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Fermilab, October 26 2000

A W–Si electromagnetic calorimeter for Higgs physics at a linear collider

Higgs Physics

Jet physics

Energy flow

Hermeticity

Granularity 3d

with few simple ideas

Hermeticity: full containment of energy
low angles covered
no cracks
no dead material $\Longrightarrow$ inside coil

Energy flow in a multijet environment
lepton identification $\Longrightarrow$ good separation

$\Longrightarrow$ granularity 3d $\Longrightarrow$ density

very high 3d granularity $\longrightarrow$ drop projectivity

E resolution $\Longleftrightarrow$ layer structure (sampling)

Choice for a high density pictorial calorimeter totally inside the coil

ECAL W-Si with tiny cells
HCAL digital "

with a software able to extract all the juice (PG talk)

ECAL mechanical structure

40 layers of W and Si

21 cm thick

30 ‖ 1.4 mm thick — $12\,X_0$
10 ‖ 4.2 — $12\,X_0$

to be optimised

starting at a radius of 1.7 m

⟹ a good area of Si ($\sim 3000\,m^2$)

dense — very small cells $1 \times 1\,cm^2$
very numerous $> 30\,T$

as many as seconds in a year!

Mechanical structure

No projectivity eases | cracks problem
| technical design
in particular end caps

The geometry allows to put the front-end electronics between ECAL and HCAL

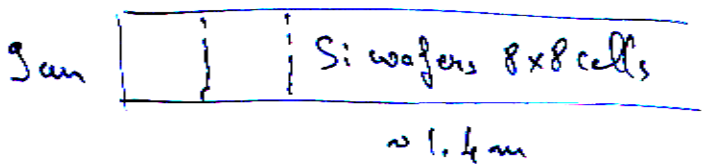
A trivial solution to mechanical structure:

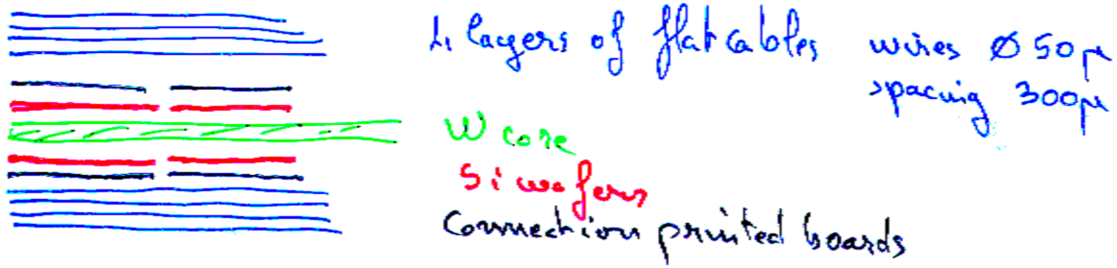
⟹ no large holes but a lot of small ones (wrt showers)

Tungsten slabs ($0.9 \times 1.4\ m^2$) are wrapped in an epoxy-carbon fibre composite leaving space for detector elements

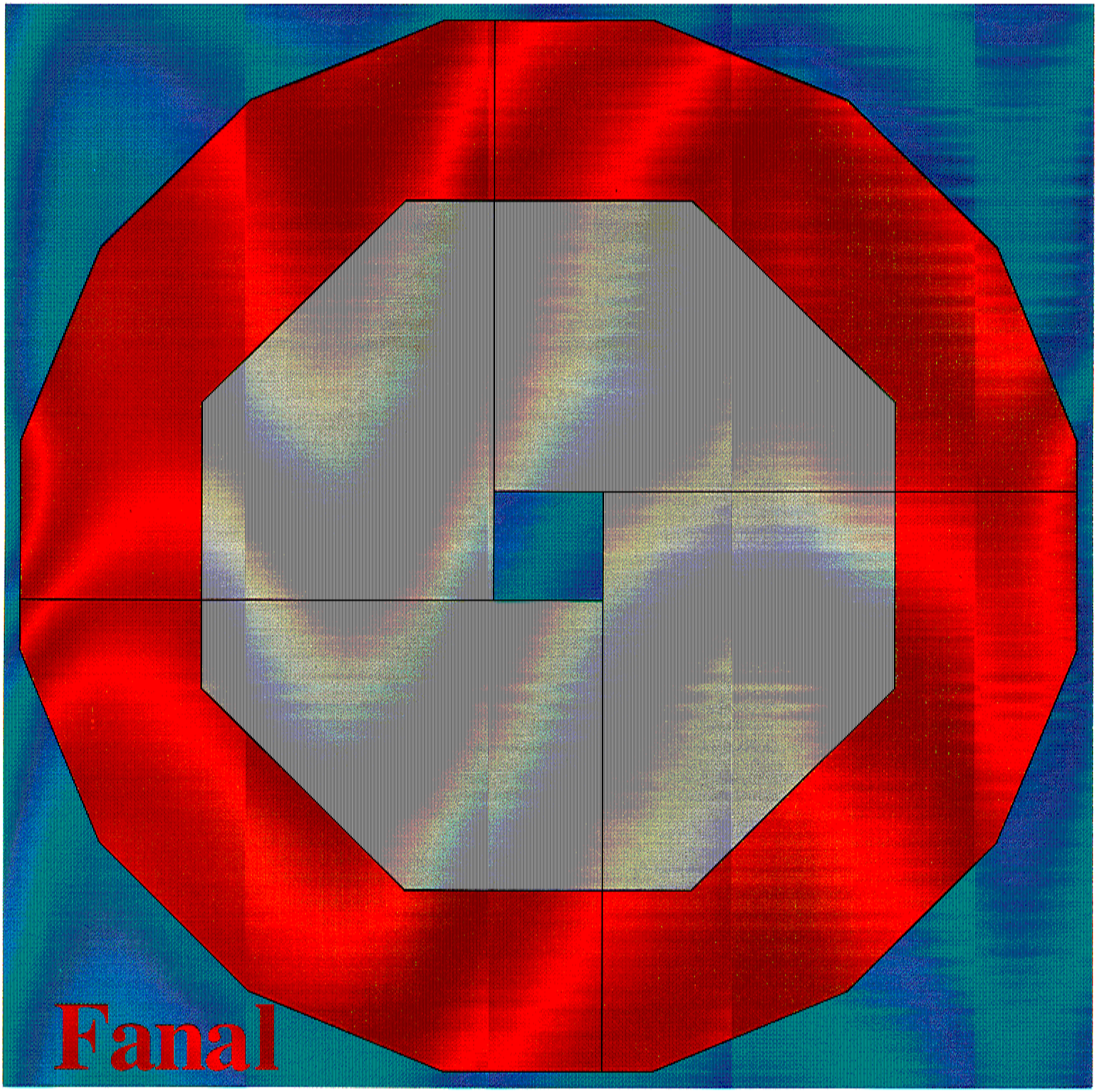
Getting the signal out

on the structure of the detector slabs

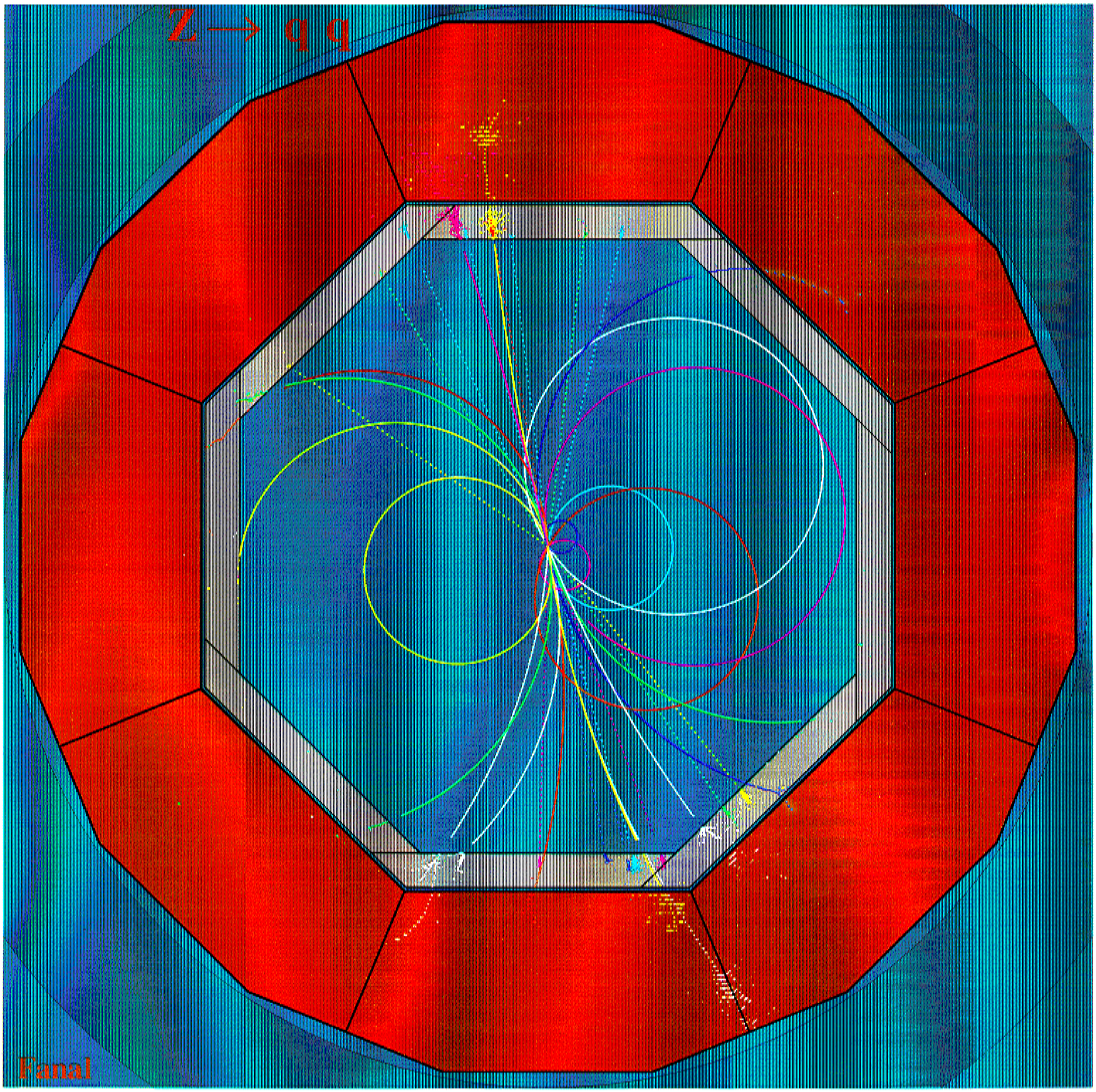




HV L.1

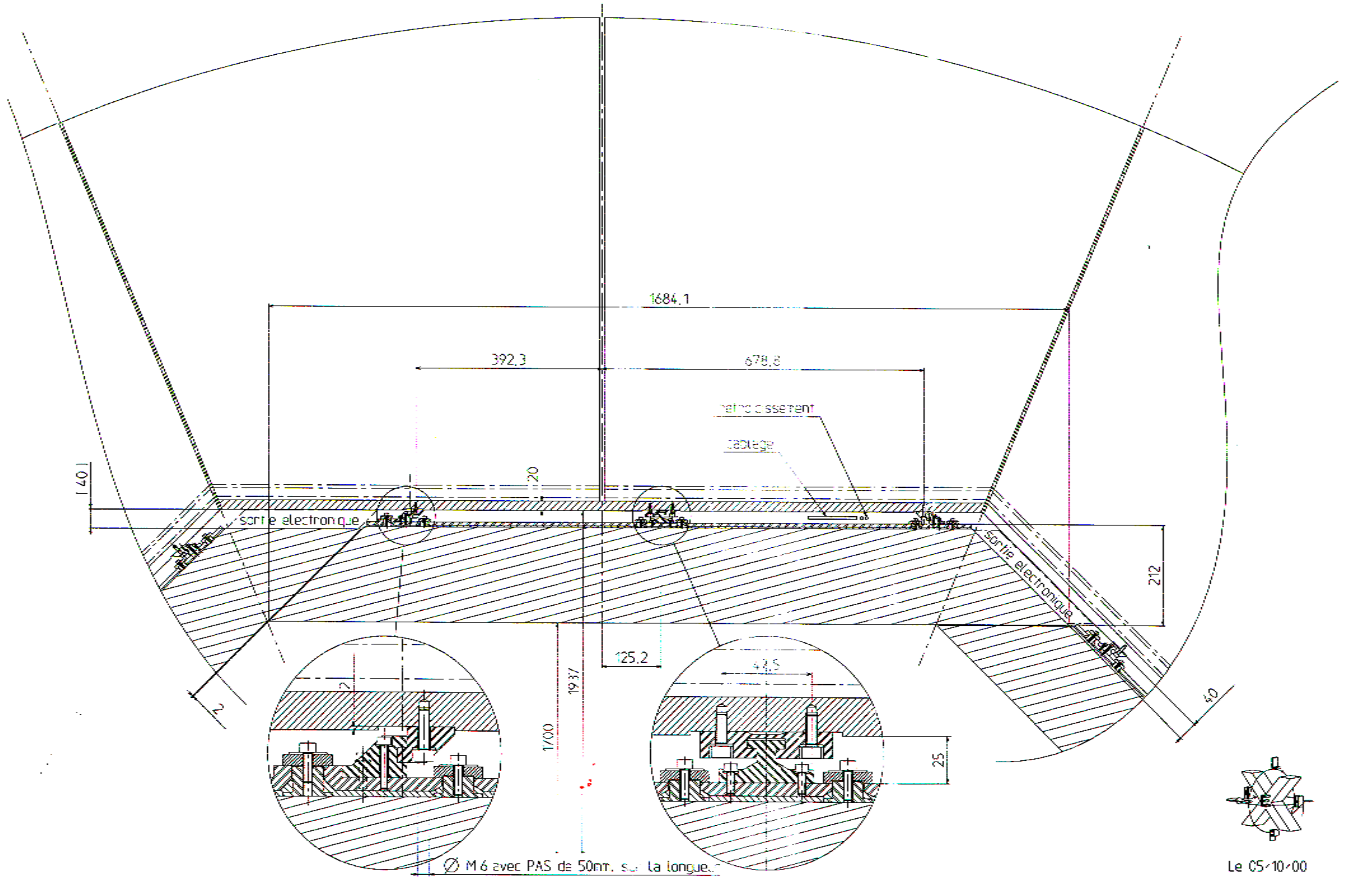


The eightfold way



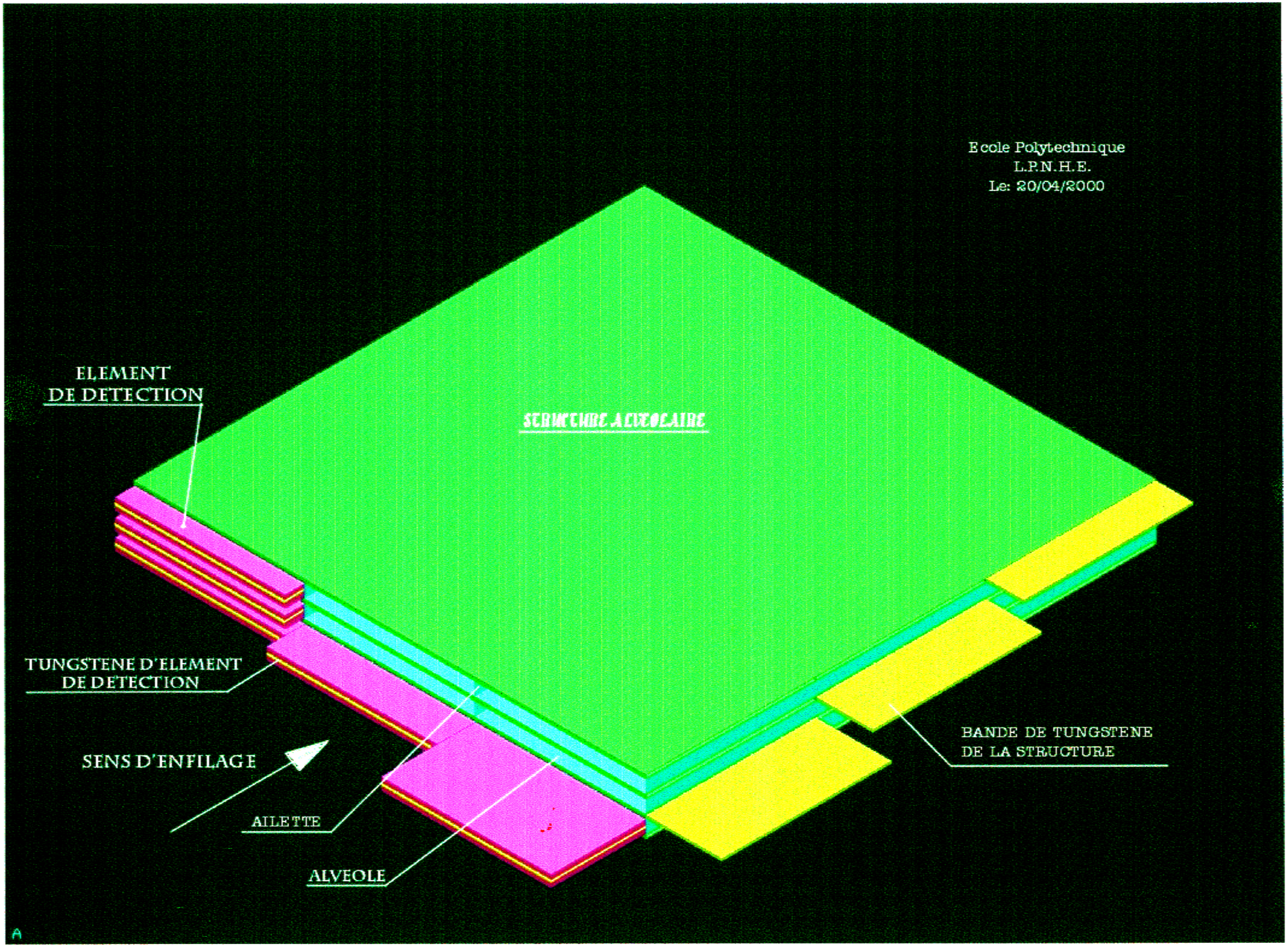
HV 2.3

INTERFACE ECAL - HCAL



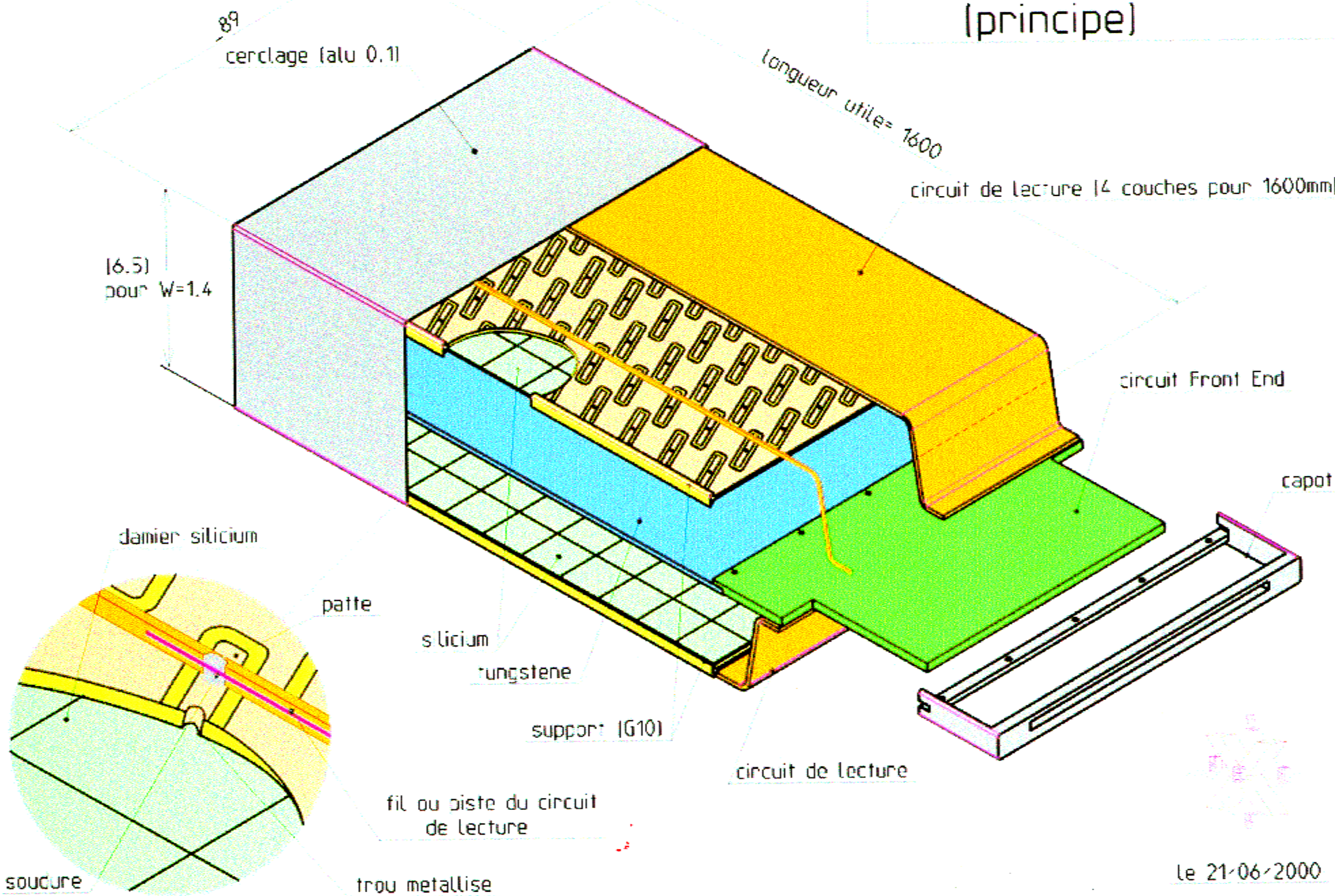
Le 05/10/00

HV
4.4


Ecole Polytechnique
L.P.N.H.E.
Le: 20/04/2000
STRUCTURE ALVEOLAIRE
ELEMENT
DE DETECTION
TUNGSTENE D'ELEMENT
DE DETECTION
SENS D'ENFILAGE
AILETTE
ALVEOLE
BANDE DE TUNGSTENE
DE LA STRUCTURE
A

HV4.5

ELEMENT DE DETECTION (principe)



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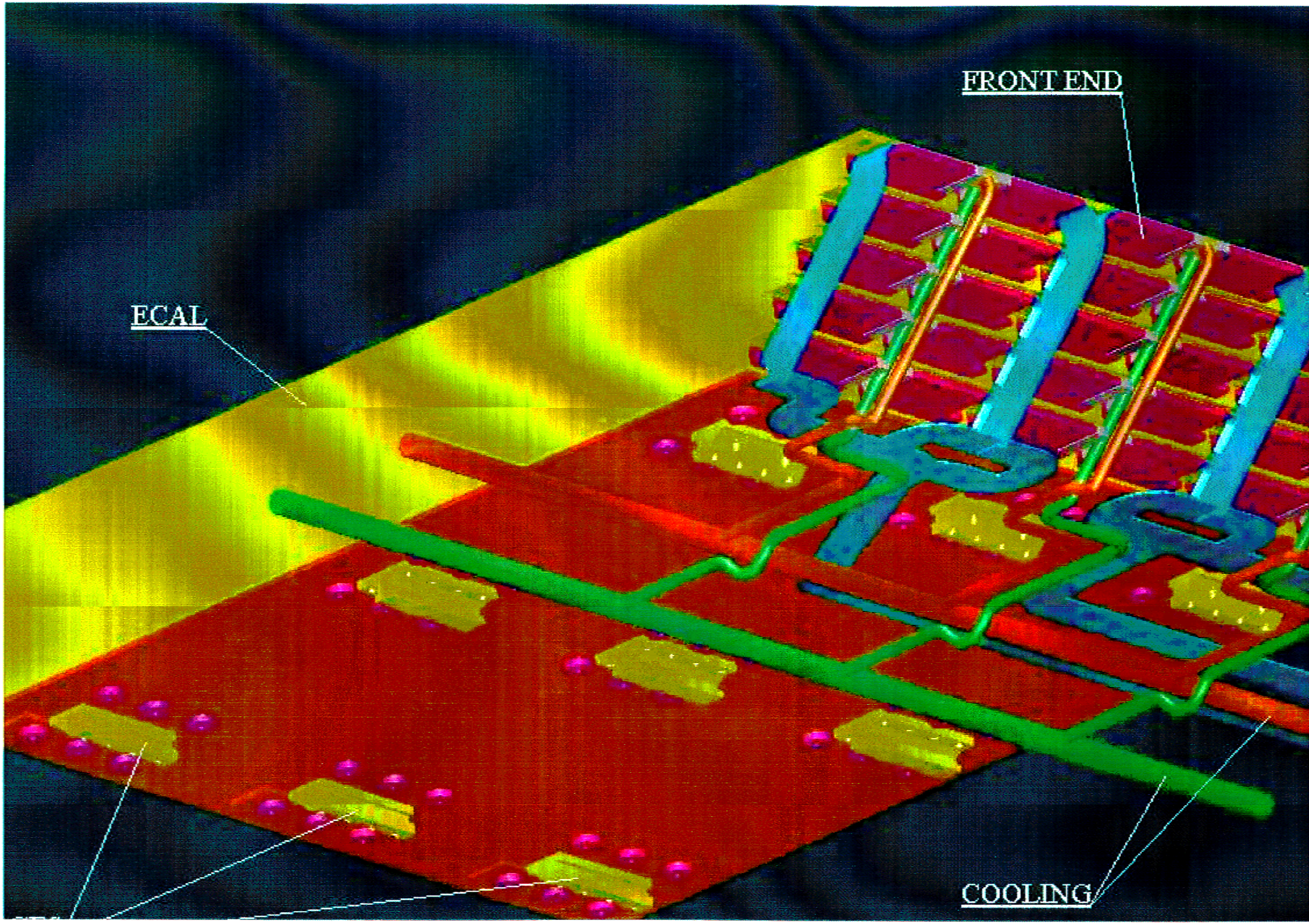

FRONT END
ECAL
COOLING

Electronics and read out

large # of channels with small occupancy.

Dynamics from a fraction of a m.i.p. to max deposit in a cell by 500 GeV electron
$\Longrightarrow$ 15 bits

precision $\Longrightarrow$ 2 gains of 10 bits each

in Tesla quite some time to integrate signal (150 ns)
incoherent noise $\sim$ 1/10 of a mip (tested)
coherent ?!

Functions amplify
cut locally at $\sim 2/3$ of a mip $\varepsilon = 97\%$
stamp bunch # address (analogically)
stores

Packaging a detector slabs contains about $2 \times 8 \times 140$ cells
to be treated in a tiny space by $(2) \times 8$ chips

Read-out a set of 40 detector slabs can be readout (through a token ring)
and digitized in few ms by one ADC $\Longrightarrow \sim 700$ 10bit ADC's + storage

a full train $\longrightarrow$ DAQ

A glimpse at the hadronic part (digital solution)

A stainless steel radiator

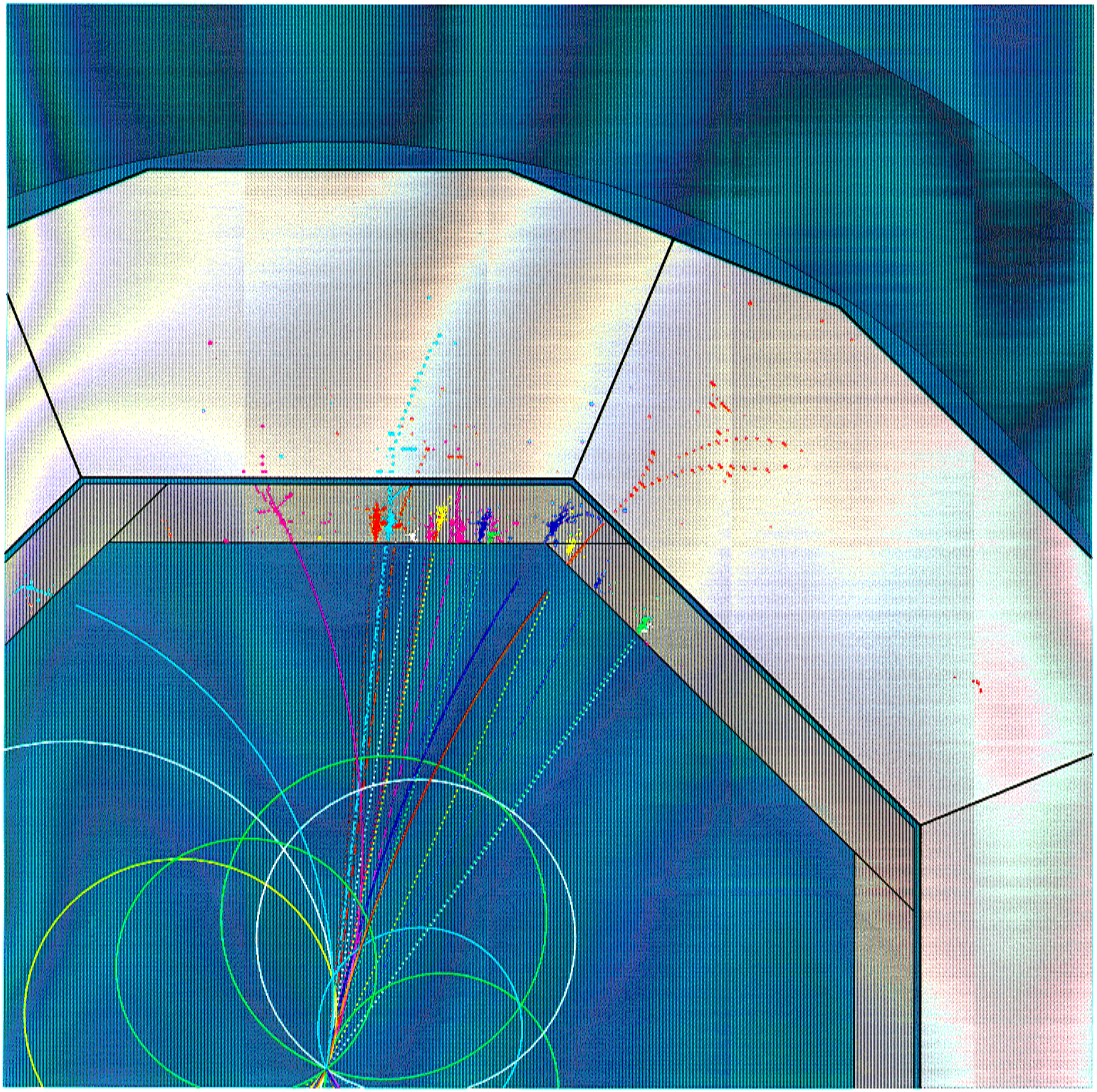
A detector providing a digital signal from small cells

Streamer or Geiger or RPC cells
read by shift registers.

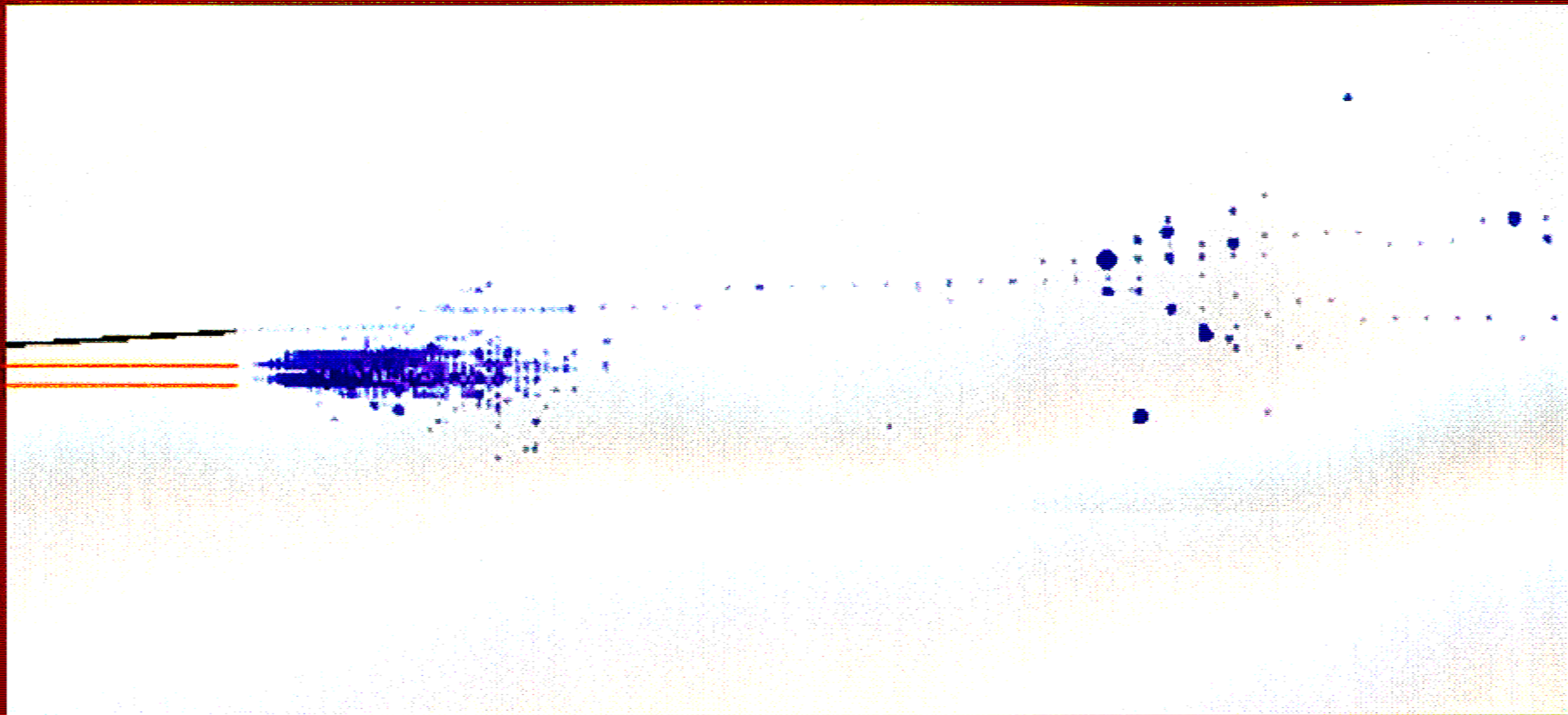
The resolution obtained that way compares well
with an analog measurement from ALEPH and simulation

Excellent pattern.

HV 6.1



HV 6.2



300 GeV $\tau \rightarrow \nu_\tau \rho$

$\rho \rightarrow \pi^\pm \pi^0$

TESLA

A high granularity ECAL and HCAL

Cell size 1x1x0.5 cm^3

Back to bubble chambers?

Performances from a Geant 4 study (talk by P. Mora de Freitas)
(talk by P. Gay)

Photons

Efficiency and rate of fakes — see plots

Energy resolution $\sim 0.12/\sqrt{E}$ ~ flat in angle

Position resolution $1/\sqrt{E} + 0.4$ mm

Angular resolution $60/\sqrt{E}$ mrad

Neutral hadrons → talk by P. Gay

Jets visible energy resolution $0.17/\sqrt{E}$ if no neutral hadrons

photon collection ~ intrinsic resolution

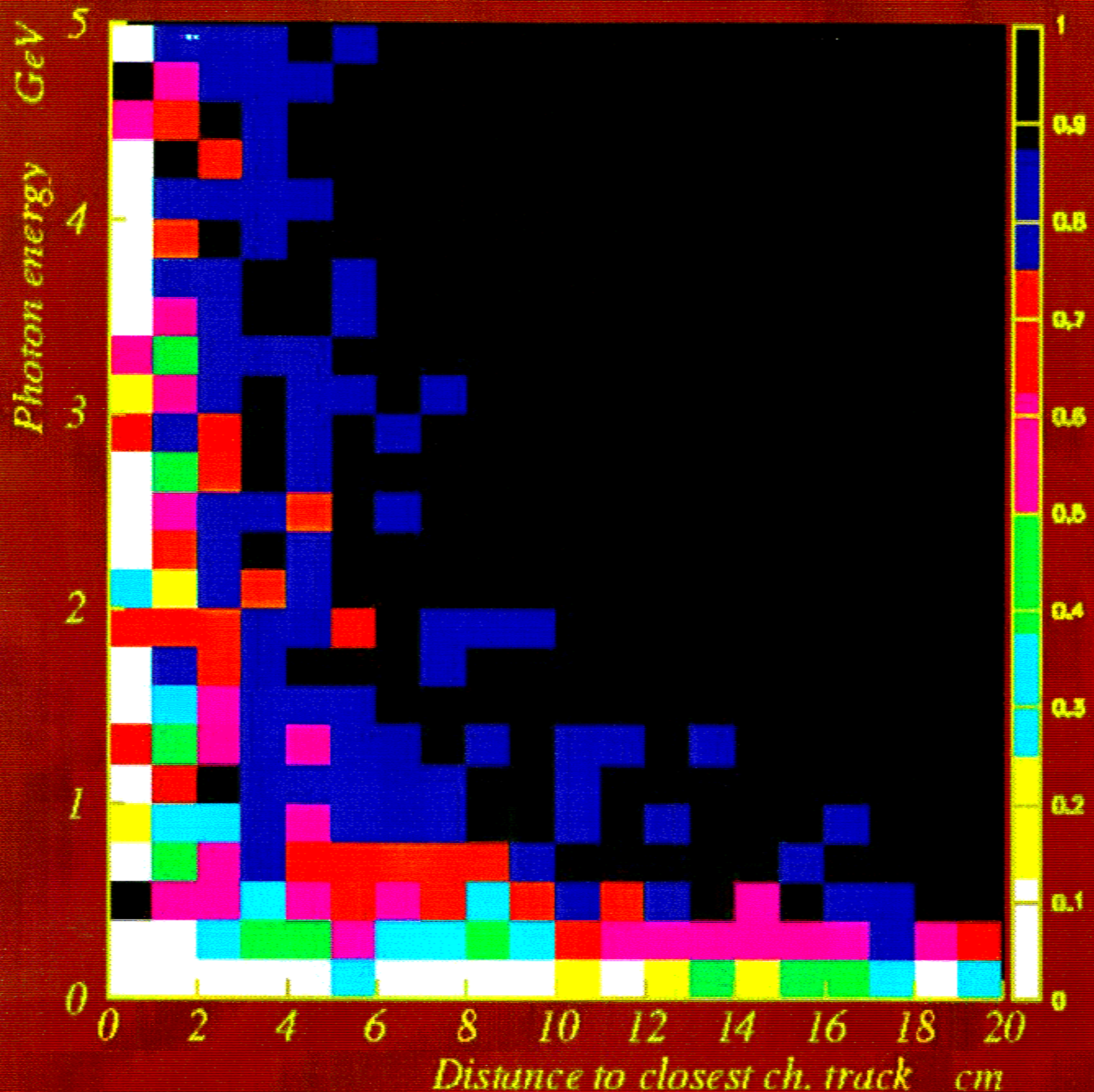
$< 0.4/\sqrt{E}$ with hadrons (~2 times better than Aleph)

dominated by HCAL ⟹ work on pattern, resolution

Identification of isolated e and μ ($p > 2$ GeV) $\varepsilon = 99.8\%$ for contamination $< 10^{-3}$

~~work~~ going on for in jets

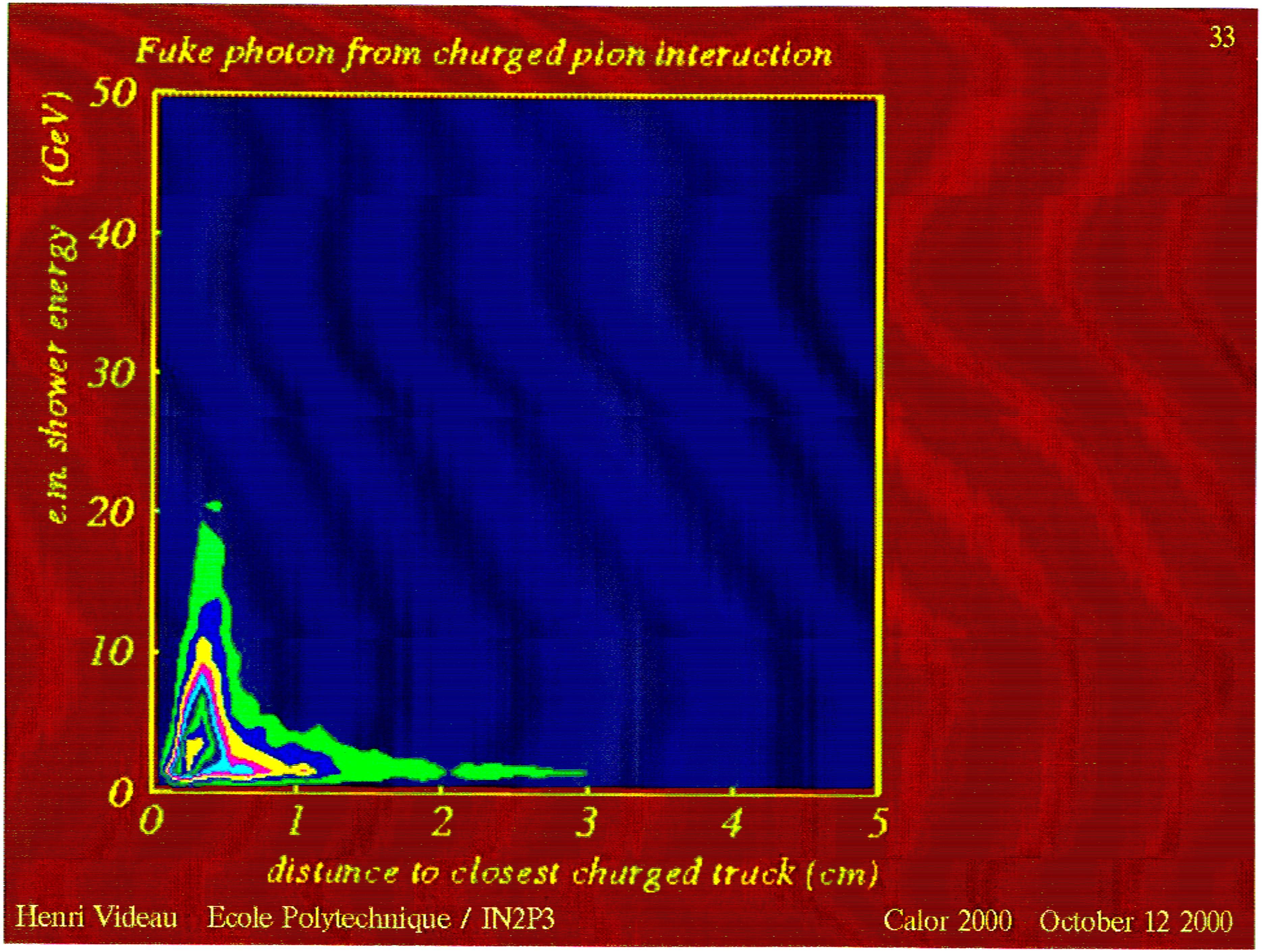
H0 7.1



Photon efficiency as a function of
- distance to closest charge track
- photon energy

In fact p_T

AV7.2


33
Fuke photon from churged pion interuction
e.m. shower energy (GeV)
50
40
30
20
10
0
0
1
2
3
4
5
distunce to closest churged truck (cm)
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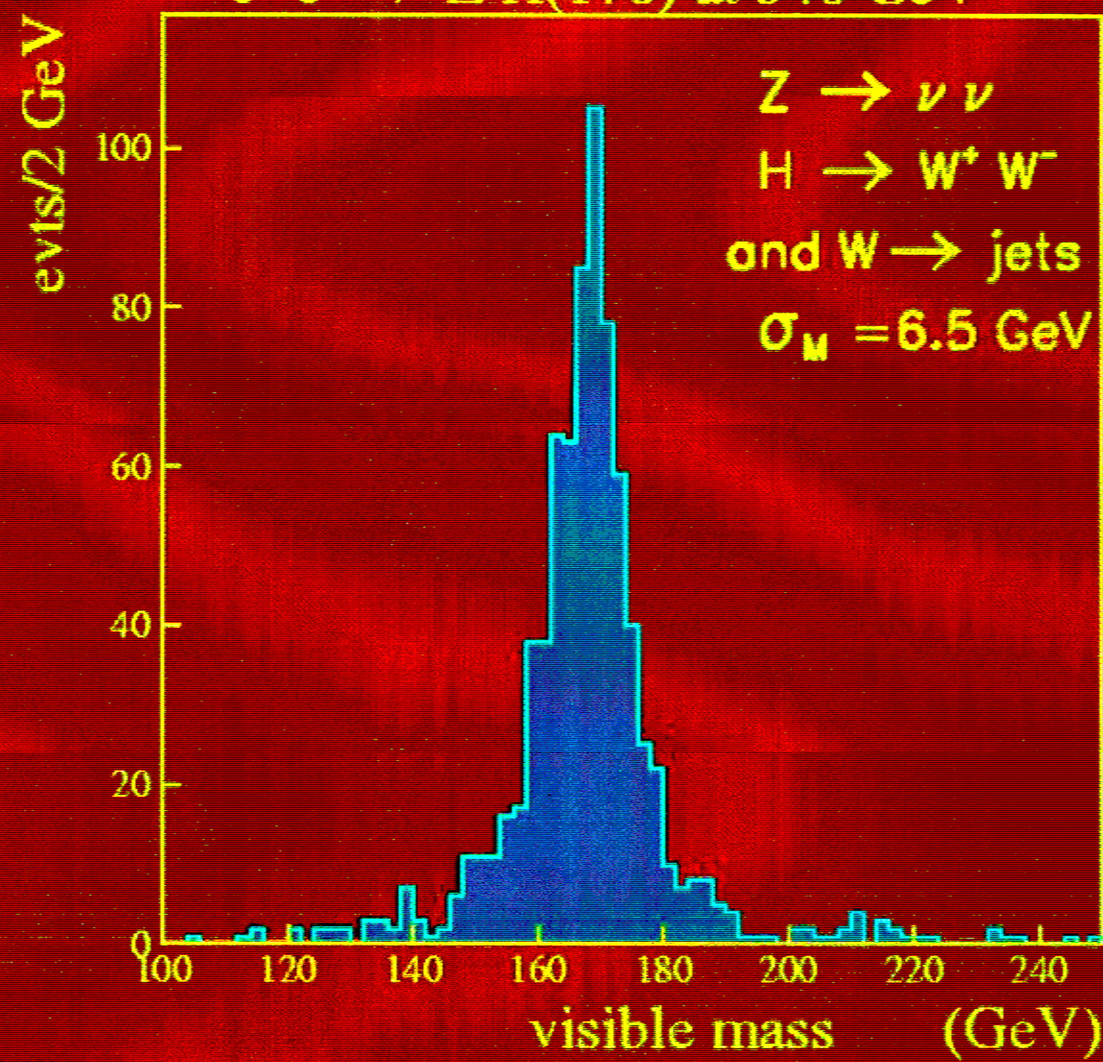
Calor 2000 October 12 2000

$e^+e^- \rightarrow Z\,H(170)$ at 340 GeV



Conclusions

We have a precise ECAL design for Higgs physics

It seems technically feasible with some delicate areas

- the detector slab or getting the signals out
- the front end electronics integration
- the industrialization of the Si processing to reduce cost.

being prototyped
chip in 2001

It remains to be optimised, in particular in its layer structure

The software to exploit its capabilities is an interesting challenge
may bring a lot

The price, as of today (130 M€), is totally dominated by the silicon area.

Its probable evolution is under study - May bring a factor 3

Read the Tesla TDR
when released.