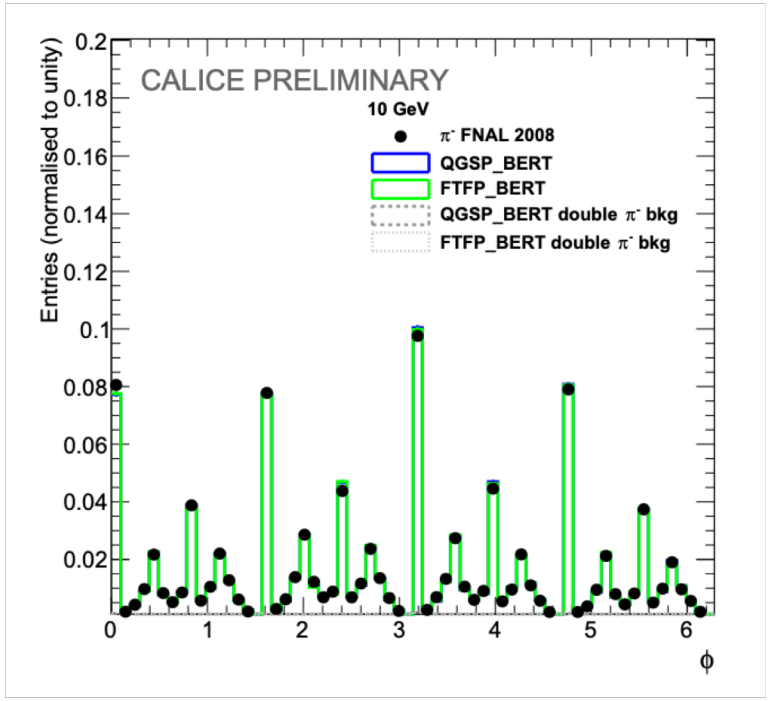
Lateral shower & longitudinal shower shapes, mean values as function of beam energy

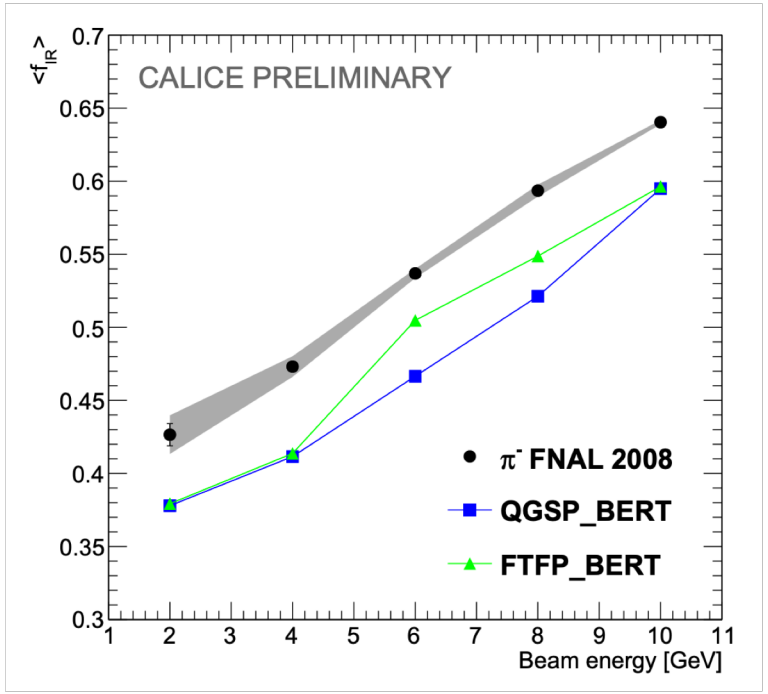




CALICE – Potential Extension…

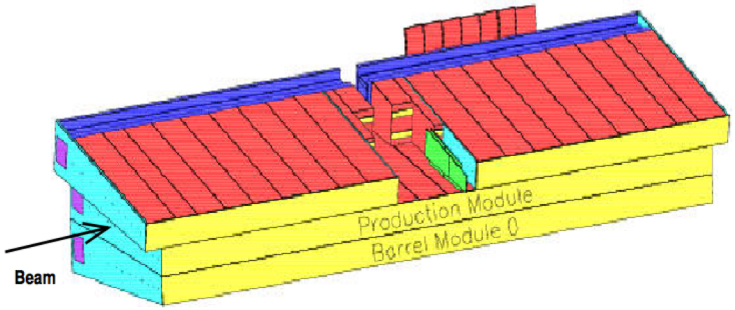
- CALICE Collaboration very happy about the results, expressed interest to elaborate and extend to other quantities such as angular distributions etc.





ATLAS TileCal Test Beam

- Fe-scintillator: 4 and 5 mm iron plates sandwiched by 3 mm scintillator tiles with periodicity of 18 mm
  - Test beam setup: one production barrel module of 5.64 m & two extended barrel modules of 2.93 m on top
  - Longitudinally showers fully contained; lateral containment 99 % (2 λ thickness) thanks to orthogonal
- SPS test beam in 2002: π^+ and p beam 20-180 GeV



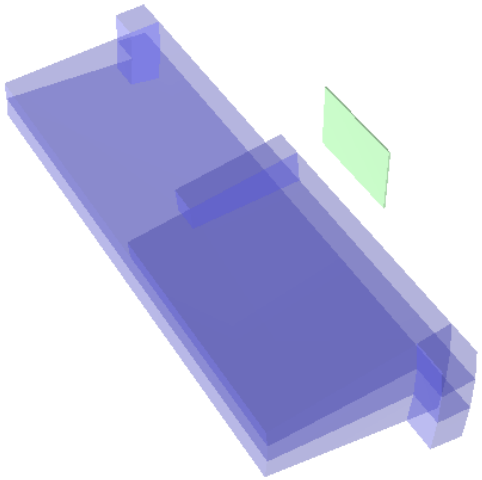
ATL-TILECAL-PUB-2007-008

Figure 2: Configuration of the calorimeter modules in the test beam set-up. The arrow indicates the direction of the impinging particles.

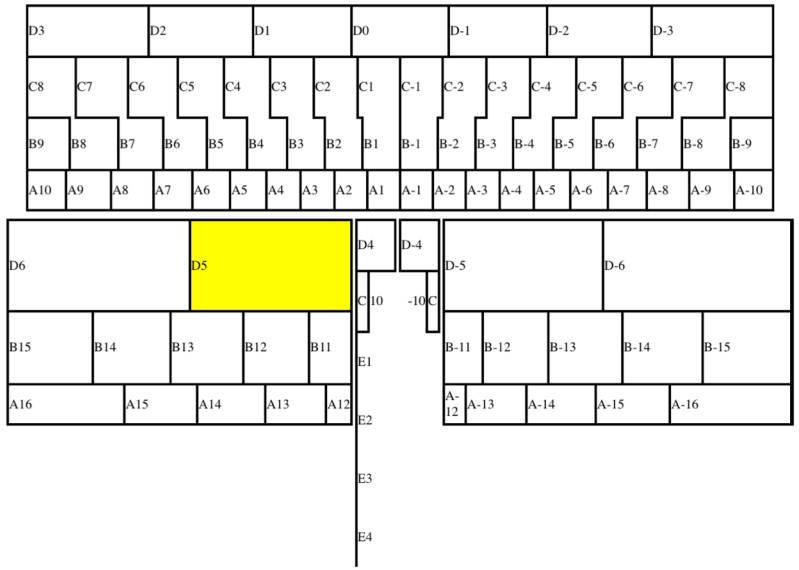
Information on:
- longitudinal shower profiles
- lateral spread (regression tests?)
- Energy resolution

ATLAS TileCal Simulation Code

Access to original code granted, however, original code strongly embedded in Athena framework, approach: GDML geometry file → standalone simulation exists, some analysis needs to be added



MB	Digi	DMU	LBA, LBC Ch	PMT	Cell	EBA, EBC Ch	PMT	Cell	EBA15, EBC18 Ch	PMT	Cell
4	8	0	0	1	D0	0	1	E3	0	1	
			1	2	A1-L	1	2	E4	1	2	
			2	3	BC1-R	2	3	D4-R	2	3	
		1	3	4	BC1-L	3	4	D4-L	3	4	
			4	5	A1-R	4	5	C10-R	4	5	C10-R
			5	6	A2-L	5	6	C10-L	5	6	C10-L
	7	2	6	7	BC2-R	6	7	A12-R	6	7	A12-R
			7	8	BC2-L	7	8	A12-L	7	8	A12-L
			8	9	A2-R	8	9	B11-R	8	9	B11-R
		3	9	10	A3-L	9	10	B11-L	9	10	B11-L
			10	11	A3-R	10	11	A13-R	10	11	A13-R
			11	12	BC3-L	11	12	A13-L	11	12	A13-L
3	6	4	12	13	BC3-R	12	13	E1	12	13	E1
			13	14	D1-L	13	14	E2	13	14	E2
			14	15	D1-R	14	15	B12-R	14	15	B12-R
		5	15	16	A4-L	15	16	B12-L	15	16	B12-L
			16	17	BC4-R	16	17	D5-R	16	17	D45-R
			17	18	BC4-L	17	18	D5-L	17	18	D45-L
	5	6	18	19	A4-R	18	19		18	19	E3
			19	20	A5-L	19	20		19	20	E4
			20	21	A5-R	20	21	A14-R	20	21	A14-R
		7	21	22	BC5-L	21	22	A14-L	21	22	A14-L
			22	23	BC5-R	22	23	B13-R	22	23	B13-R
			23	24	A6-L	23	24	B13-L	23	24	B13-L
2	4	8	24	27	D2-R	24	27		24	27	
			25	26	D2-L	25	26		25	26	
			26	25	A6-R	26	25		26	25	
		9	27	30	BC6-L	27	31		27	31	
			28	29	BC6-R	28	32		28	32	
			29	28	A7-L	29	28		29	28	



Cell->PMT mapping

Energy calculation in Tile TB

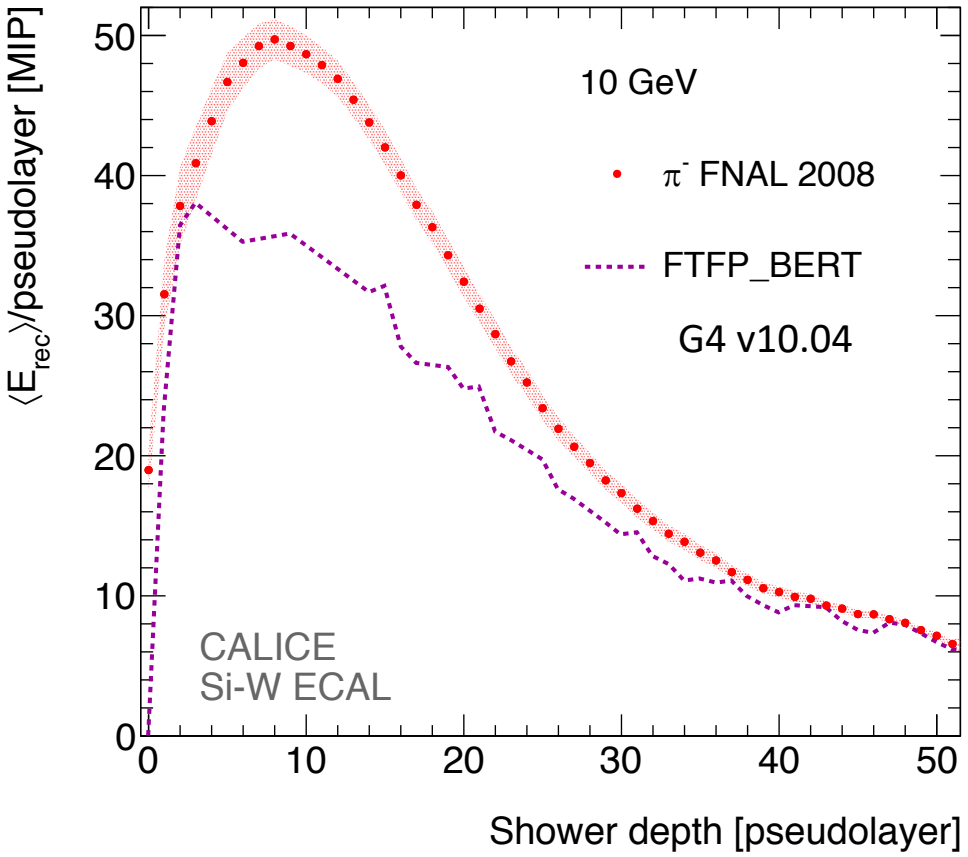
- Each side (positive & negative) of Barrel Module connected to 48 PMTs but only 45 used, with each cell (A, B, C and D) being connected to 2 PMTs
- Select events with total energy within 3 sigma around peak
- Get energy distribution as function of depth in Barrel Module 0; depth is taken as size of the B sub-cell
- Some PMTs not used in Barrel Module
- For longitudinal shower only Barrel 0 considered and multiplied by 2
- Truncate tail of the distribution where energy ~ at noise level

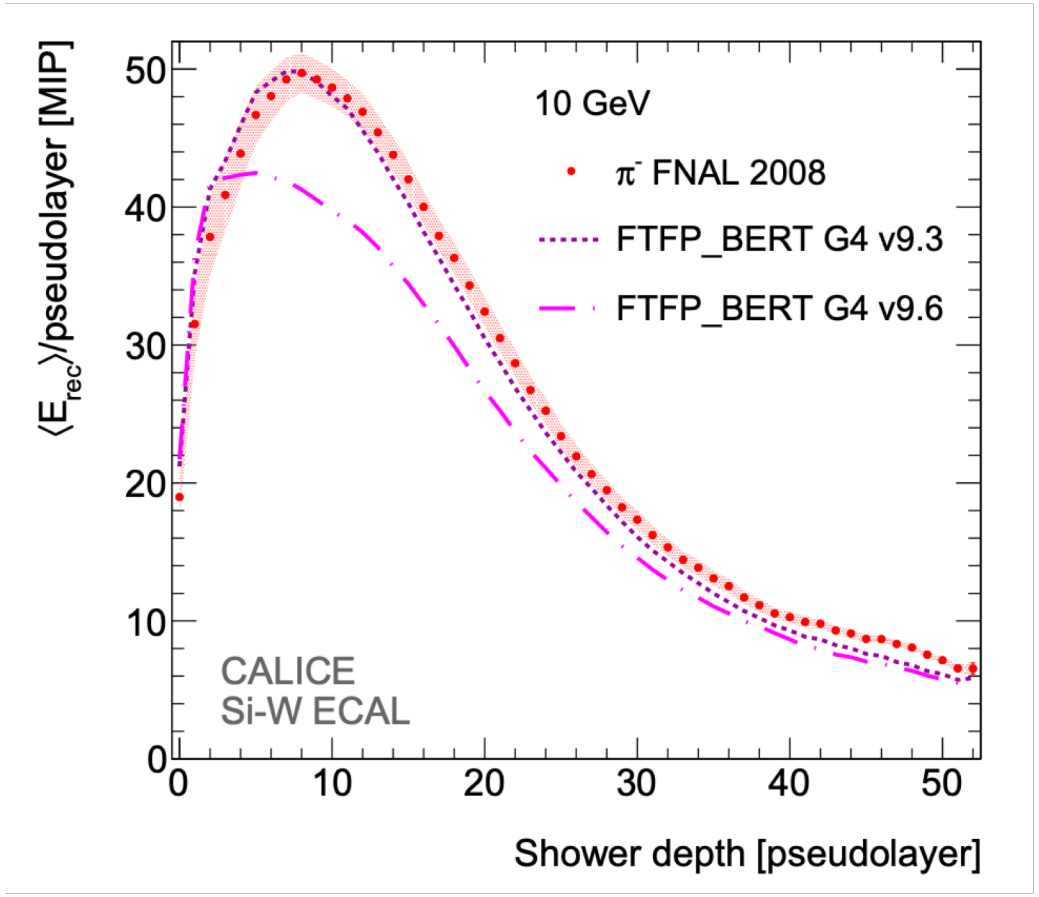
Conclusions & Outlook

- **3 test beam candidates** for physics validation
  - energy region covered: 2-180 GeV
- **CALICE** TB simulation done, simulation code & some analysis scripts on gitlab; integration into validation framework currently being done
- **ATLAS TileCal TB** geometry files retrieved as GDML, standalone simulation code using CALICE approach ”under construction”; details such as mapping of TileCal cells and PMTs still needs some work

Backup

CALICE – longitudinal shower shapes





ATLAS Hadronic Endcap Calorimeter

- Simulation software as received originally already standalone
- Retrieved GDML file of test beam setup, construction simulation « skeleton » around; original code can be made to run but needs a bit of work
- SPS test beam 2000-2001
  - electrons: 6-150 GeV
  - charged pions: 10-200 GeV
  - muons: 120,150,180 GeV

Access to
- Longitudinal shower shape
- Energy response and resolution
- Hadronic shower shapes (fraction of energy in a HEC layer w.r.t. total energy reconstructed in pion cluster)
- e/π ratio
- lateral spread (regression tests?)

ATLAS HEC Test Beam

- HEC: Liquid Argon sampling calorimeter with parallel Cu absorber plates, 8.5 mm gap between absorber plates
- Two modules: front HEC1 (82 cm length, 25 mm absorber thickness) & rear HEC2 (96 cm length, 50 mm absorber thickness)

NIM A 482 (2002) 94-124

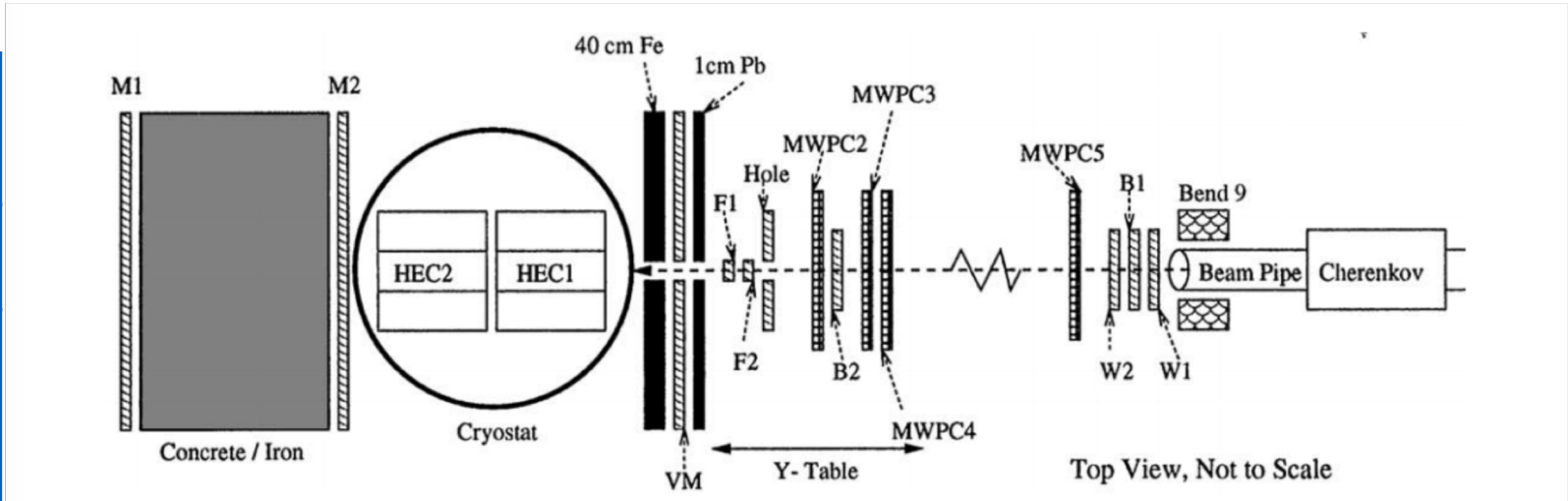


Fig. 5. The setup used for data taking in the beam tests. The trigger is defined by the scintillation counters B1, F1 and F2 and the scintillation counter walls VM, M1 and M2.

- Total thickness of calorimeter is 103 radiation lengths X_0 and 10 absorption lengths λ
- transverse granularity is $\Delta\eta \times \Delta\phi = 0.1 \times 2\pi/64$ $(0.2 \times 2\pi/32)$ for the pseudorapidity region $|\eta|<2.5$ ($|\eta|>2.5$)