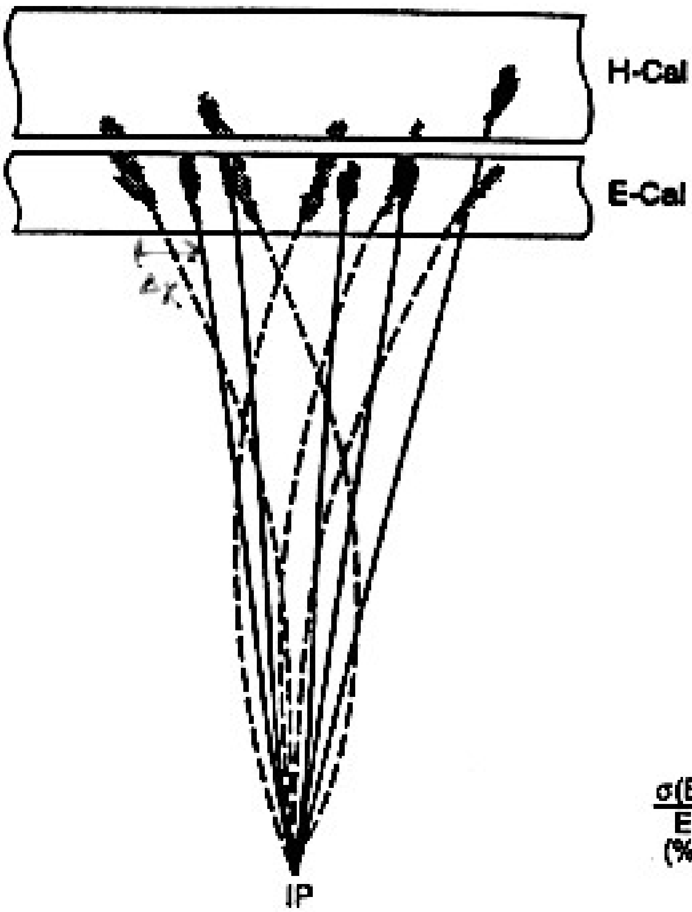
Selected LCD Calorimetry Issues

R. Frey, Aug 1, 00

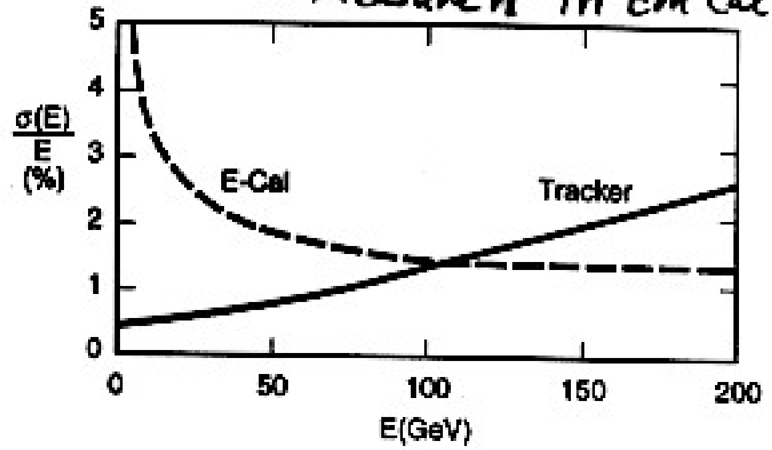
- Physics requires "good" jet reconstruction
  - Jet angles: *e.g.* couplings from angular dists.
  - $M_{\rm jj}$: *e.g.* ZH *vs* WW *vs* ZZ
- Energy Flow
  - What is it?
  - Is "excellent" jet reconstruction achievable?
  - How much does it cost?
- Path

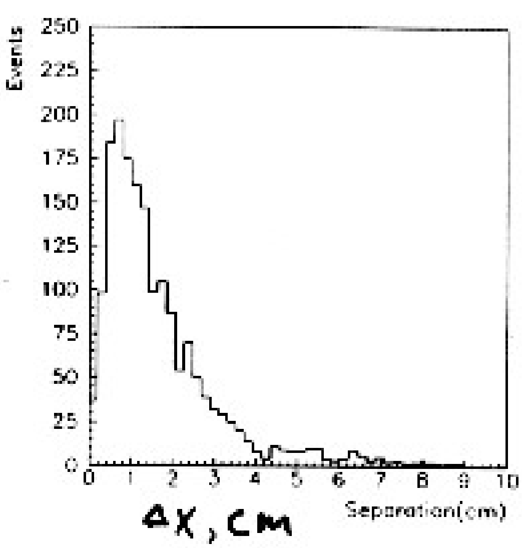


How well can one do $\gamma/h^{\pm}$ separation?

Requires highly-segmented EM calor. and/or an embedded highly-segmented layer(s)

- Measure $h^{\pm}$ in tracker
  ↳ subtract from Cal.
- Measure π^0 in EM Cal.





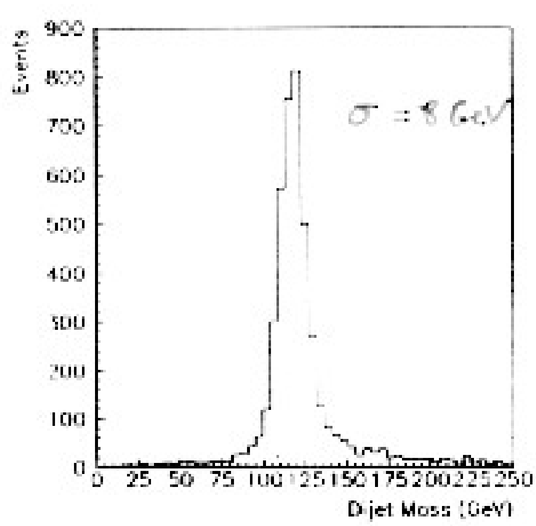
$h^{\pm}/\gamma$ separation at cal. face
($E_T > 10$ GeV)

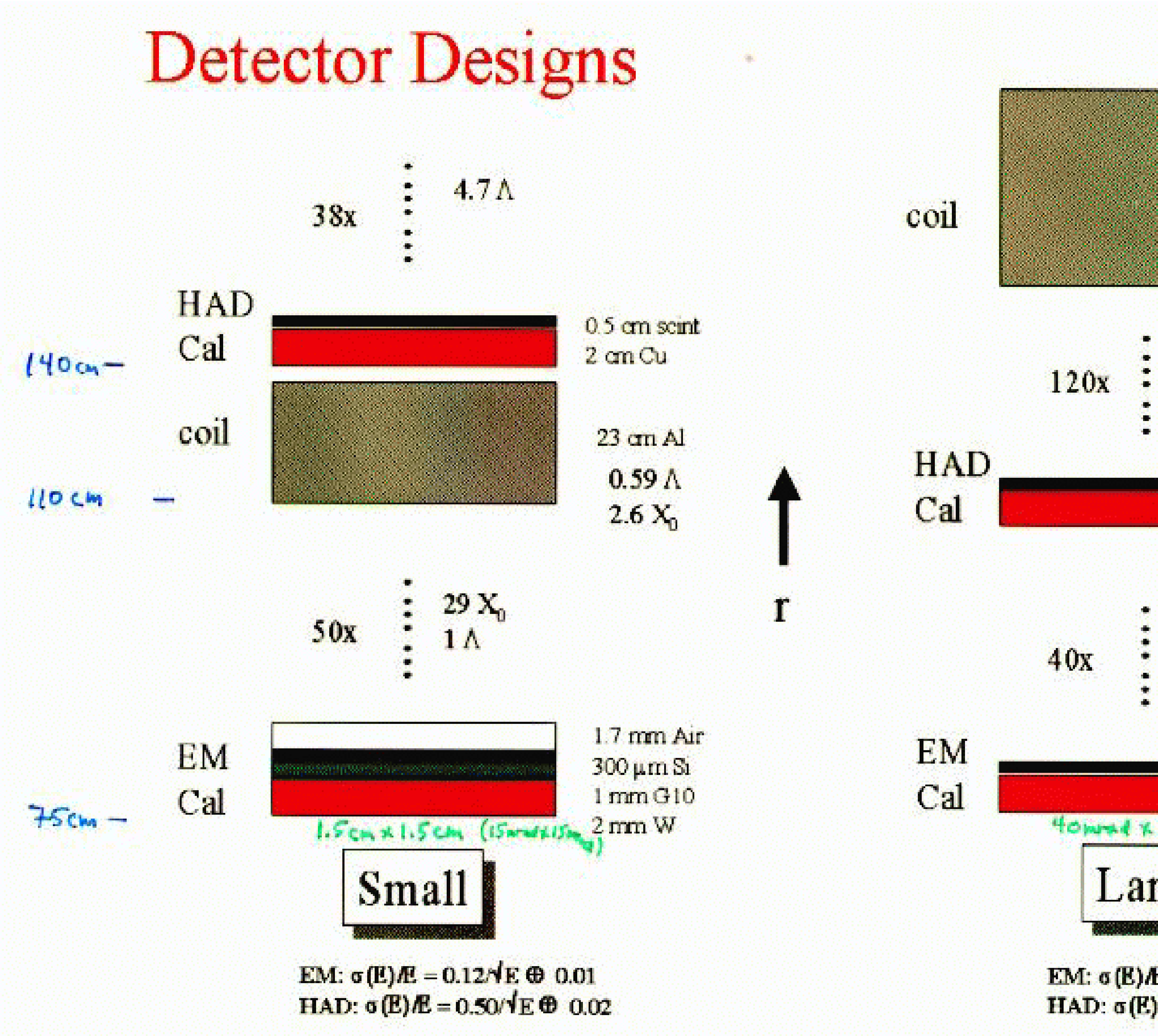
→ Need separation at few mm level

Snowmass 96 Si-W (Bray, et al)

$e^+e^- \to Z h^\circ \to q\bar{q}\, b\bar{b}$

Resulting $M_{b\bar{b}}$ dist. →





Detector Designs
38x
4.7 Λ
HAD
Cal
0.5 cm scint
2 cm Cu
140cm –
coil
23 cm Al
0.59 Λ
2.6 X_0
110 cm –
r
50x
29 X_0
1 Λ
EM
Cal
1.7 mm Air
300 μm Si
1 mm G10
2 mm W
75cm –
1.5cm x 1.5cm
Small
EM: $\sigma(E)/E = 0.12/\sqrt{E} \oplus 0.01$
HAD: $\sigma(E)/E = 0.50/\sqrt{E} \oplus 0.02$
coil
120x
HAD
Cal
40x
EM
Cal

Field Strength – Coil/EM cal. Radius

- Curl up pairs : $B \gtrsim \frac{p_T^{MAX}}{0.3\, r_{VTX}}$, $p_T^{max} \sim 20$ MeV/c

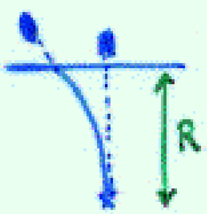
  $\therefore r_{VTX} \simeq 1\,cm \Rightarrow B \gtrsim 6\,T$

- Magnet stored energy : $E \propto B^2 R^2 L$

  $E_{max} \sim 150\,MJ$

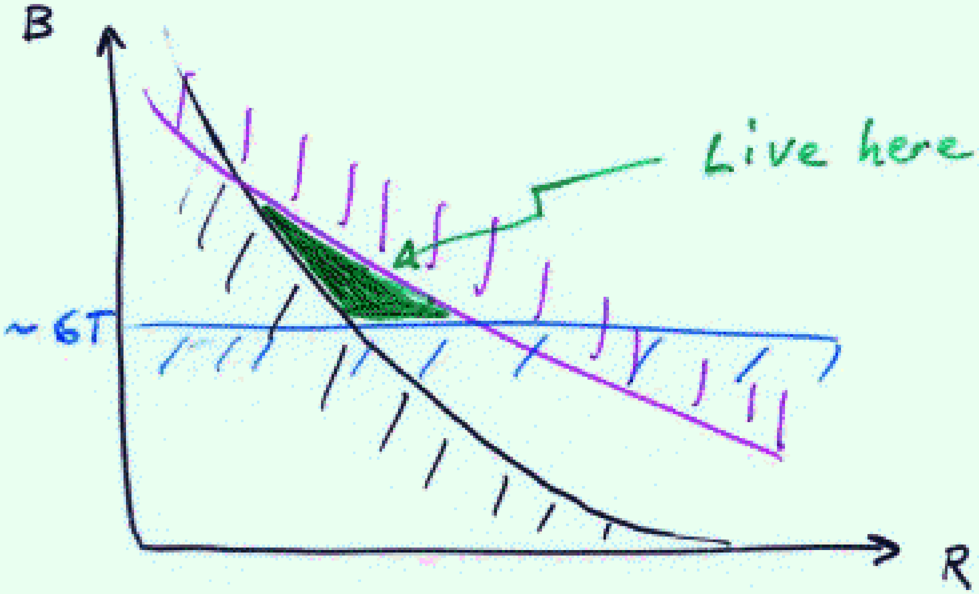
  $\Rightarrow B(T) \lesssim \frac{12}{\sqrt{L}\,R} \sim \frac{8}{R(m)}$

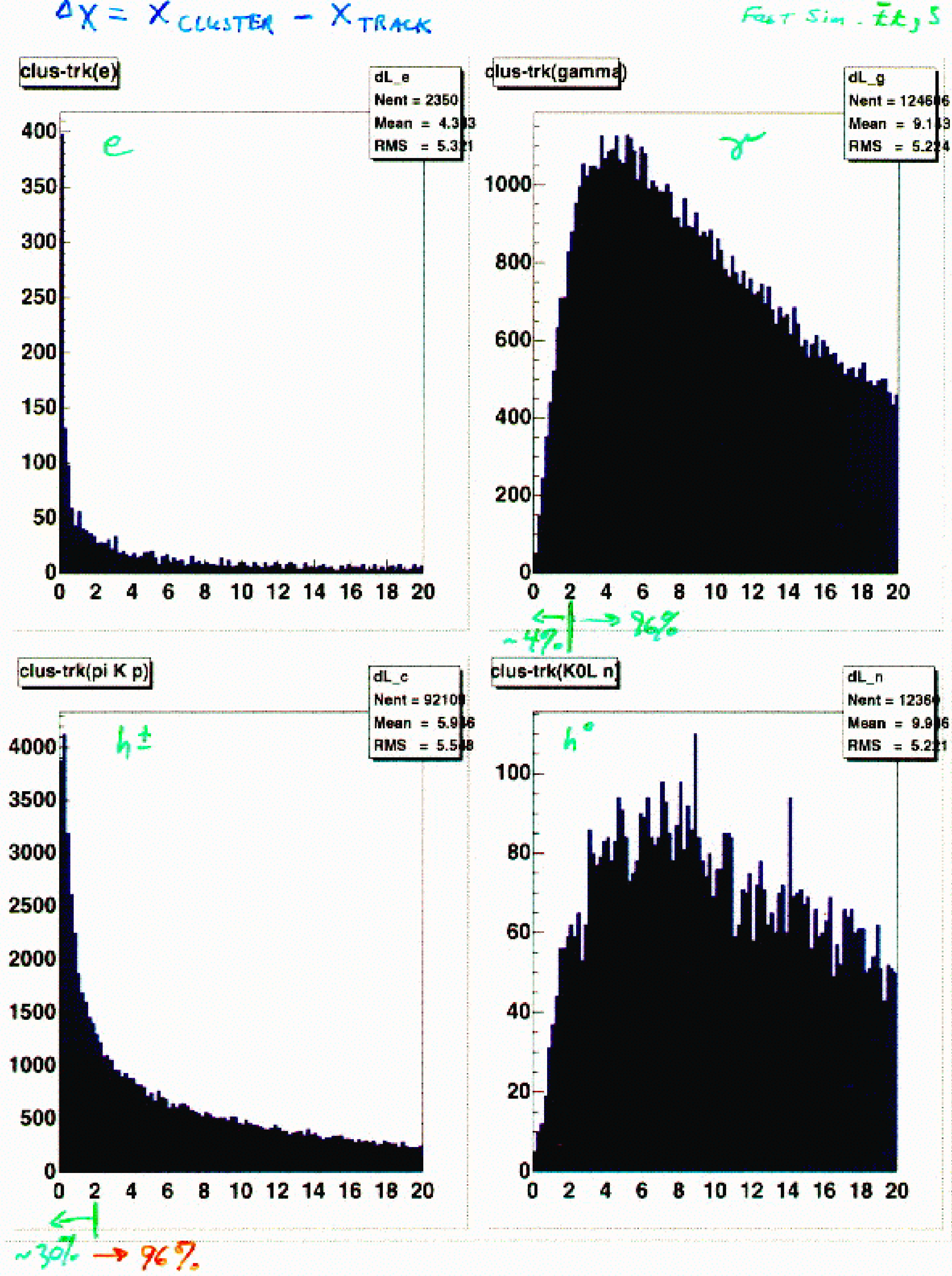
- $h^{\pm} - h^{0}$ separation :



  sagitta $\propto BR^2 \Rightarrow B \gtrsim \frac{K}{R^2}$

  (K to be determined by sim.)



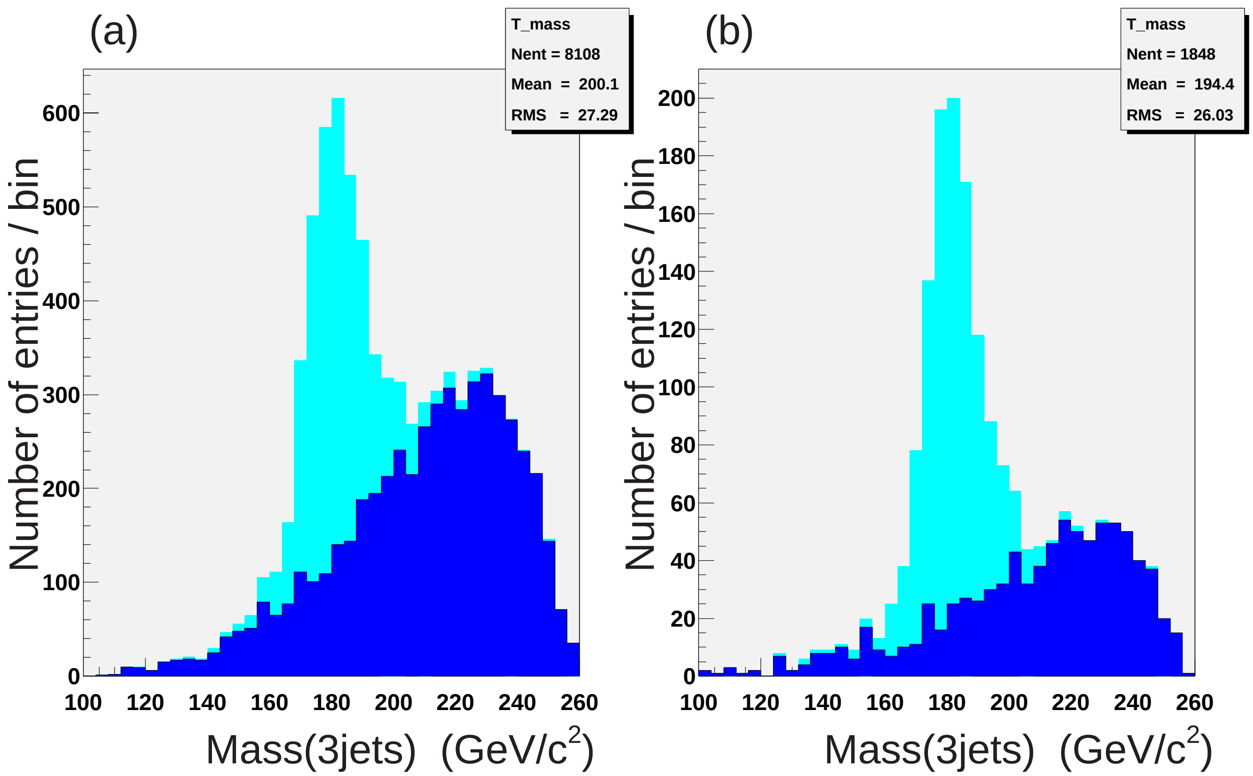


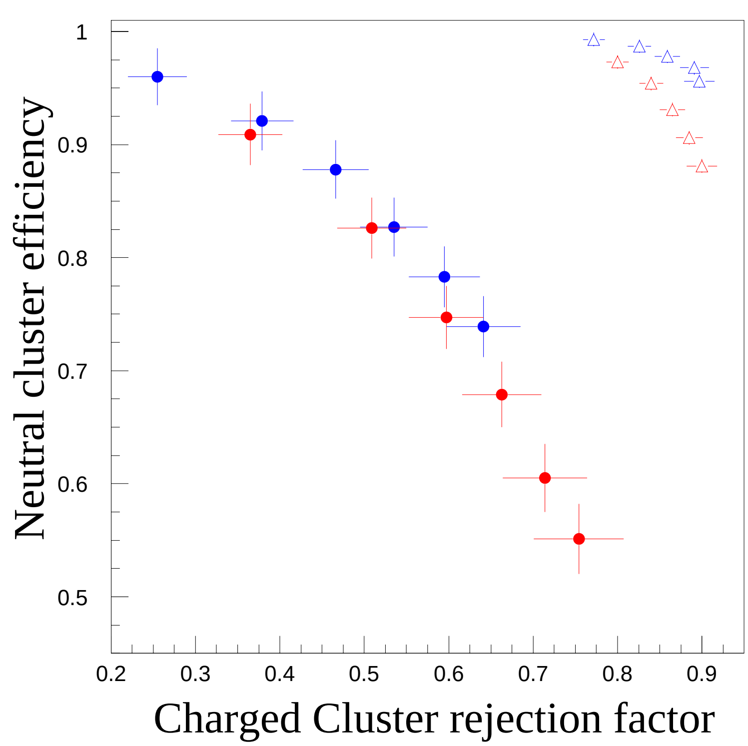
ΔX = X CLUSTER − X TRACK
clus-trk(e)
dL_e
Nent = 2350
e
clus-trk(gamma)
dL_g
γ
~4%
96%
clus-trk(pi K p)
dL_c
h±
~30%
96%
clus-trk(K0L n)
dL_n
h°

Energy Flow Studies

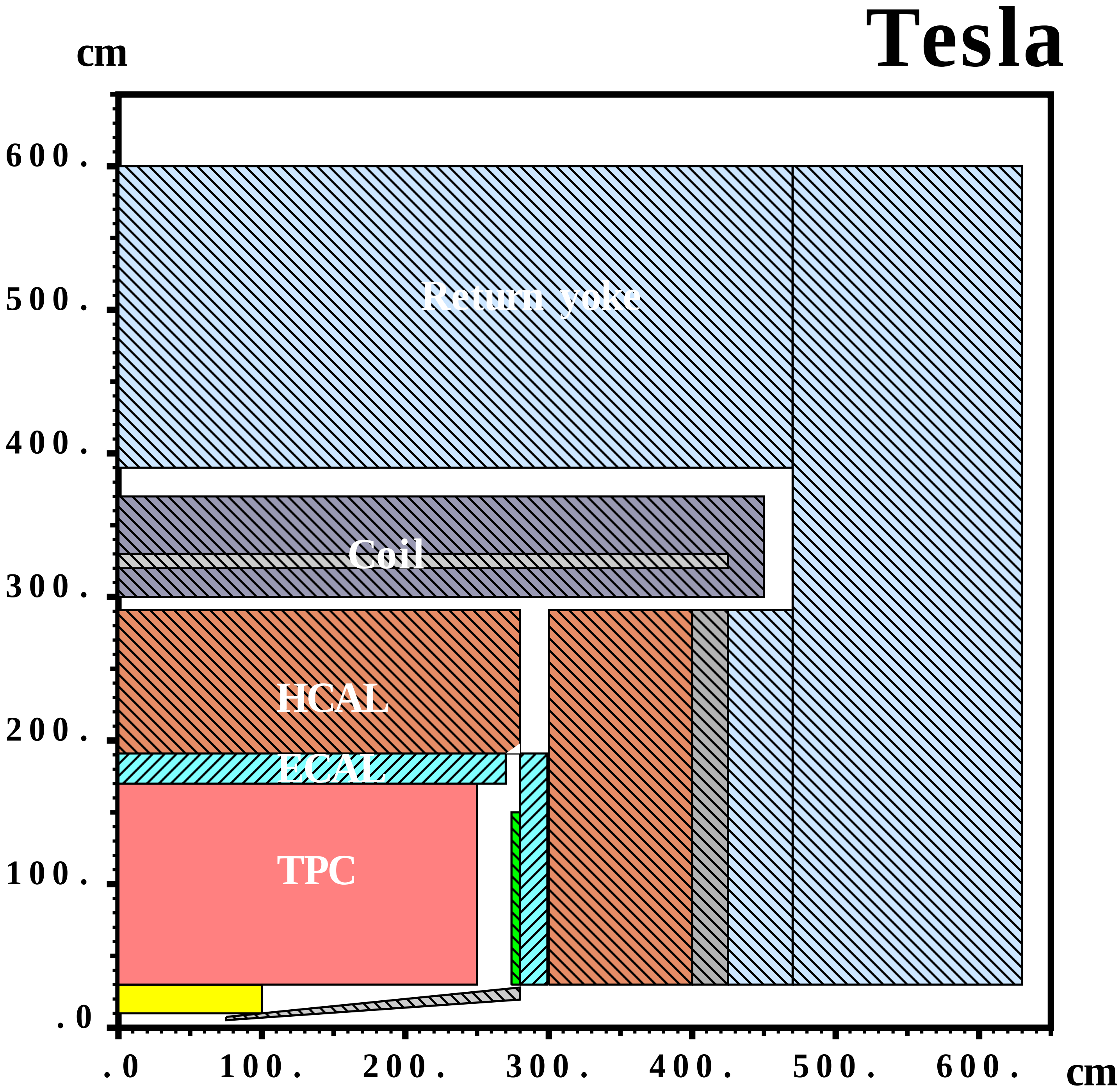
Use $e^+e^- \to t\bar{t} \to 4/6$jets

Masako Iwasaki

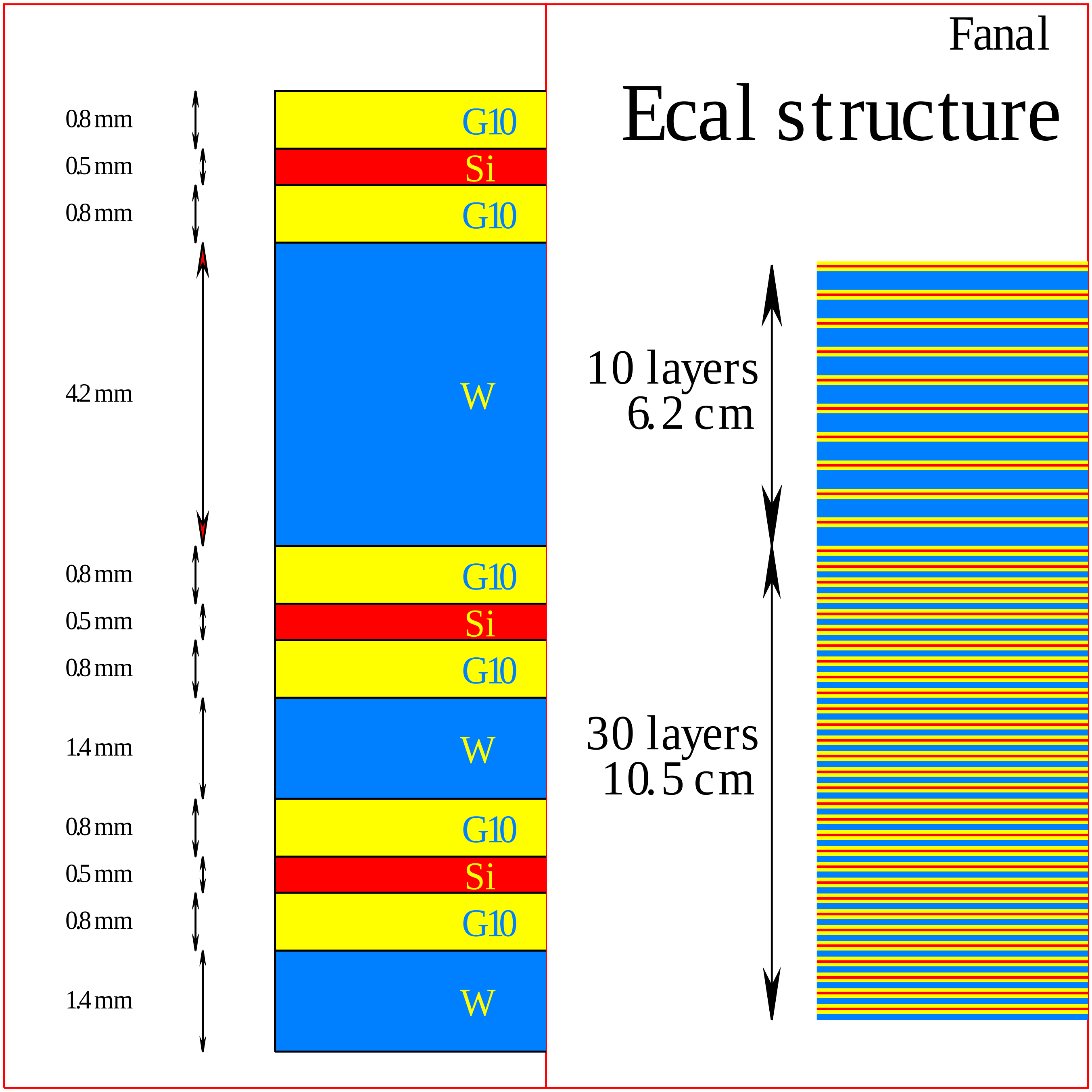




view of the detector



configuration



Electromagnetic calorimeter Si-W

- **Sandwich Tungsten - Silicon**
- **40 layers**
- **pad size of 1x1 cm**
- **3500 m^2 of Si pads**
- **35 Million channels**
- **130 T of tungsten**

configuration

- **30 layers**

each layer is 1.4mm Tungsten (0.4X0), 0.5mm Si pad and 1.6mm for the read-out

- **10 layers**

each layer is 4.2mm Tungsten (1.2X0), 0.5mm Si pad and 1.6mm for the read-out

This configuration is a compromise between

▷ *the energy resolution at low energy (stochastic term)*
▷ *the total thickness of the ECAL*
▷ *and the area of Silicon*

it gives :

- a total ECAL thickness of about 20 cm
- 24 radiation lengths at $\cos\theta=0$.
- A stochastic term of about 10%

This configuration can be further optimized

Conclusion on ECAL

A **Tungsten-Si sandwich calorimeter with large number of sampling** seems a good tool for multi-jets events, which is one of the most interesting final state for e^+e^- collision up to the TeV region.

It provides both

- **A good efficiency for photon reconstruction, even for photons as close as 1 cm from a charged track**
- **a good stochastic term** $\Delta E/E \sim 10\% \,/\sqrt{E}$

More , this calorimeter has a good potential for improvement which has not been explored yet :

- *Counting the pads of the shower to estimate the energy must improve the resolution at low energy*
- *The use of mathematical method for the image processing to improve the EFLOW*

A lot of R&D to do

- for the Si diode on the industrial side, on the micro-mechanics and micro-bounding
- for the highly integrated low noise front-end electronic
- for the software/algorithm to be used for the EFLOW

Project with increasing community

NIKEHF-Amsterdam, LPC-Clermont, MSU-Moscow Univ.
LAL-Orsay, LPNHE-X-Ecole Polytechnique, LPNHE-P6/7-Paris Univ.

Calorimeter Cost Exercise

Frey
5/23/0[illegible]

- S EM (Si/W) → here
- S HAD (Cu/scint), L EM&HAD (Pb/scint) → Andre Turcot

S EM Configuration:

☆ Assume Energy Flow jet reconstruction ☆

⇒ highly segmented, dense EM cal.
(+good tracker, B~few T)

⇒ Si/W (Snowmass '96)

- Transverse seg. 1cm × 1cm (2π/300)
- Long. seg.: 50 × [5mm = (2mm W, 0.3mm Si)]

⇒ **Total Area Si ≅ 1100 m^2** (= W area)

(nb: 3500 m^2 for TESLA design)

× 1.5\$/cm^2 W (includes machining, Ref. D. Strom, OPAL Lum)

× 6\$/cm^2 Si = CMS + assembly
− falling costs, larger (8")

⇒ Barrel: 76.2 m\$ (3.5×10^4 clusters)
Endcap: 6.1
LUM: 0.4

d\$/dR ≃ 1.0 m\$/cm

d\$/dn ≃ 1.6 m\$/layer

- 50 → 40 Layers: 83 → 67 m\$
- 40 Lay, R = 0.75 → 1.7m: 156 m\$

What Path ?

- What do we really need for Jet Recon.?
  - Role of Fast Sim: Quantify from known processes
  - Exploration Tool: Better than good enough (if affordable!)
- The Energy Flow Paradigm: Is it really the best approach?
  - A fundamental LCD issue: So far, not answered !
- This requires:
  - Full Simulation (shower library OK)
  - Cluster Reconstruction
  - Physicists using the Full Sim !
- To be studied:
  - BR^2 *vs* shower separation (granularity & density/Moliere)
  - B, R separately
  - optimal clustering algorithms
  - the role of the hadron "calorimeter"

    i.e. charged hadrons followed by K_L^0, n catcher
- Eventually hope to parameterize EF performance in fast sim.
- Cost optimization for an EF device
  - granularity which decreases with depth
  - total depth
  - where to put the coil
  - can the "catcher" also do muons
- Jet recon. studies in parallel with other physics studies
- Other Calorimeter Issues:
  - small-angle 2-photon tagging
  - medium angle Bhabha acollinearity $\Rightarrow d\mathcal{L}/dE$
  - $BR(H \to \gamma\gamma)$: particle id. problem?