HCAL optimisation

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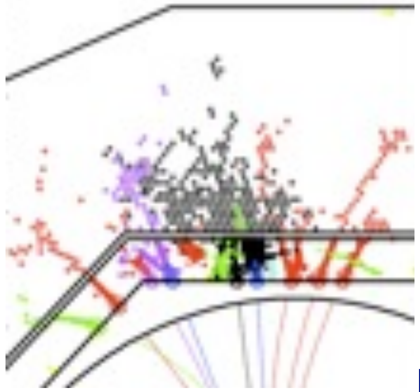
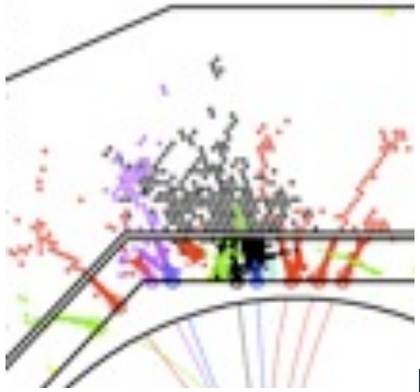
CLIC workshop
CERN, February 4, 2014



Outline

- Physics justification
- Roles of ECAL and HCAL
- Common parameters for cost and performance
- Status of tools



Detector optimisation

- Physics performance vs cost =
  - physics impact of detector performance → justification
  - detector performance vs parameters → optimisation studies
  - cost coefficients of parameters → engineering prototypes
  - performance optimisation, cost minimisation → R&D, industrialisation

- Need to factorise
  - physics impact hard to quantify in objective way
  - physics analyses often dilute detector effects
  - but need to be prepared to defend the case
- Coherent approach

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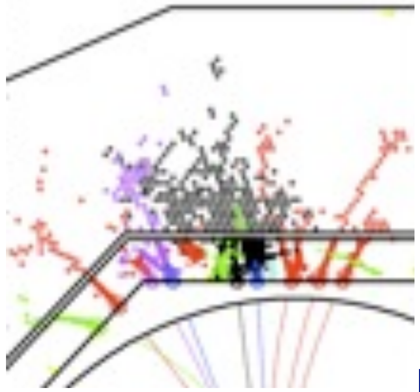
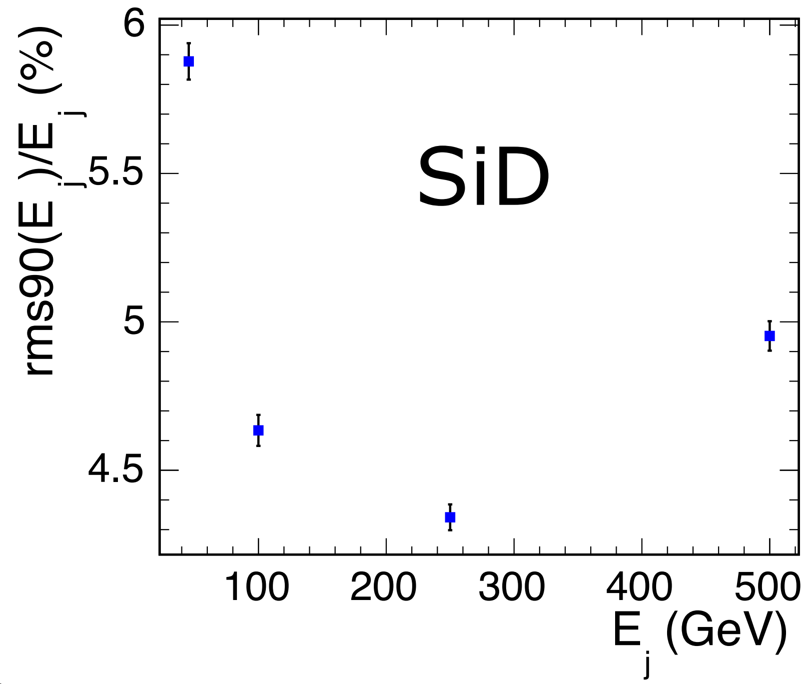
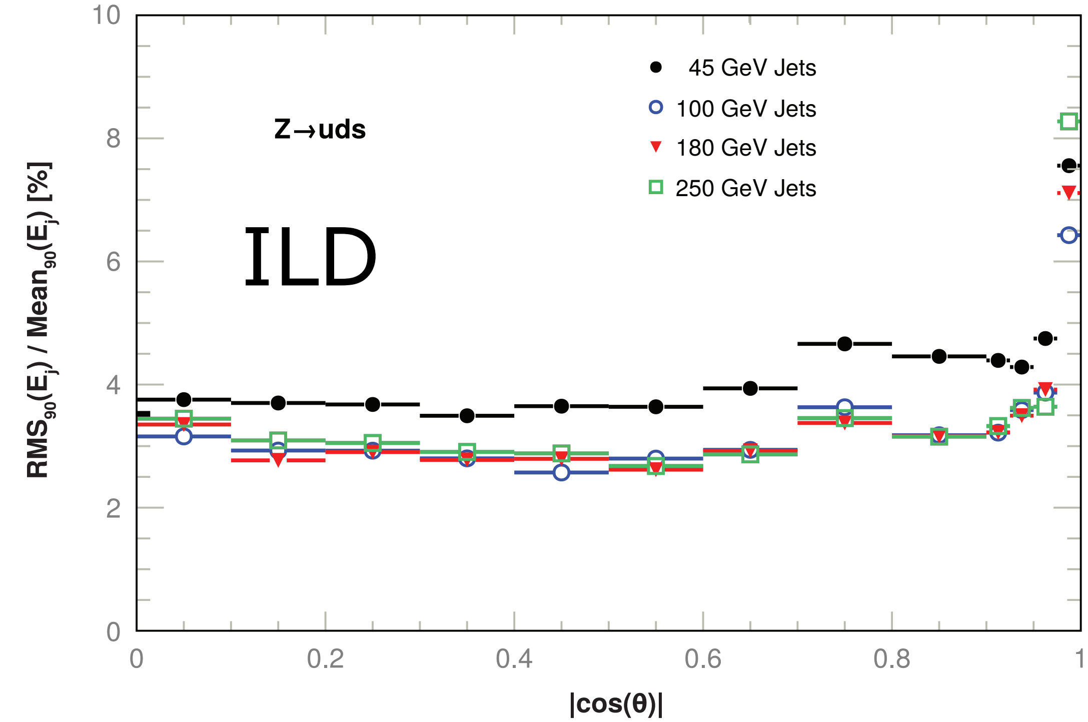
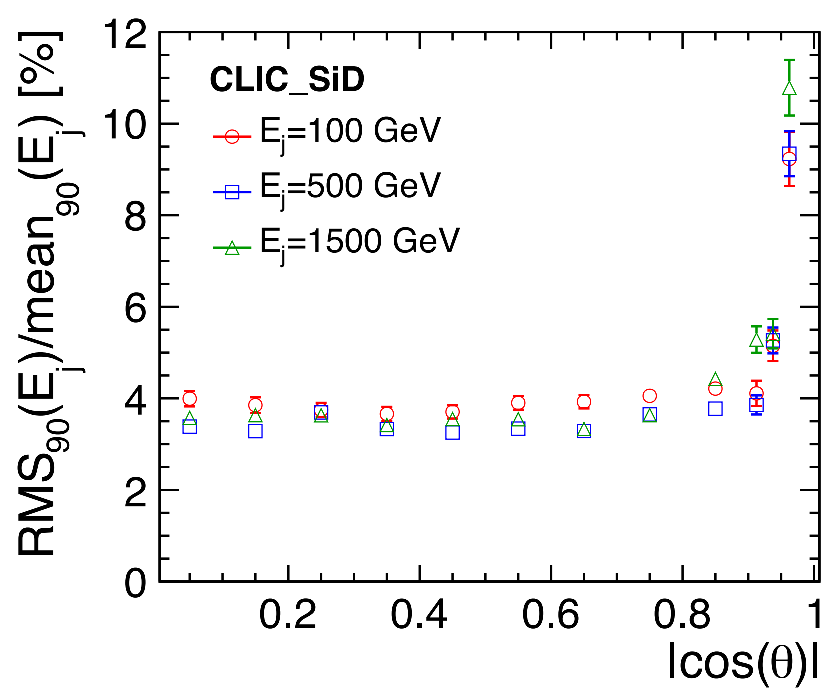


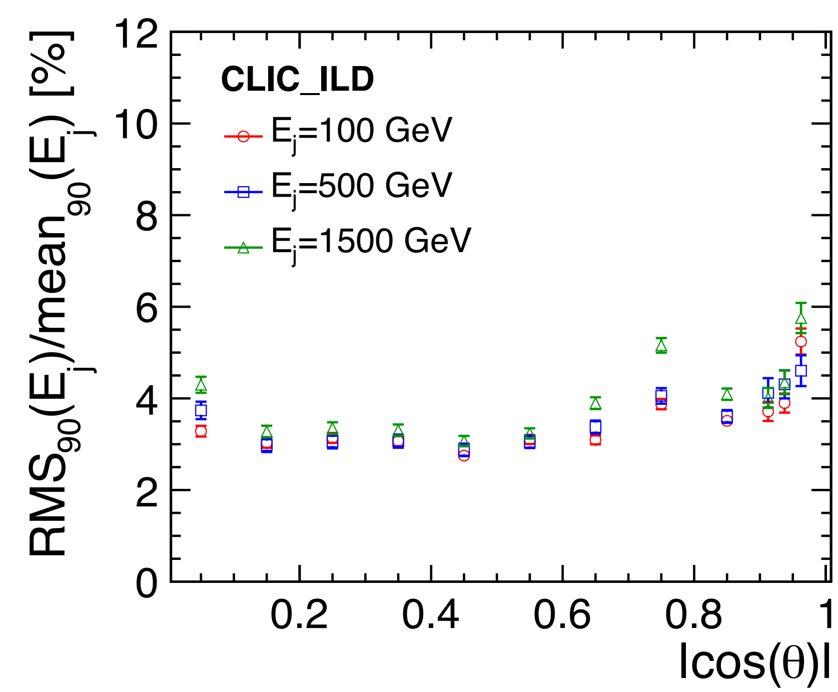
ILD and SiD jet performance



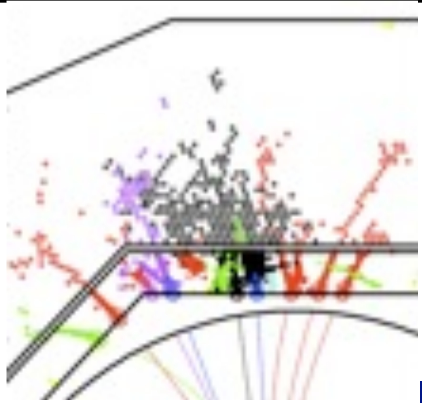


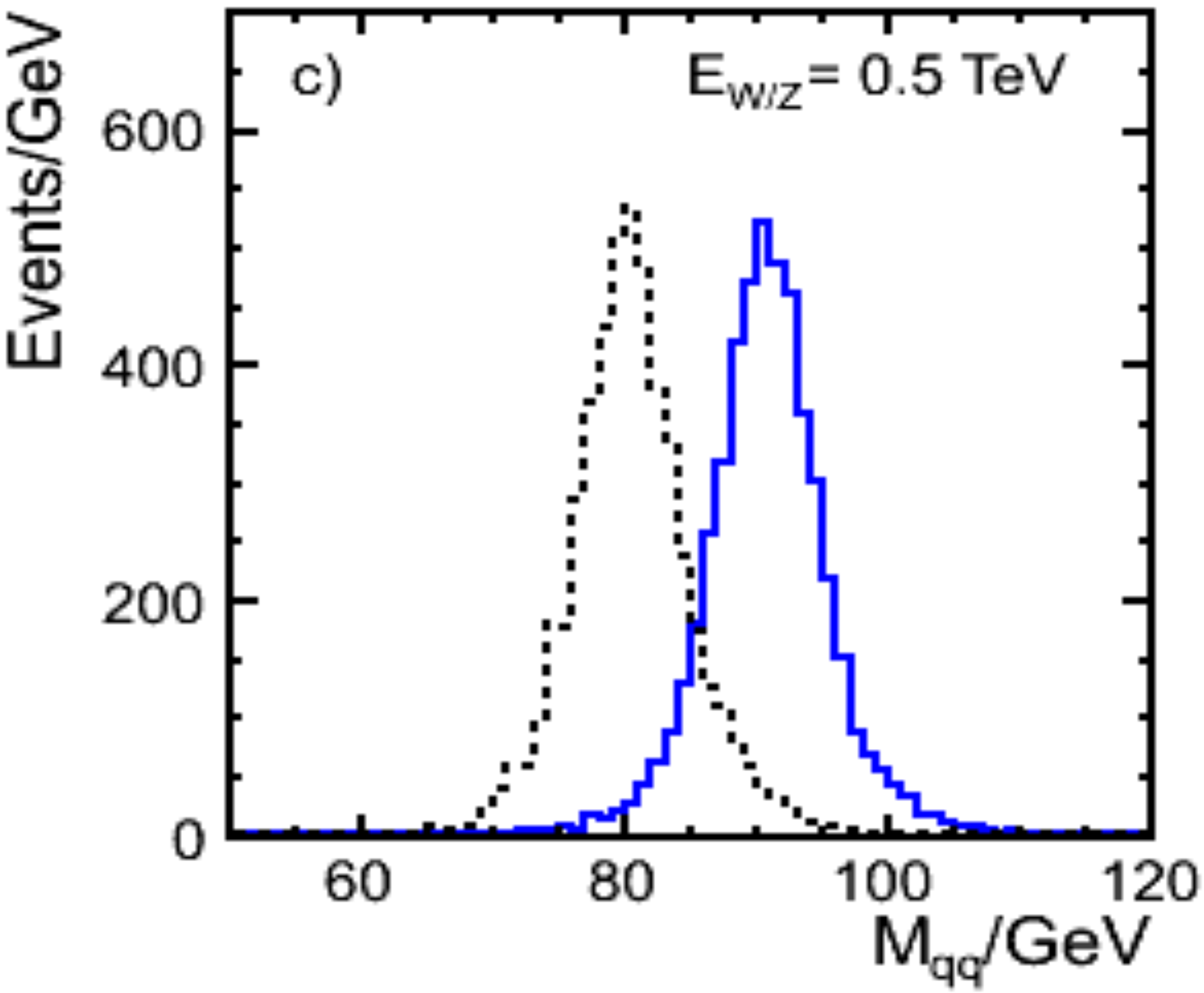
- ILD has clear advantages
- Barely shows up in physics performance
- Cost justification questioned
- Were the benchmarks appropriate?

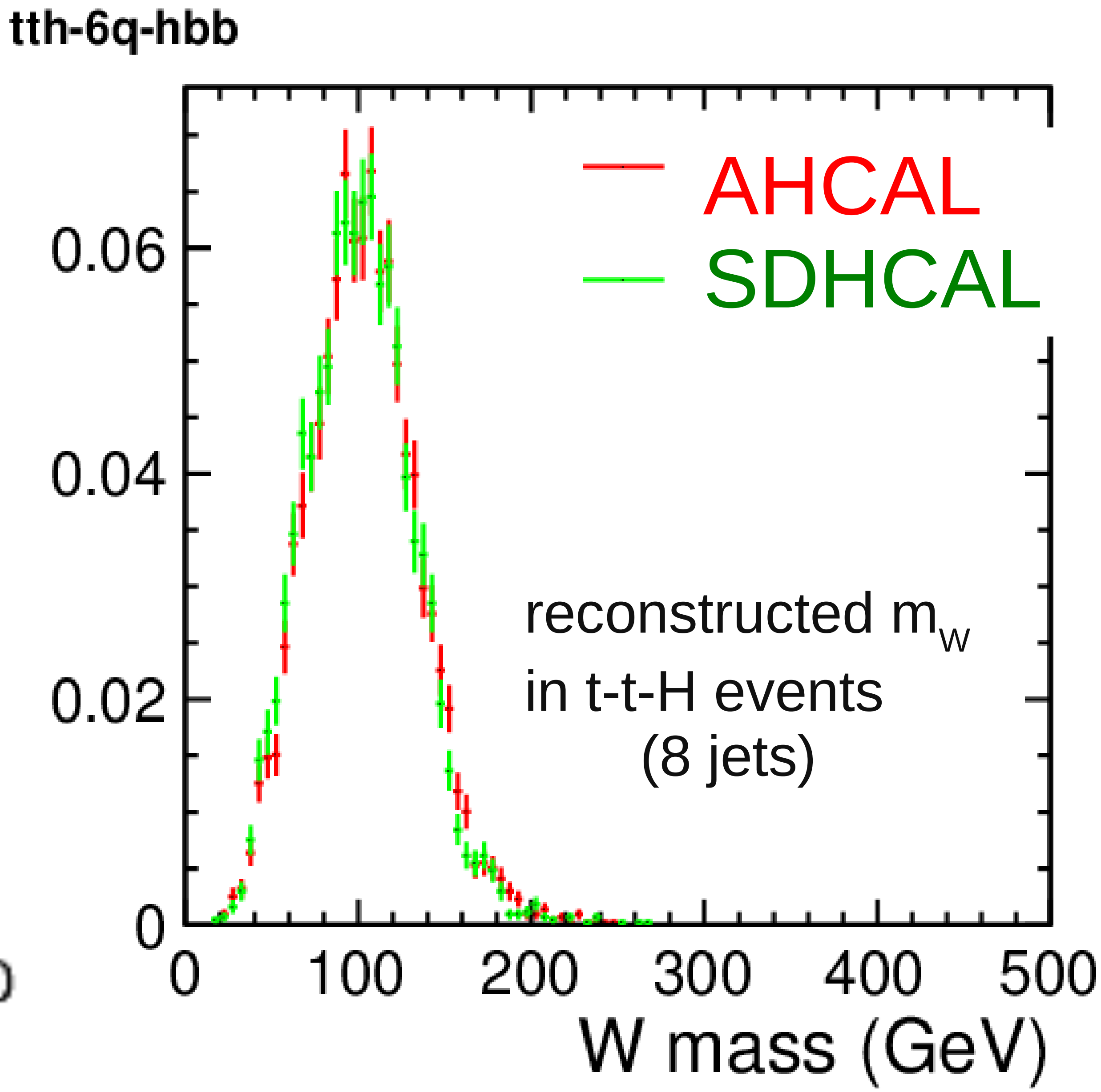




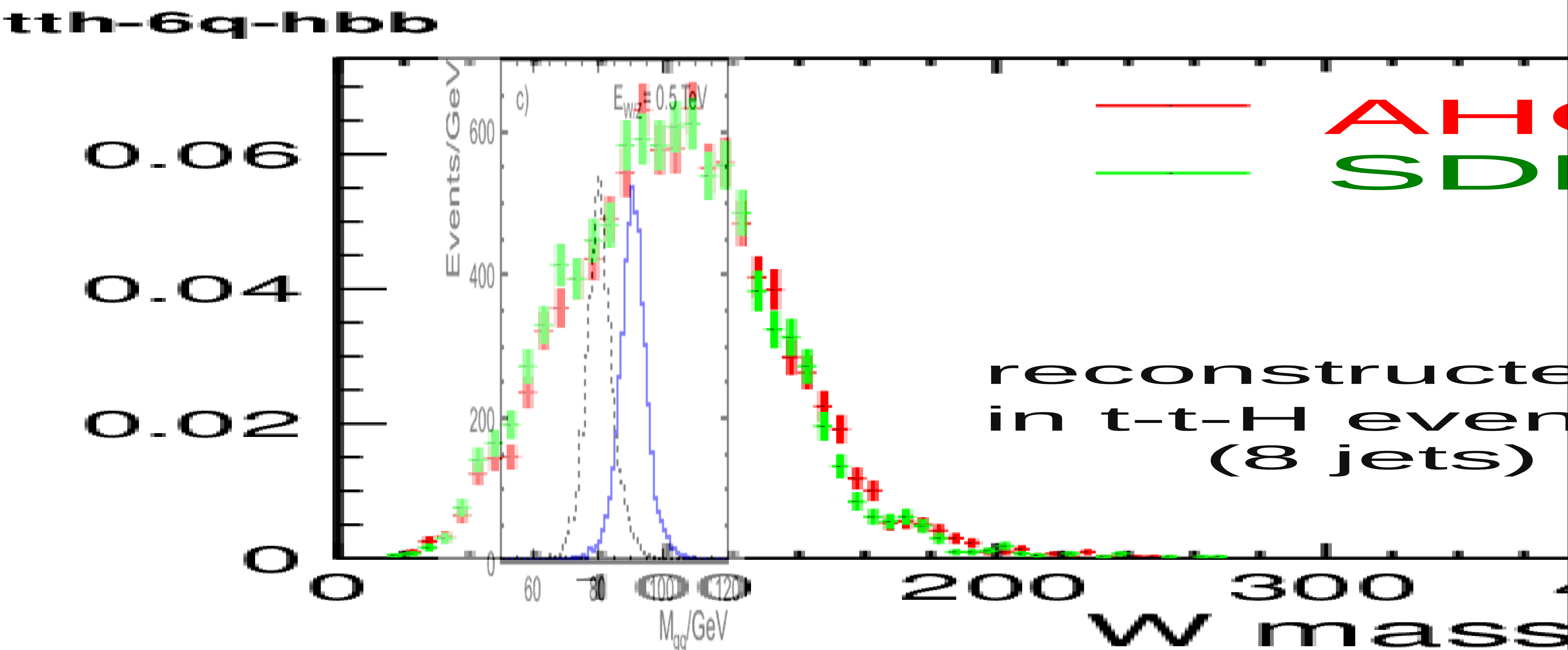
W Z separation vs W in multi-jets



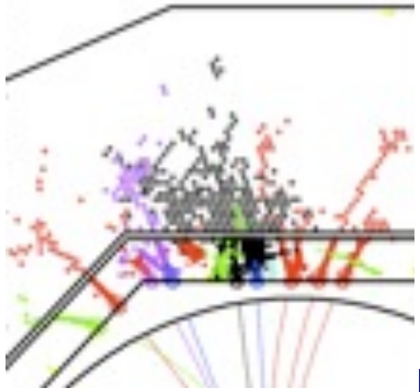




W Z separation vs W in multi-jets

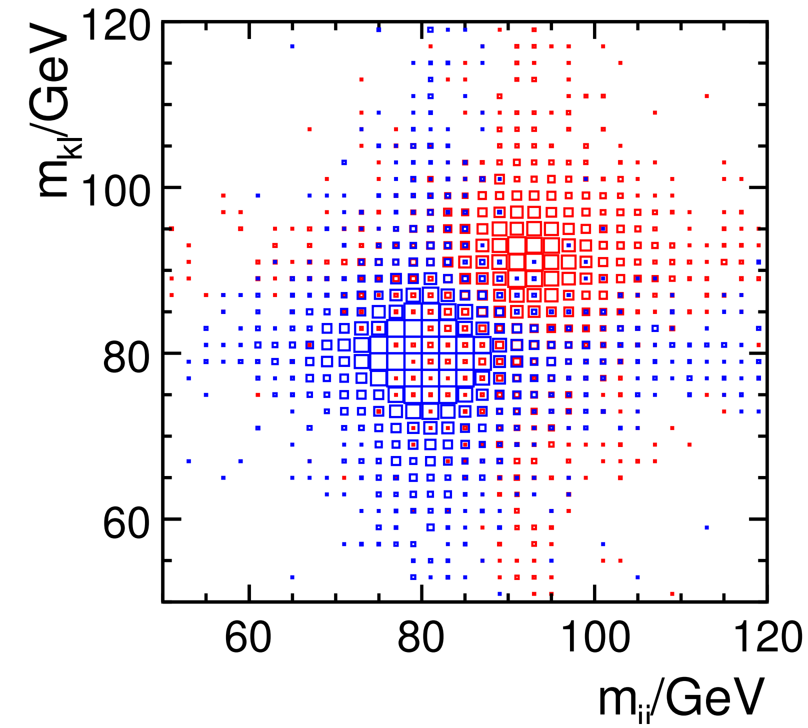


- important physics
- but useless for detector optimisation

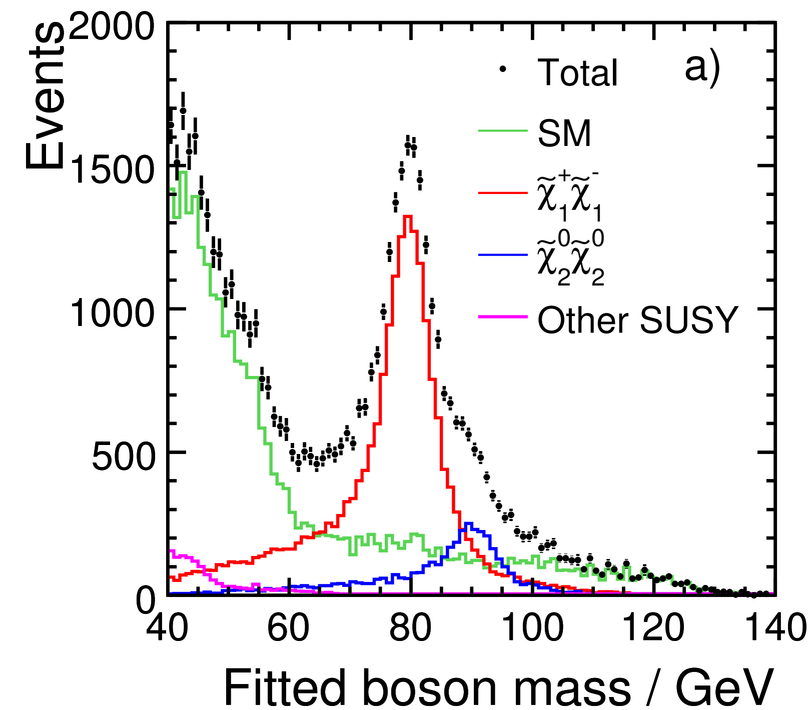


Better candidates?

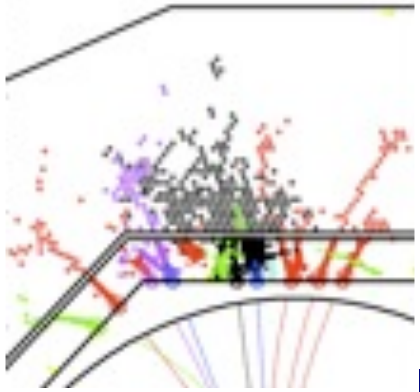
- Famous “blue plot”: study strong electro-weak symmetry breaking at 1 TeV
  - WWvv, ZZvv production
  - but this is not the only one



- H → WW*, ZZ* (total width)
- H → cc, Z → vv
- Chargino neutralino separation

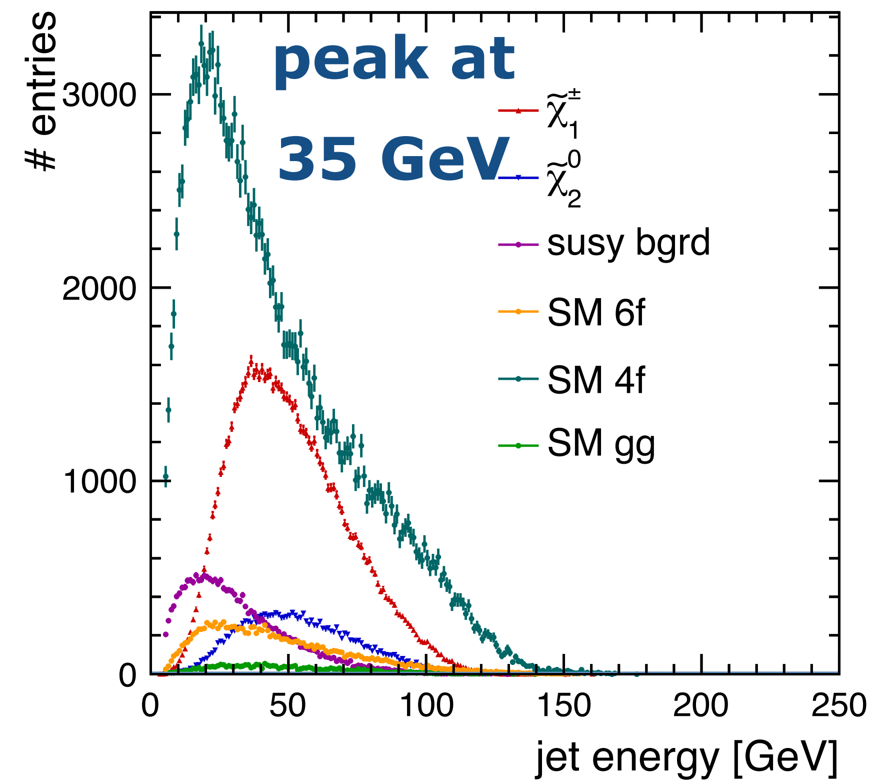


- Higgs recoil with Z → qq
- invisible Higgs
- WW fusion → H → WW
  - total width and g_{HWW}

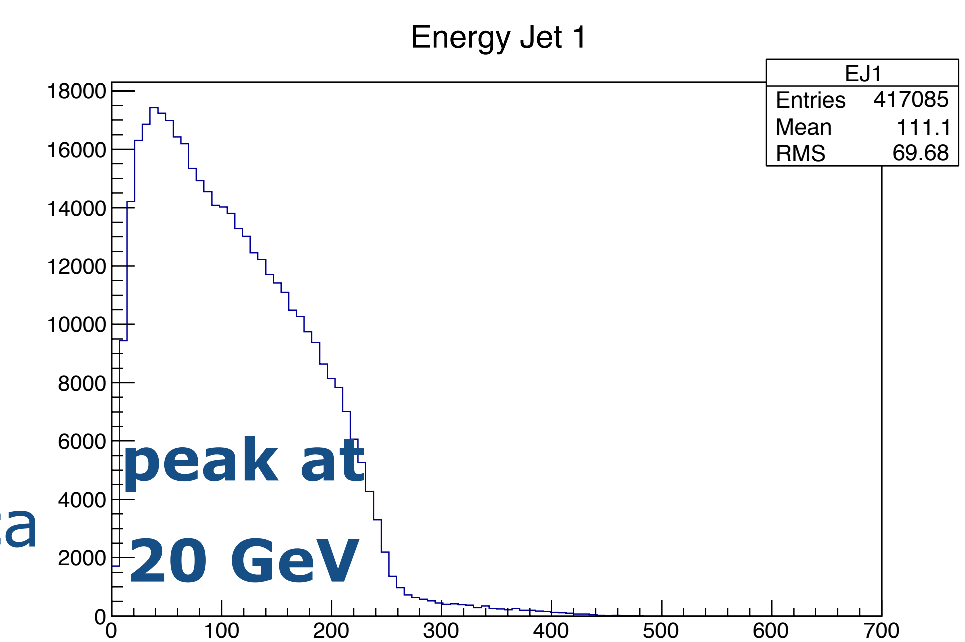


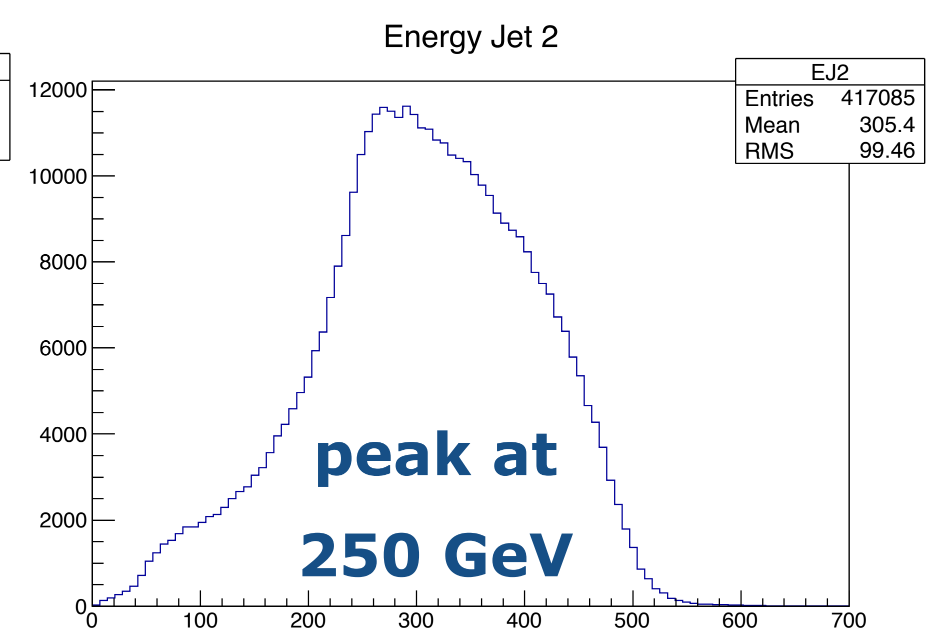
Jet energies

- $\sigma_m/m = 1/2\ \sqrt{(\sigma_{E1}/E_1)^2+(\sigma_{E2}/E_2)^2}$
  - lowest E dominates



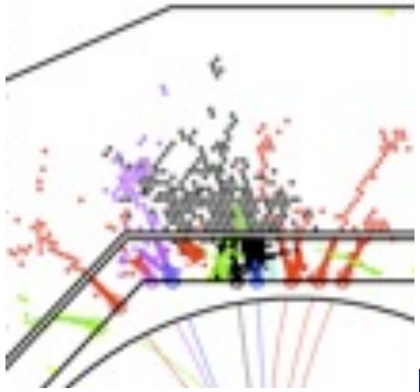
- At $\sqrt{s}$ = 500 GeV
- example SM 4f plus chargino, neutralino → qq + invis.
- At $\sqrt{s}$ = 1 TeV
- example WW→H → WW → lvqq
- forward!





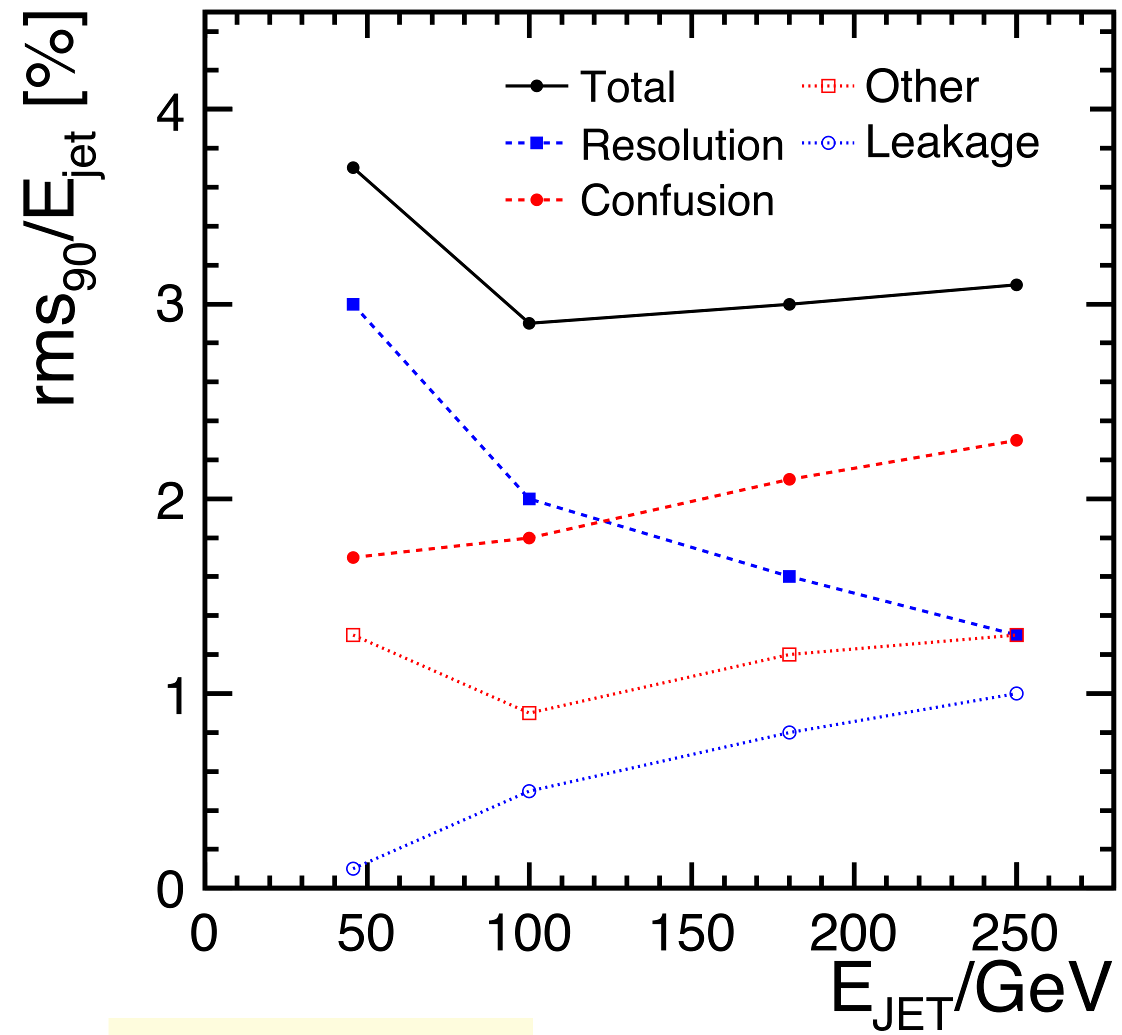
- At CLIC?

plots:
J.List, M.Chera, A.Rosca



Role of the HCAL

- Measure the energy of neutral hadrons
  - dominant up to ~ 100 GeV
- Charged Hadron - neutral hadron separation
  - dominant confusion term for high energy jets
- Transition region may move to somewhat lower energy for smaller detector
  - to be studied



at 250 GeV:

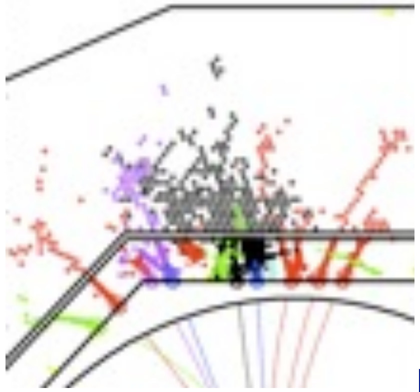
Total Resolution	3.1 %
Confusion	2.3 %
i) Photons	1.3 %
ii) Neutral hadrons	1.8 %
iii) Charged hadrons	0.2 %

had energy resolution

M.Thomson

energy and topology

containment, constant term



Parameters: performance and cost

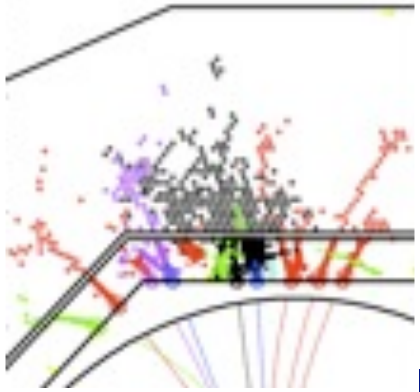
- Chose a parameterisation basis for cost and performance study
  - **R** inner radius ⟷ confusion
    - ε aspect ratio
    - z barrel length εR
  - **T** total thickness ⟷ leakage
  - **N** number of layers ⟷ resolution
    - g active gap thickness (const.)
    - d absorber layer thickness (T-Ng)/(N+1)
  - **s** tile size ⟷ confusion

physics motivated parameters

- Cost = $C_V * V + C_C$ = 45M (ILD)
  - Constant C_C = 10M
  - Rest scales with Volume ~ $2R^2T+RT^2$
    - Absorber 10M ~ V * d/(d+g)
    - Instrum. Area 16M ~ V / (d+g)
    - Channels 10M ~ V / s^2(d+g)
    - adjusted to DBD numbers

Cost impact factor	[% / %]
Radius	1.4
Thickness	0.5
No layers	0.5
Tile size	0.4

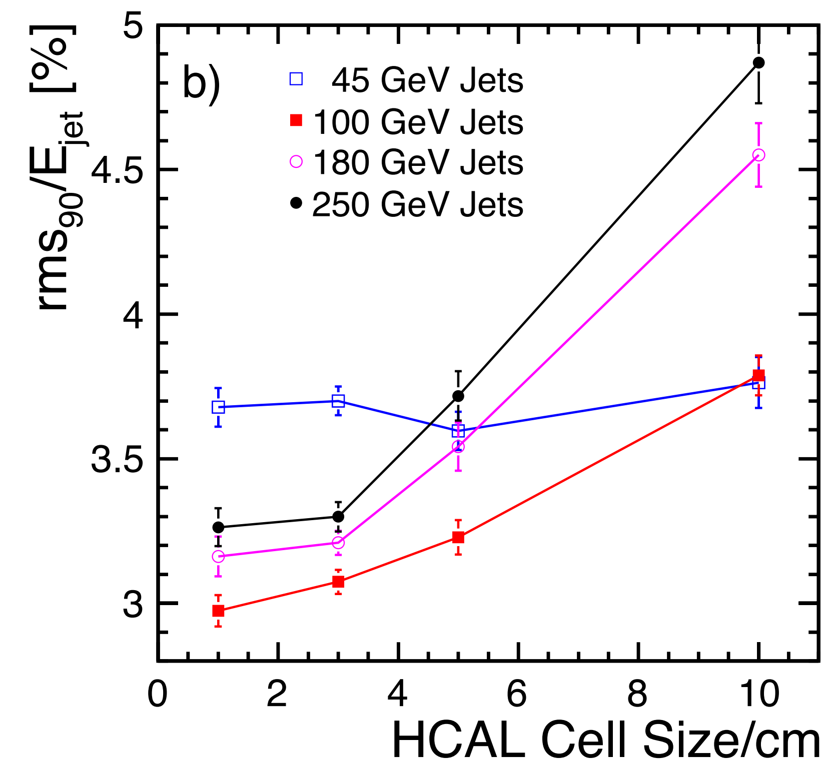
for small variations only!

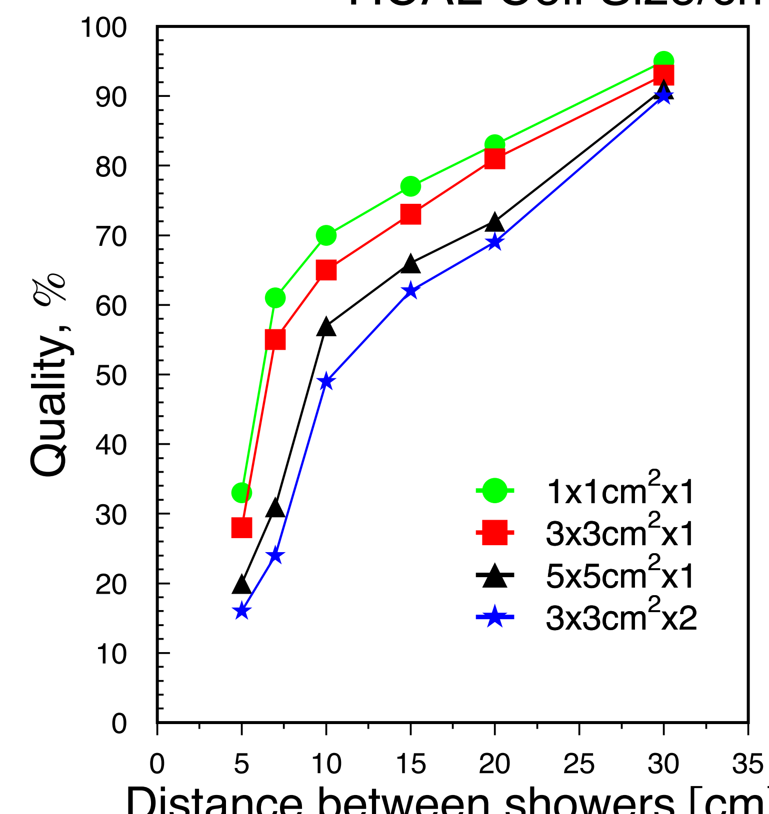


Correlations

- Leakage depends only on thickness
- Energy resolution depends only on no of layers
  - only weakly on scintillator thickness, as seen from 5 to 3 mm
  - not on tile size (analogue case)

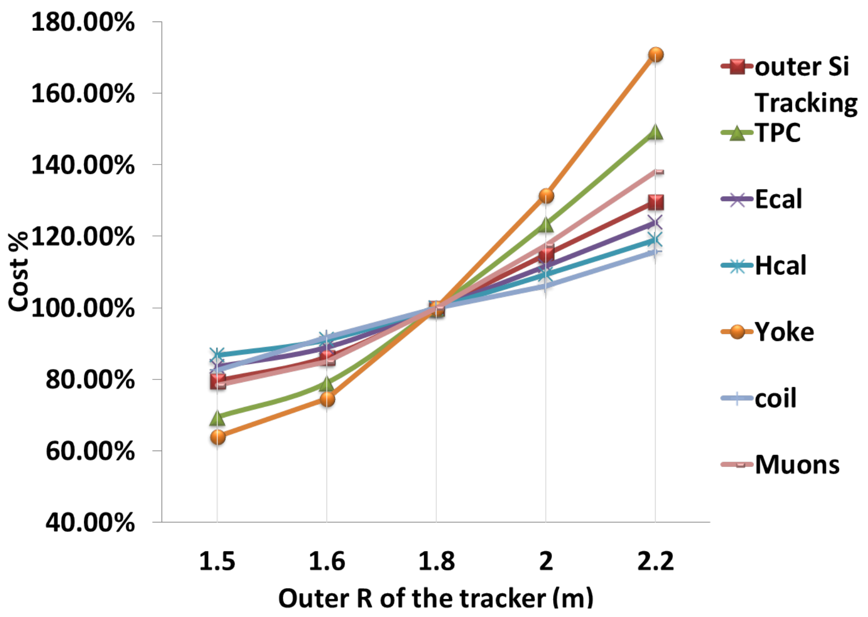
- Confusion depends on both radius and tile size
  - test beam prototype optimisation: confusion as function of particle distance - not much to gain below 3cm
  - smaller radius - smaller particle separation
  - dependence on longit. sampling to be studied again
- Expect earlier onset of size dependence, but same optimum
  - feature size rather train characteristic separation
  - to be verified with Pandora

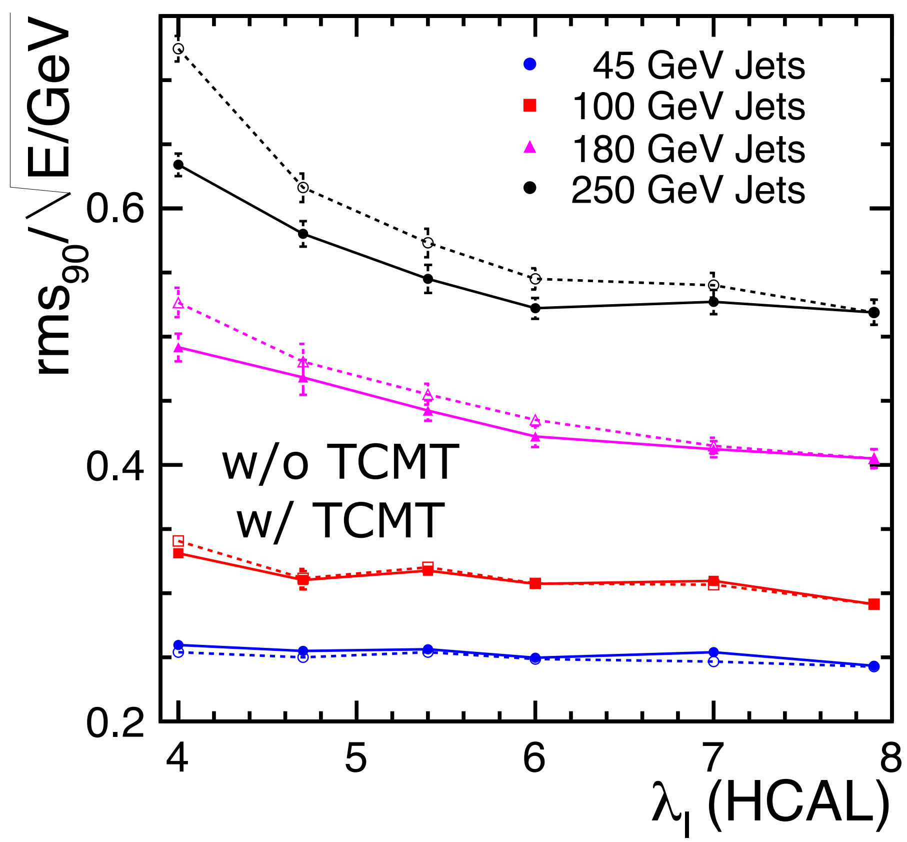


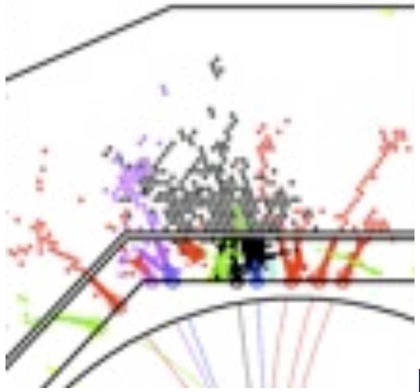


External correlations

- Thickness and TCMT:
  - moderate cost impact on HCAL proper, but drives coil and yoke like ECAL and TPC
  - balance total cost vs performance
  - need to include TCMT in performance analysis
  - possibly stronger sensitivity to TCMT design if HCAL thinner

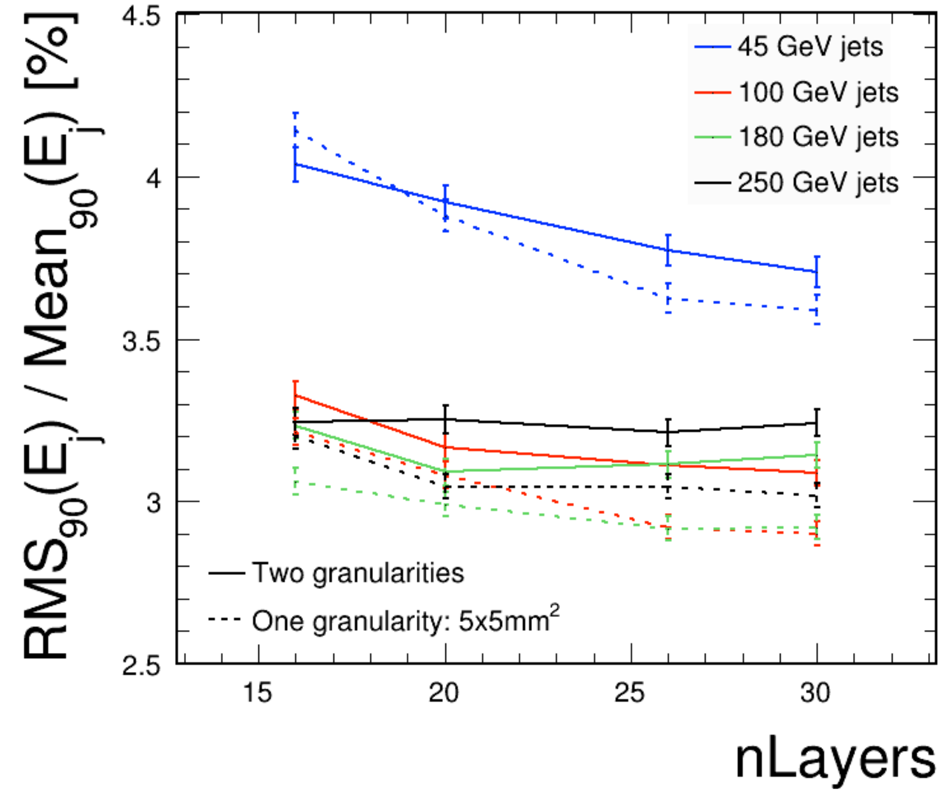


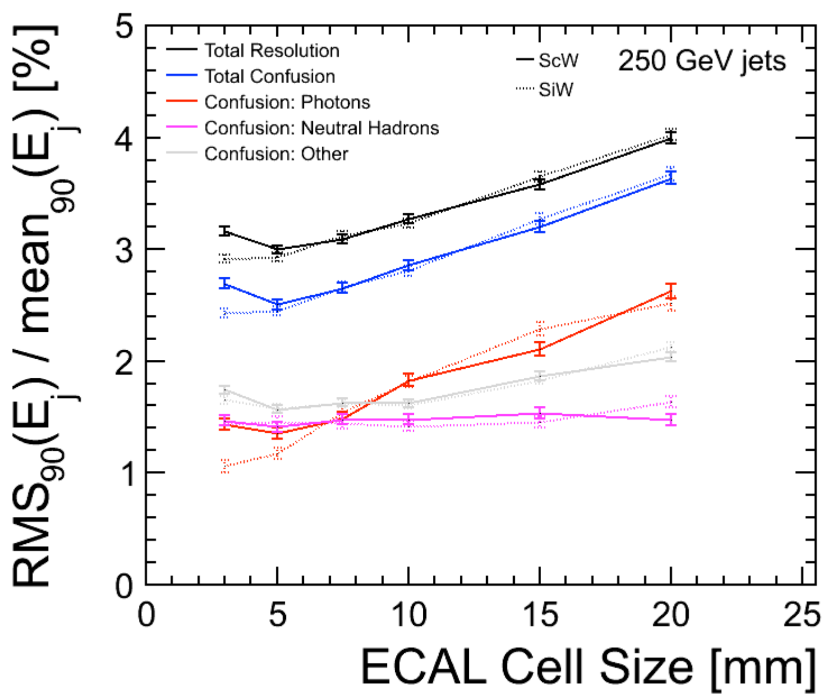


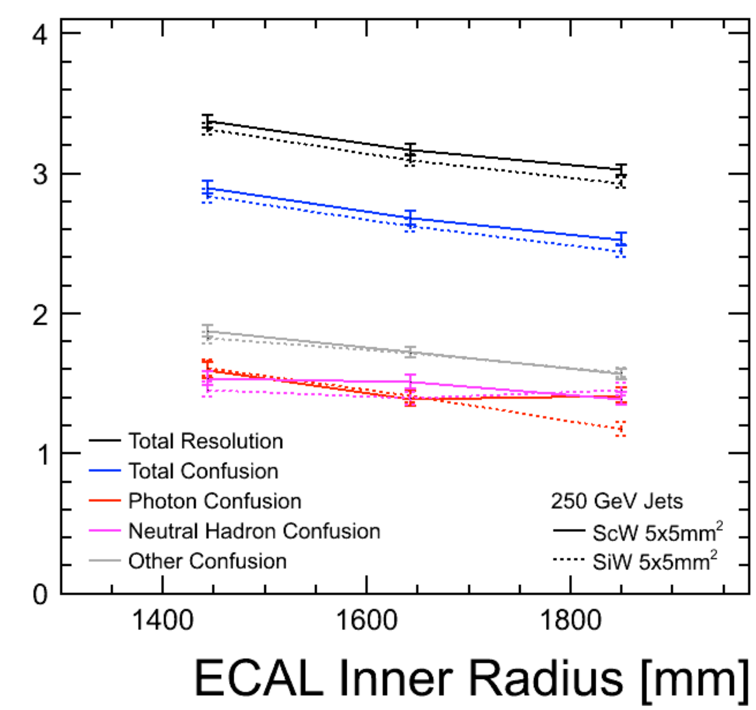


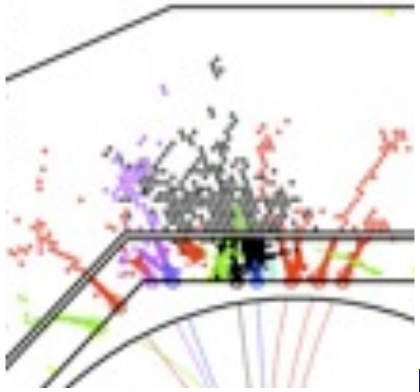
ECAL and HCAL

- ECAL optimisation study (John):
  - sampling counts at low E
  - granularity counts at hi E
  - mainly in first 1/3
- ECAL granularity drives the photon hadron confusion, but not hadron hadron
- Hadron confusion varies with radius (and nL?)
- "Other" (hadron fragments) with R and nLayers (resolution)
- Study HCAL radius, granularity and nL









Strategy

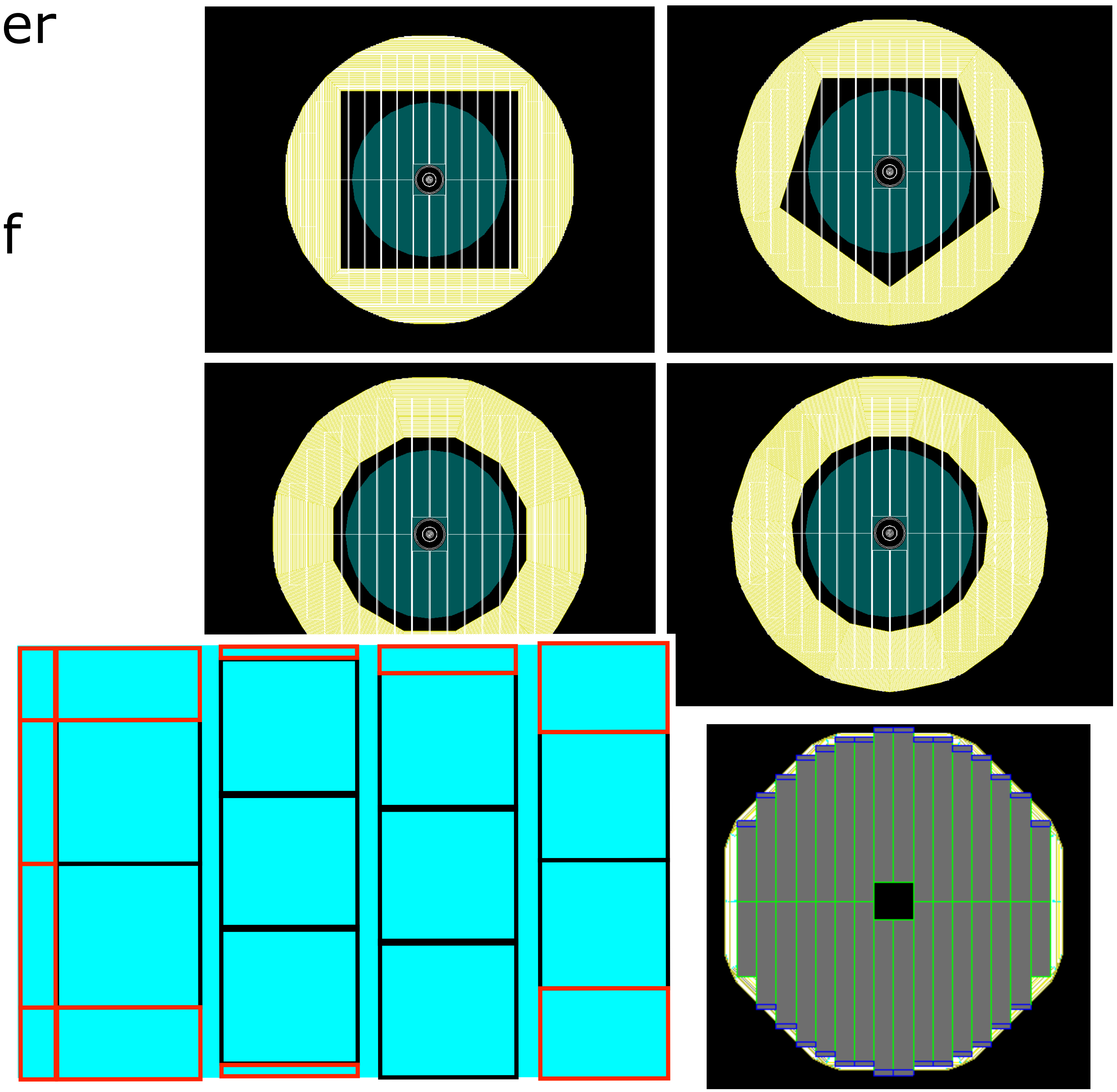
- In the case of the AHCAL, quite orthogonal mapping of parameters on performance
- For stronger variation of radius, need some study
- interesting: ECAL (and HCAL) resolution or longity. sampling impact on confusion

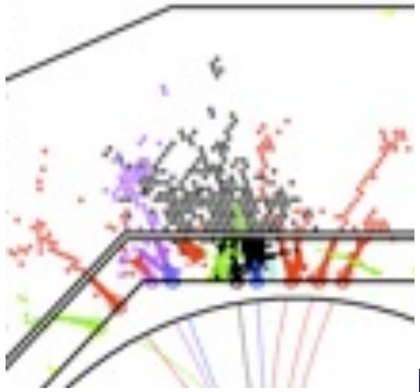
- Need to study HCAL before fixing ECAL radius

- Proposal: two-step procedure
  - 1. Choose 2 or 3 radii (in total) and redo internal optimisation
    - suggestion: R_{ILD}, R_{SiD}, $\sqrt{R_{ILD}R_{SiD}}$
    - use singe particle or di-jets, no mass production
  - 2. Define detector models for 2 or 3 different radii, with possibly adapted internal parameters
  - larger production, to be used for physics benchmarks
  - This might be appropriate for other sub-detectors as well

Degrees of freedom: Mokka

- Flexible and scalable driver for optimisation studies
  - ILD_o1_v06
- Already used in studies of ECAL radius variations
- Ongoing work: flexible granularity, varying with depth
- Keep realism, but avoid artificial dead regions
  - max 1cm gap at module edges





Summary

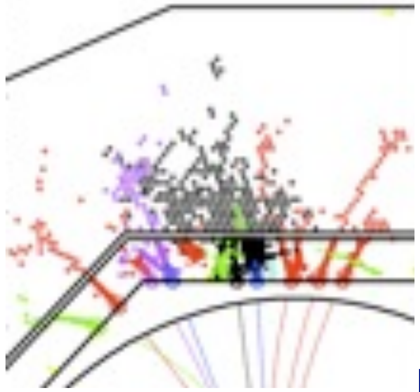
- Particle flow has driven the detector design and cost - but is under-exposed in the physics benchmark studies
- Need to link to the physics case for good jet energy resolution, understand its impact and the relevant jet energy range

- Optimisation studies teach us a lot about performance drivers
  - disentangle impact of energy and space resolution
  - need to better understand hadron and “other” confusion
  - important guidance for R&D

- Soon ready to study HCAL granularity in full flexibility

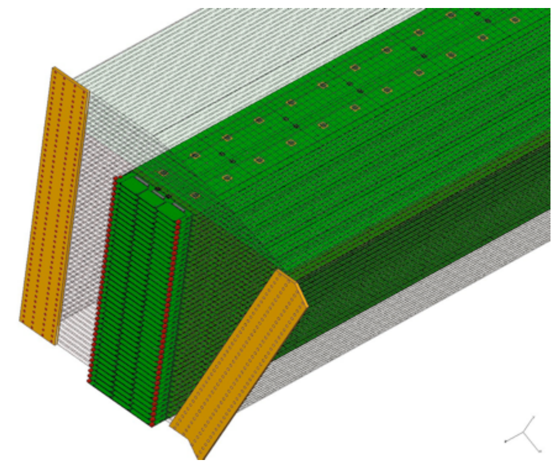
- HCAL cost parameterisation exists in “physics" basis

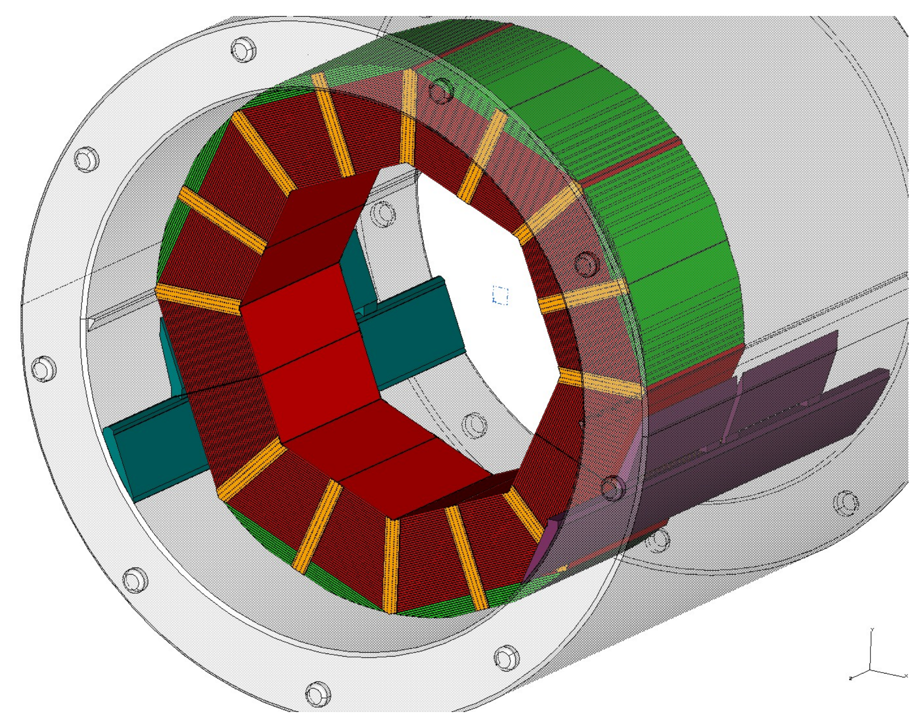
Back-up



Absorber geometry

- The AHCAL group prefers the "TESLA" structure for *technical* reasons
  - access to layer interfaces
- Expect little performance differences relative to "Videau" structure
  - not an optimisation parameter, but an integration topic





- Can verify this with single particle and dijets
  - no extra mass production
  - models exist
- Keep T structure for AHCAL benchmarks