HCAL performance studies and software integration

FCC-hh detector meeting February 2017

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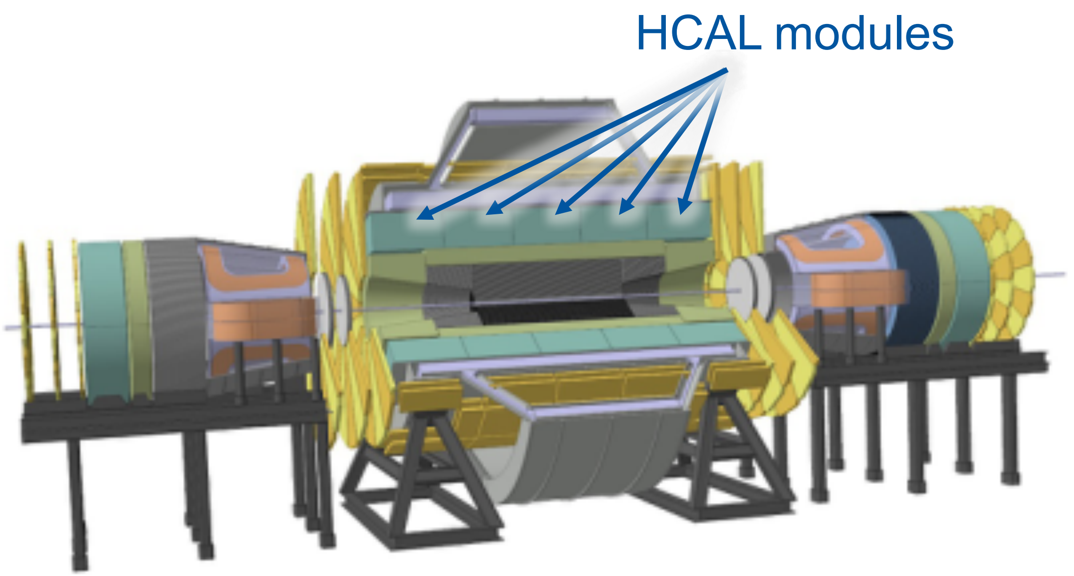
FCC HCAL barrel based on ATLAS TileCal

Design until FCC week 2016:

- 12m bore solenoid (6T)
- Active HCAL depth ≈ 2m
- 10λ + 2λ ECAL ≈ 12λ



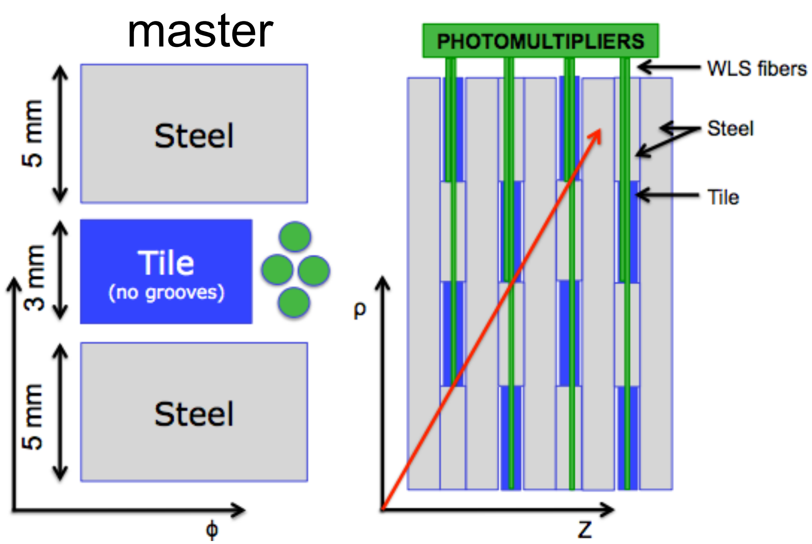
Current baseline:

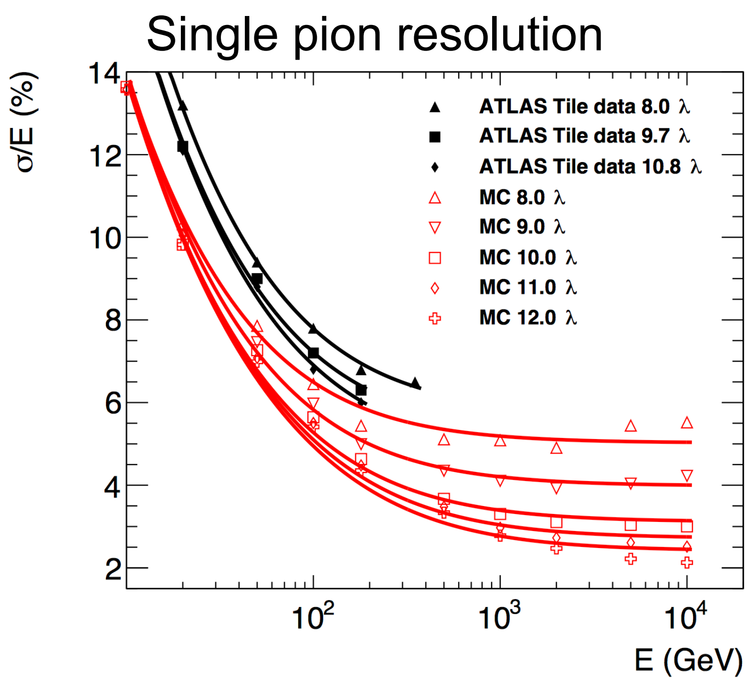
- 10m bore solenoid (4T)
- Active HCAL depth 1.8m within $(2.85 - 4.65)m$
- 9.0λ + 2λ ECAL = 11λ

Old FCC-hh detector design

Study of impact of containment by increasing HCAL depth

→ 12λ favourable



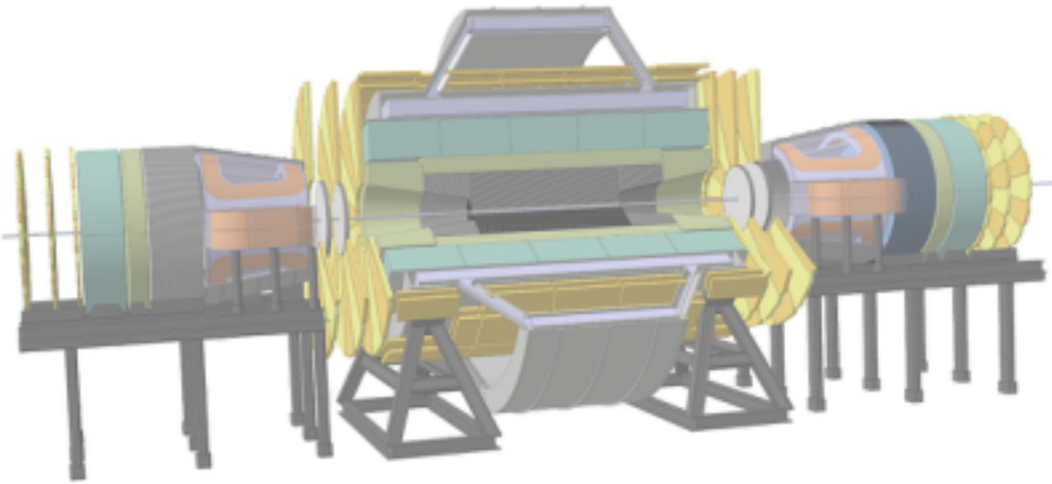


2016 JINST 11 P09012

New FCC-hh HCAL requirements

Current baseline:

- 10m bore solenoid (4T)
- Active HCAL depth 1.8m
- 9.0λ + 2λ ECAL $= 11\lambda$



Idea

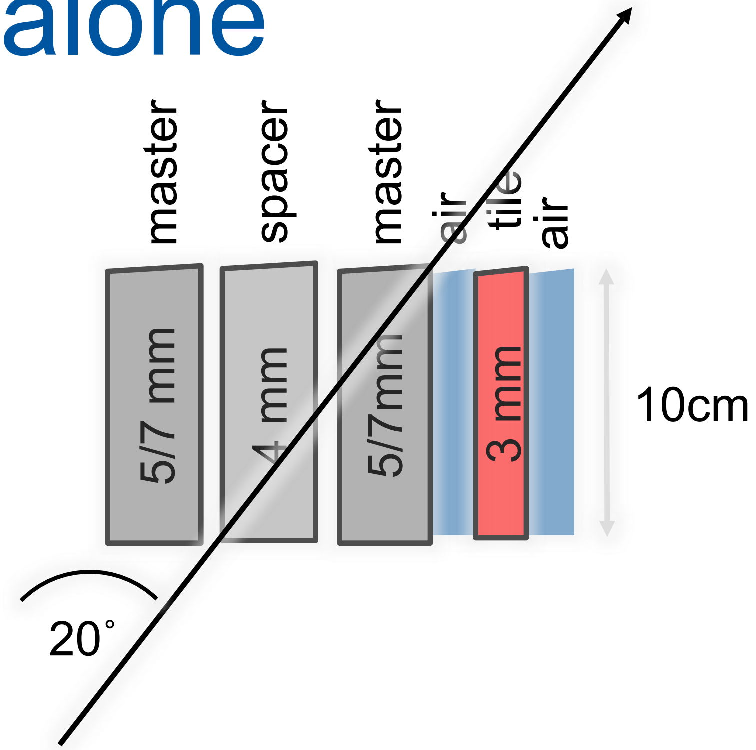
Increase of #interaction lengths by increasing Fe/Sci ratio from 4.7 to 6 (master thickness from 5 to 7mm)

Fe/Sci ratio	**4.7**	**6.0**
λ_{eff}	**20.6cm**	**19.8cm**
Active depth $(\eta = 0)$	180cm	180cm
$\#\lambda\ (\eta = 0)$	**8.7**	**9.1**

HCAL Geant4 standalone

- FTFP_BERT physics list
- No ECAL
- Changes to earlier study:
  - Radius:
    - from (2.5 - 6)m to (3.6 - 5.4)m
    - from 35 to 22 layers
  - Master thickness:
    - from 5 to 7mm

    → sequence from 18 to 22mm



Fe/Sci ratio	**4.7**
λ_{eff}	**20.6cm**
Effective depth	180cm * arccos(20˚)
$\boldsymbol{effective\ \#\lambda}$	**9.3**

10,20,100 and 2000GeV single π's

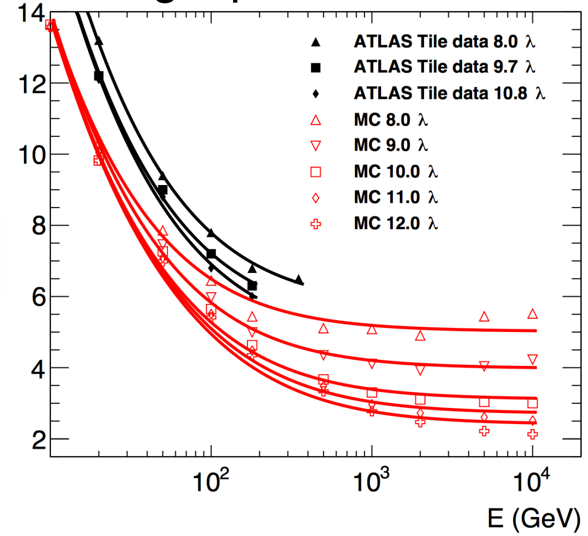
Validation

Fe/Sci ratio	**4.7**
Master th.	5mm
Scintillator th.	3mm
Sampling fraction	2.5%
λ_{eff}	**20.6cm**
Effective depth	174.2cm * 1.06
$\boldsymbol{effective\ \#\lambda}$	**9.0**
σ/E	$\frac{42.6\%}{\sqrt{E}} \oplus 3.9\%$

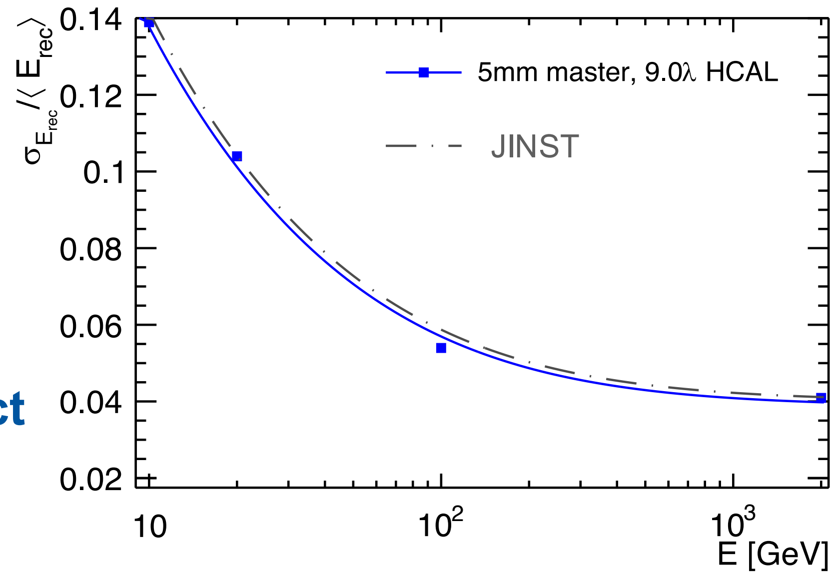
Containment of hadron showers in FCChh paper
2016 JINST 11 P09012

	Sigma	
Depth (λ)	a (%GeV$^{1/2}$)	c (%)
8	41	5.0
9	43	4.0
9.5	-	-
10	43	3.1
11	43	2.7
12	43	2.4

Single pion resolution



Close to perfect agreement

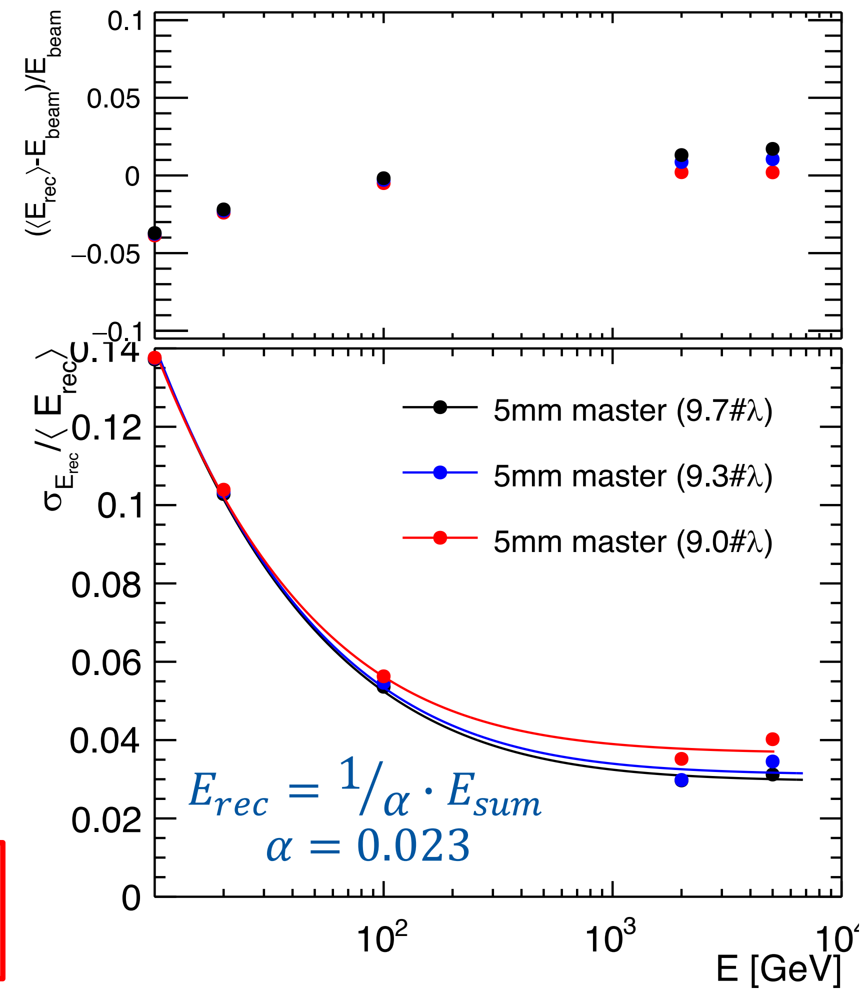


Impact of larger Fe/Sci ratio

- By increasing Fe/Sci ratio
  1. Decreased sampling fraction 2.5% → 1.8%
  2. Increased #interaction lengths 9.3 → 9.7

→ Check of impact of increased $\#\lambda_n$ on linearity:
- Leakage is visible > 100GeV

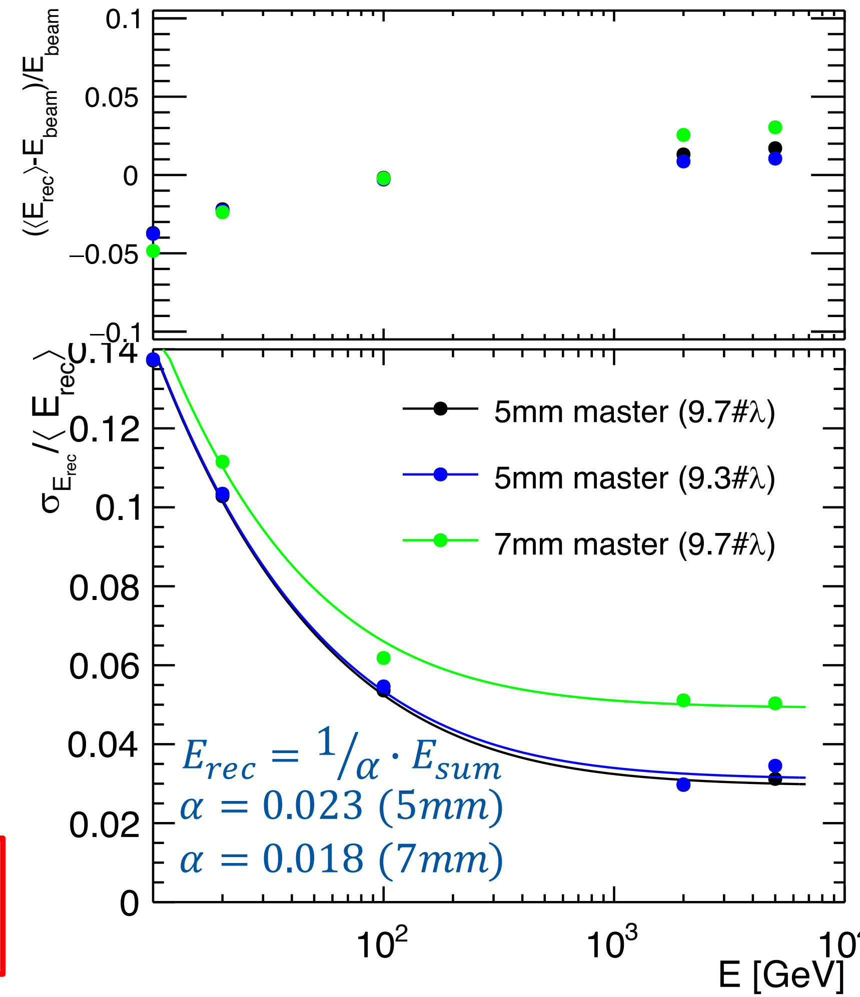
The non-linearity of pion response affected by e/h > 1 and leakage



Impact of larger Fe/Sci ratio

- By increasing Fe/Sci ratio
  1. Decreased sampling fraction
     2.5% → 1.8%
  2. Increased #interaction lengths
     9.3 → 9.7

→ Impact of decreased sampling fraction:
- Worse resolution and linearity



Larger non-linearity for higher Fe/Sci ratio, surprising since e/h~1

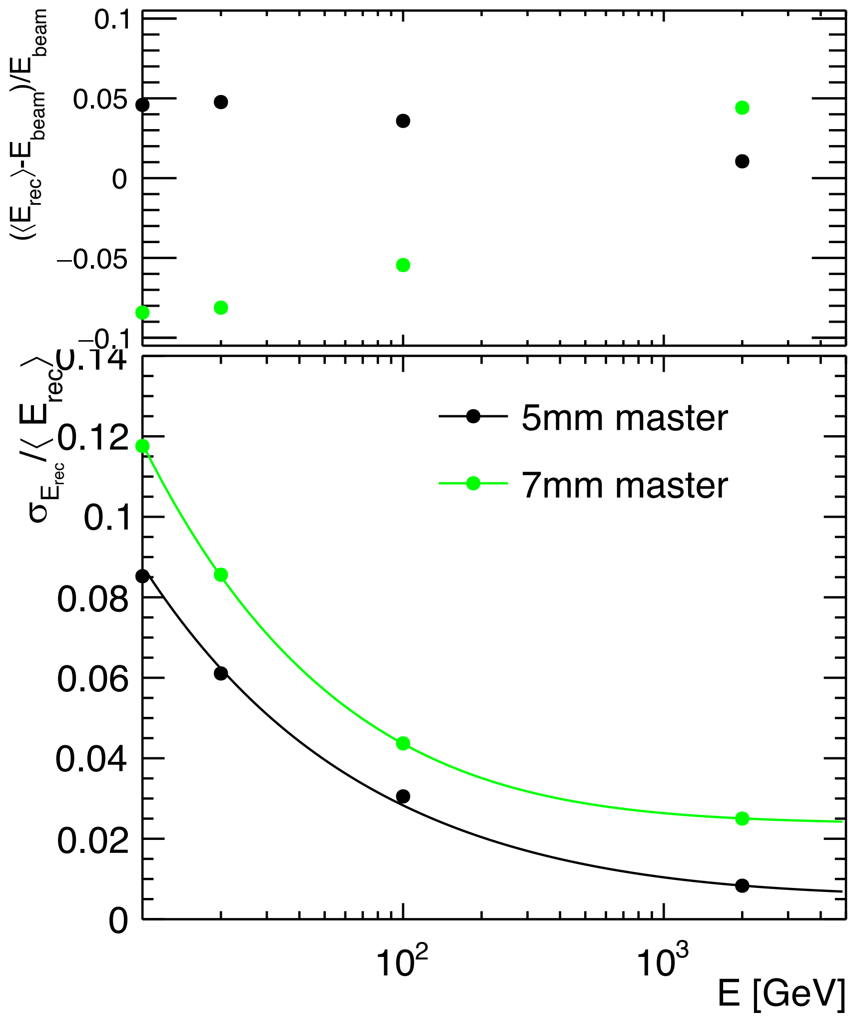
Summary electrons

Fe/Sci ratio	**4.7**	**6**
Master th.	5mm	7mm
Scintillator th.	3mm	3mm
Sampling fraction	2.5%	1.8%
σ/E	$\frac{27.8\%}{\sqrt{E}} \oplus 0.6\%$	$\frac{36.3\%}{\sqrt{E}} \oplus 2.4\%$

- ATLAS TileCal electron resolution $\frac{27.8\%}{\sqrt{E}} \oplus 2.8\%$

→ increased η dependence due to worse sampling frequency

→ investigation on-going!



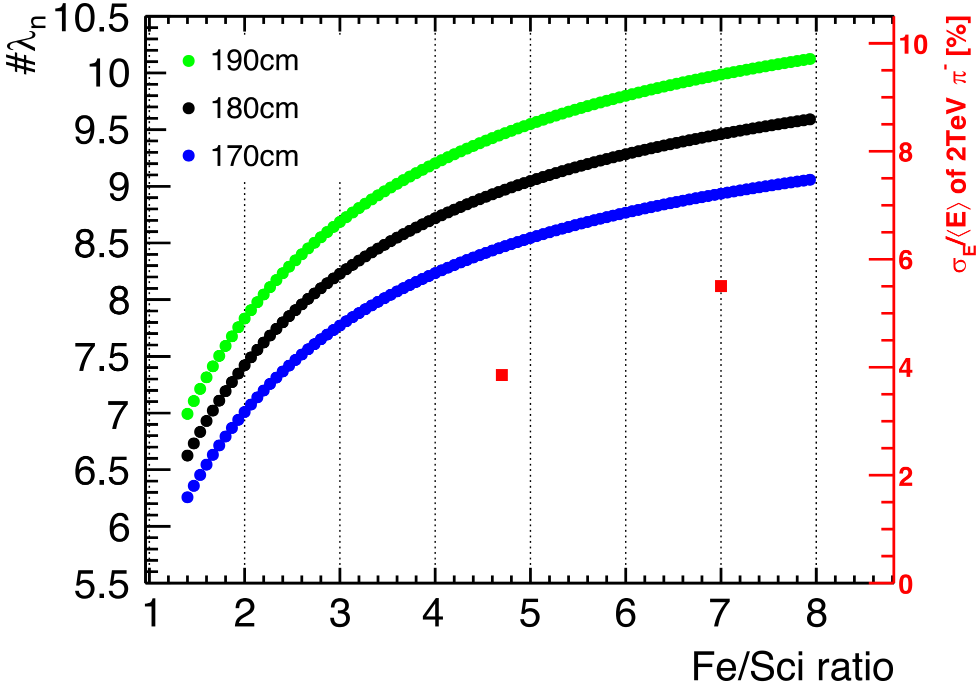
Summary pions

Fe/Sci ratio	4.7	4.7	4.7	6
Master th.	5mm	5mm	5mm	7mm
Scintillator th.	3mm	3mm	3mm	3mm
Sampling fraction	2.5%	2.5%	2.5%	1.8%
λ_{eff}	**20.6cm**	**20.6cm**	**20.6cm**	**19.8cm**
Effective depth	174cm * 1.06	**180cm** * 1.06	189cm * 1.06	**180cm** * 1.06
$\#\lambda$	**9.0**	**9.3**	**9.7**	**9.7**
σ/E	$\frac{42.6\%}{\sqrt{E}} \oplus 3.9\%$	$\frac{43.5\%}{\sqrt{E}} \oplus 3.3\%$	$\frac{43.6\%}{\sqrt{E}} \oplus 3.0\%$	$\frac{44.1\%}{\sqrt{E}} \oplus 5.0\%$
e/h		1.2		~1

Summary

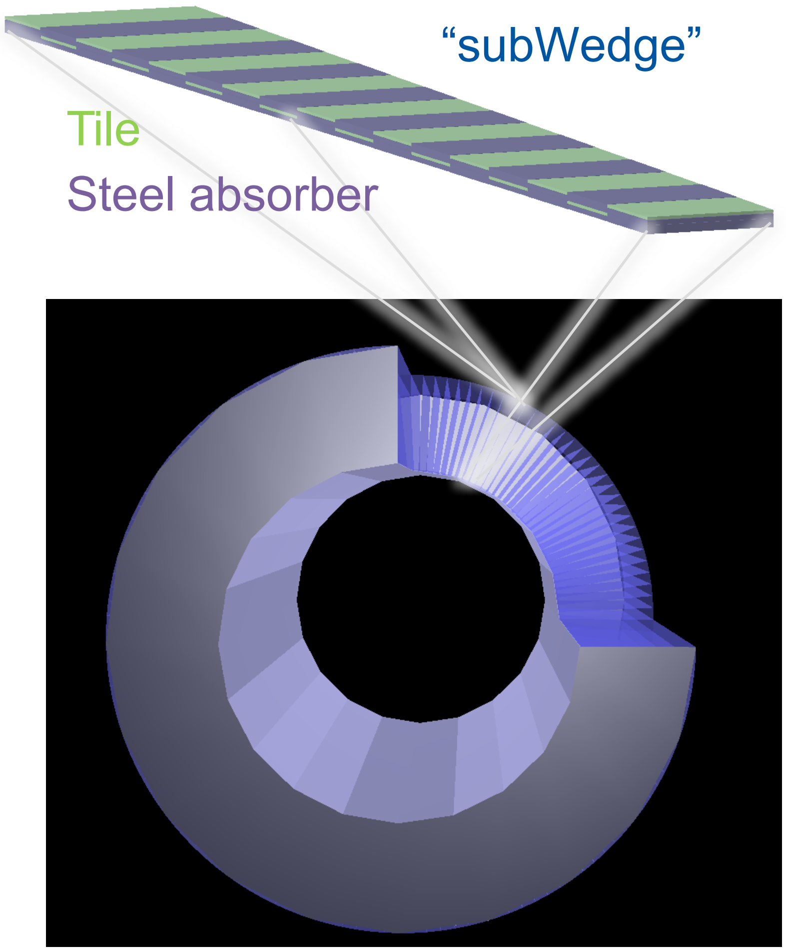
- Larger sampling fraction preferred over larger $\#\lambda_n$
- Profit of smaller Fe/Sci ratio questionable (study postponed)

→ Keep as baseline the original design with Fe/Sci ratio of 4.7 (as in ATLAS)



HCAL geometry in FCCSW

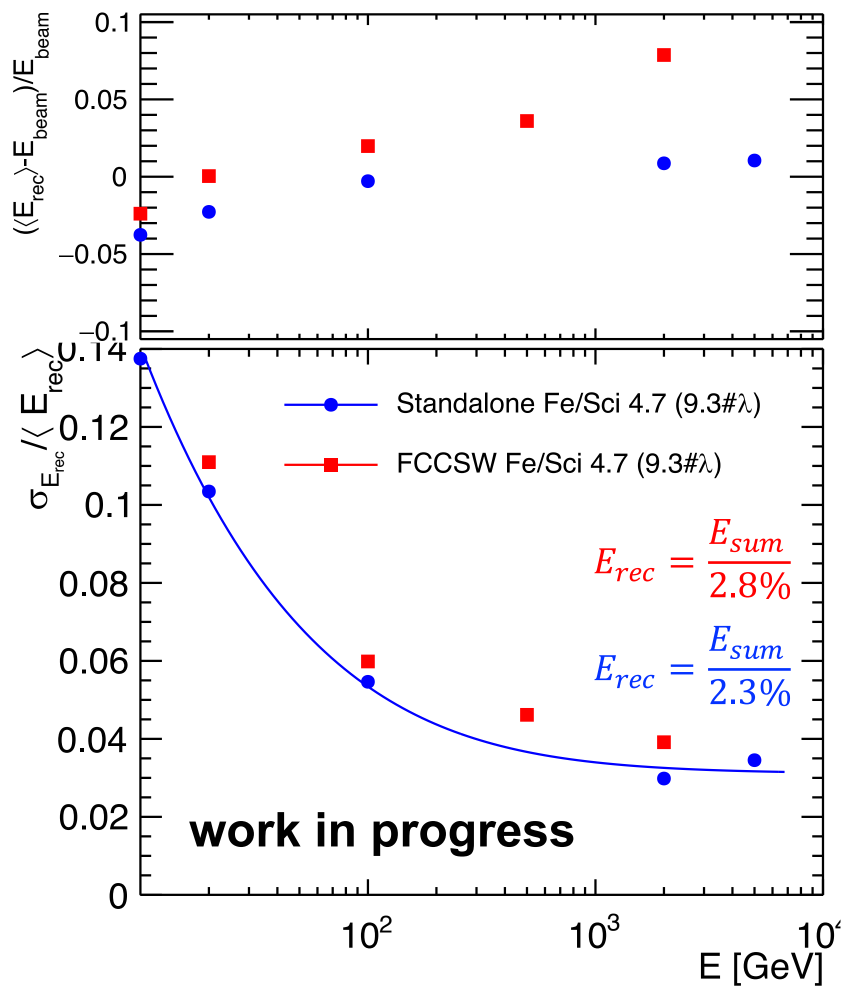
- Check of geometry implementation HCalBarrel_geo.cpp – **done**
- Birks law for the scintillator included



Validation of HCAL in FCCSW

- First glimpse into single pions revealed
  - larger response
  - slight degradation of resolution

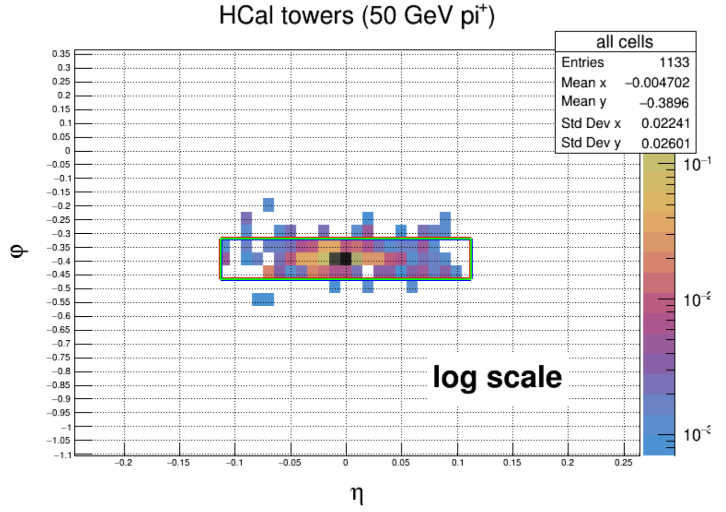
→ **Under investigation!** electrons, η dependence, bugs in the code…

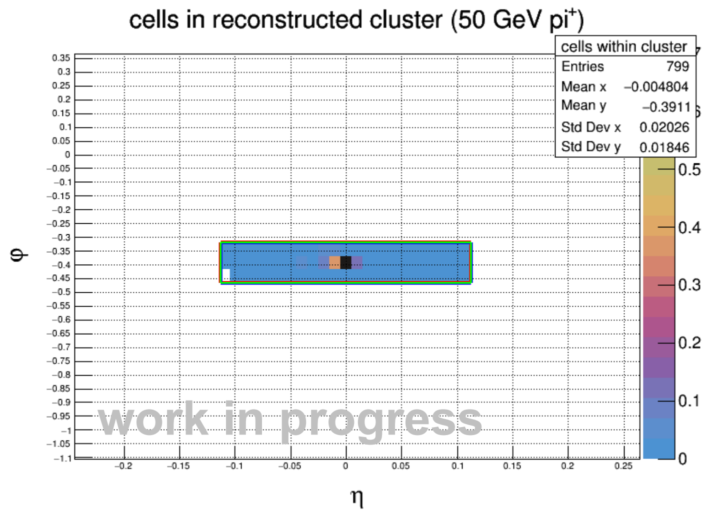


Software for calorimeter system

Goal is a combined reconstruction

- Reconstruction tools (generalized for different technologies/geometries)
  - Merging of energy deposits into cells ✔
  - Position of cells ✔
  - Noise (simple) ✔
  - Sliding window algorithm (single CAL) ✔





Software for calorimeter system

Ongoing

- Sliding window for E + HCAL
- Contact with LC ECAL expert on SiW ECAL simulation
  → integration in FCCSW

More plans

- Building topo-clusters to build jets
- Using topo-clusters as PFA input
  → contact with ATLAS expert established

THANK YOU!