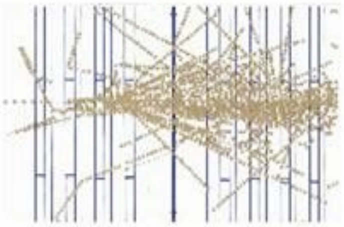


Introduction to CALOR 06:

Calorimeter issues today

CALOR 2006

June 5-9, 2006 Chicago, USA

A. Ereditato - University of Bern

A bit of history

The CALOR conference series started this way:

Adam Para organized a (successful) Workshop at FERMILAB in 1990 (b.t.w. he created the logo)

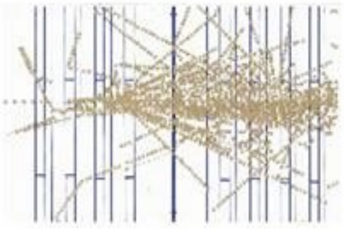
A.E. intented to bring some friends to Capri for further discussions (shall we make a series out of it ?)

Peter Jenni joined the group and together we decided to actually create a series…

International Conference on Calorimetry in High Energy Physics (Fermilab, 1990)
2nd International Conference on Calorimetry in High Energy Physics (Capri, 1991)

Followed by Corpus Christi (1992), Elba (1993), Brookhaven (1994), Frascati (1996), Tucson (1997), Lisbon (1999), Annecy (2000), Pasadena (2002), and Perugia (2004).

We are here to start the XII edition at Chicago (good luck to Rik and Steve)



Some statistics

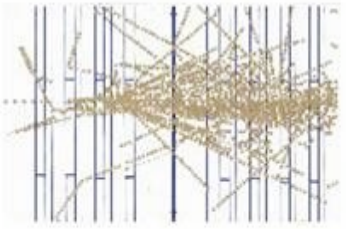
- The Conference has successfully reached the XII edition, basically alternating US and EU venues with a 1-1.5 years periodicity

- in more than 15 years the CALOR conference:
  - hosted the debate between SSC/LHC detectors
  - featured the design, prototyping, construction and commissioning of LHC calorimeter
  - included papers on the construction and operation of non-collider calorimeters
  - experienced the move from HEP to particle physics calorimetry
  - certified the growing relevance of astroparticle/neutrino applications
  - played the role of the main forum where new ideas and R&D studies are presented
  - is (will be) the place where design and tests of ILC calorimeters are (will be) discussed

- The conference format and program evolved together with the technology and under the pressure of the community

- more than1000 (!) invited and contributed papers were submitted in 12 editions covering all aspects of basic detection principles, R&D studies, performance of running calorimeters and studies on future detectors

All in all, a great success!



My introductory talk to CALOR06:

Not the usual review on calorimetry (excellent papers by distinguished colleagues are available)

Not a politically-correct gallery of results and achievements from past and present calorimeters

Not the advertising of my last paper on the subject…

Instead, let me start telling you what I learned working for many years with these detectors, mostly in realizing neutrino physics experiments, and then continue with a few selected topics…

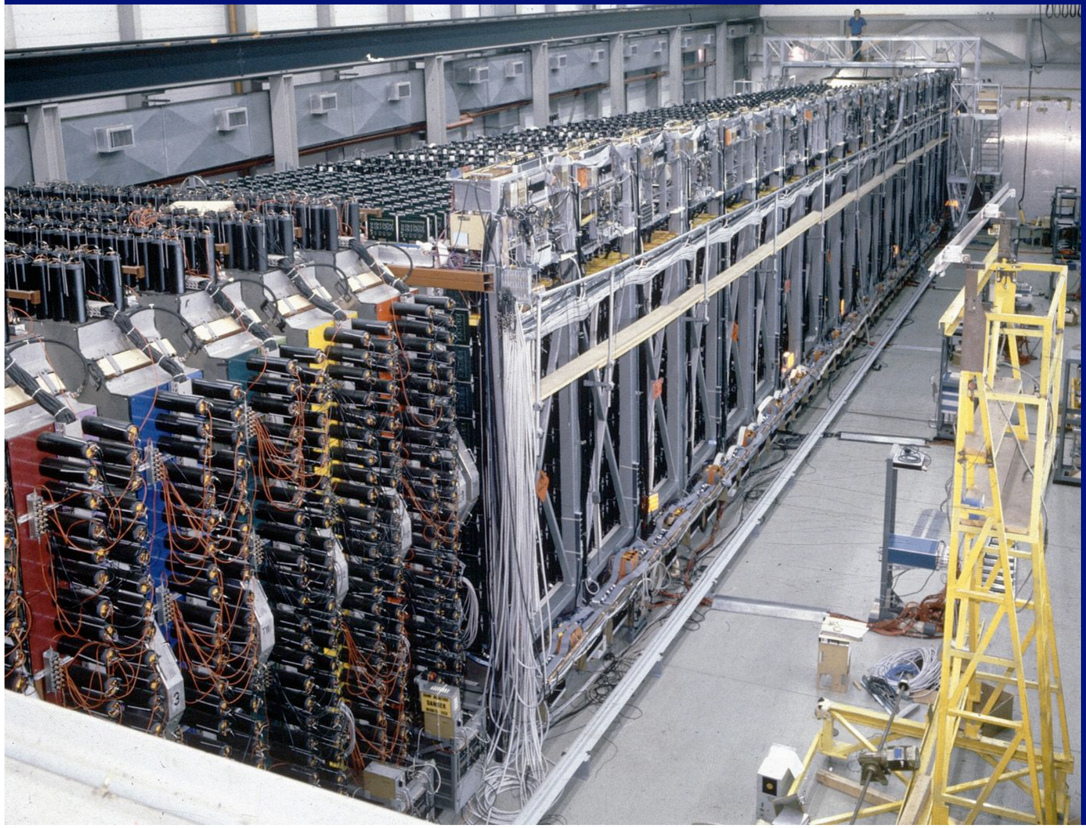
Fine grained (~200 k dig+analog channels), large mass (700 t), low density (glass), gas (LST), sampling (1/2 X_0)

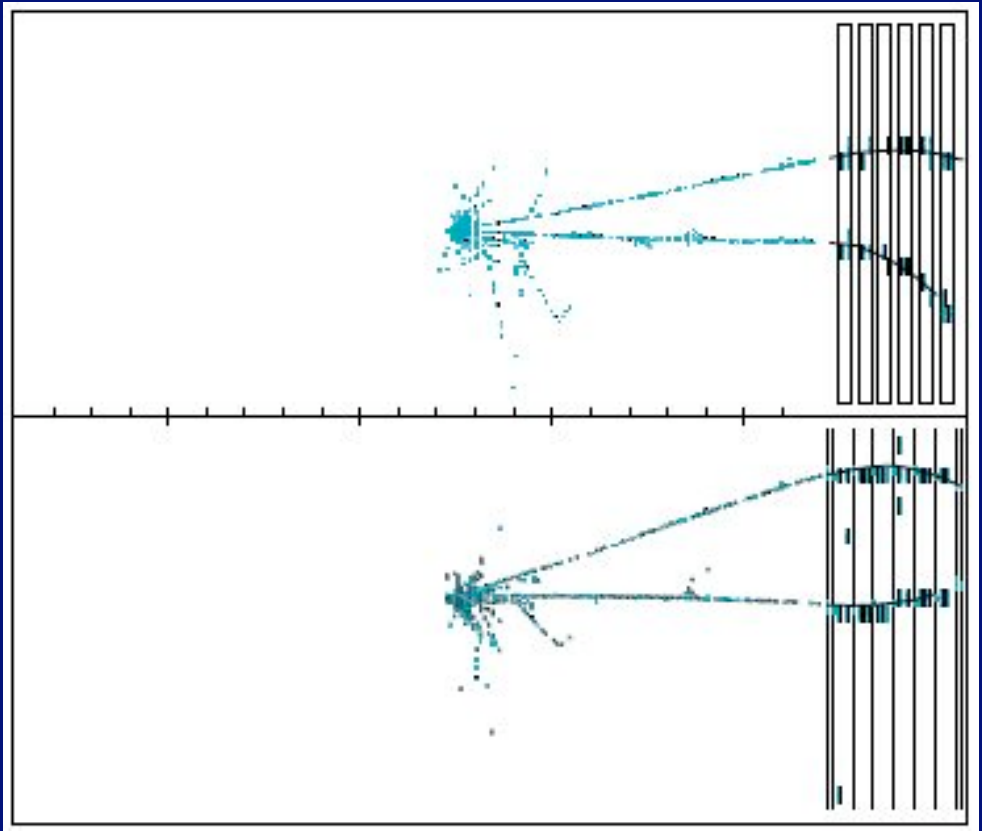
calorimeter for neutrino physics (ν-e scattering, ν DIS interactions)

The fashion of high granularity gas calorimeters

achievement: collection of ~2000 ν_μ - ν_e scattering events

CHARM II detector at CERN (1984-1990)



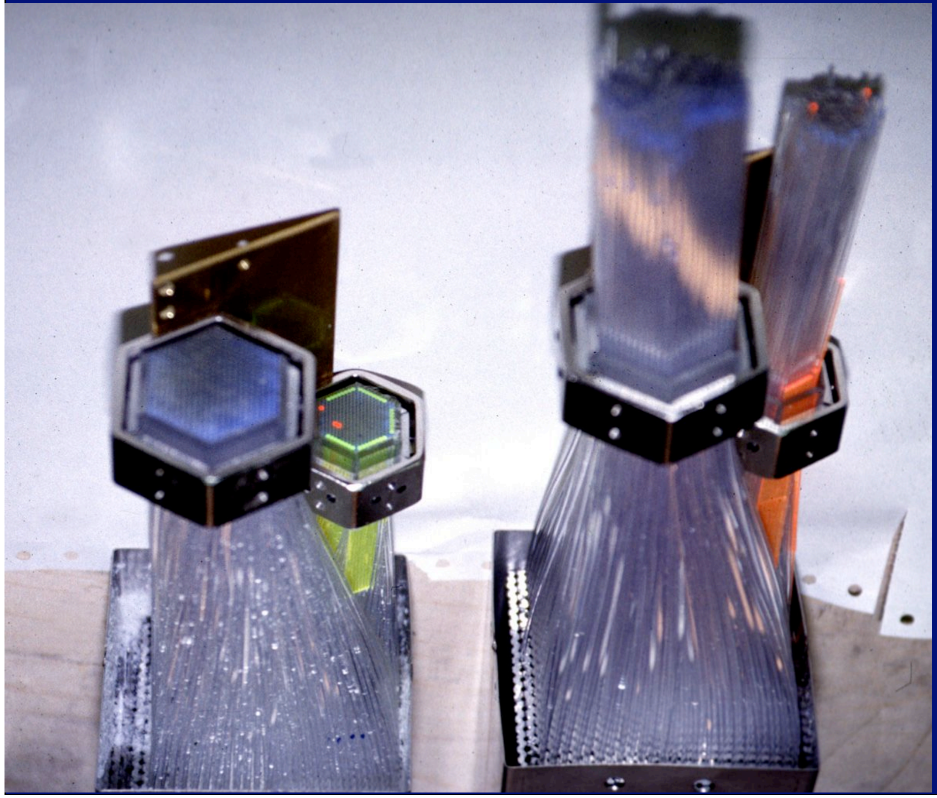


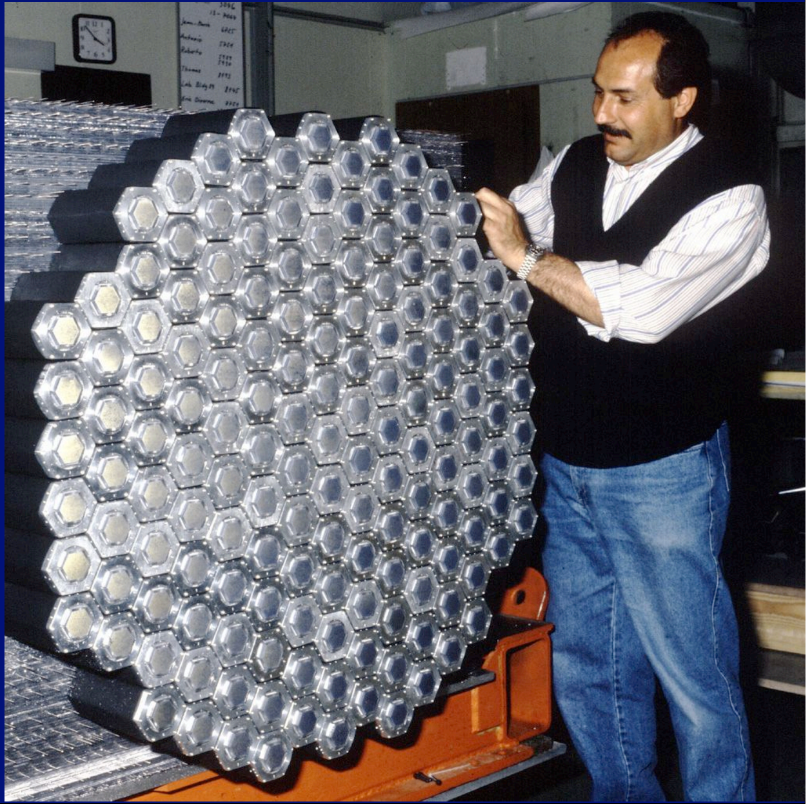
Lead-scintillating fiber, compensating, EM/HAD integrated calorimetry for collider physics (SSC/LHC experiments)

Compensation: a major breakthrough in understanding the basic principles

achievement: world record hadronic energy resolution (~ 0.3/√ E)

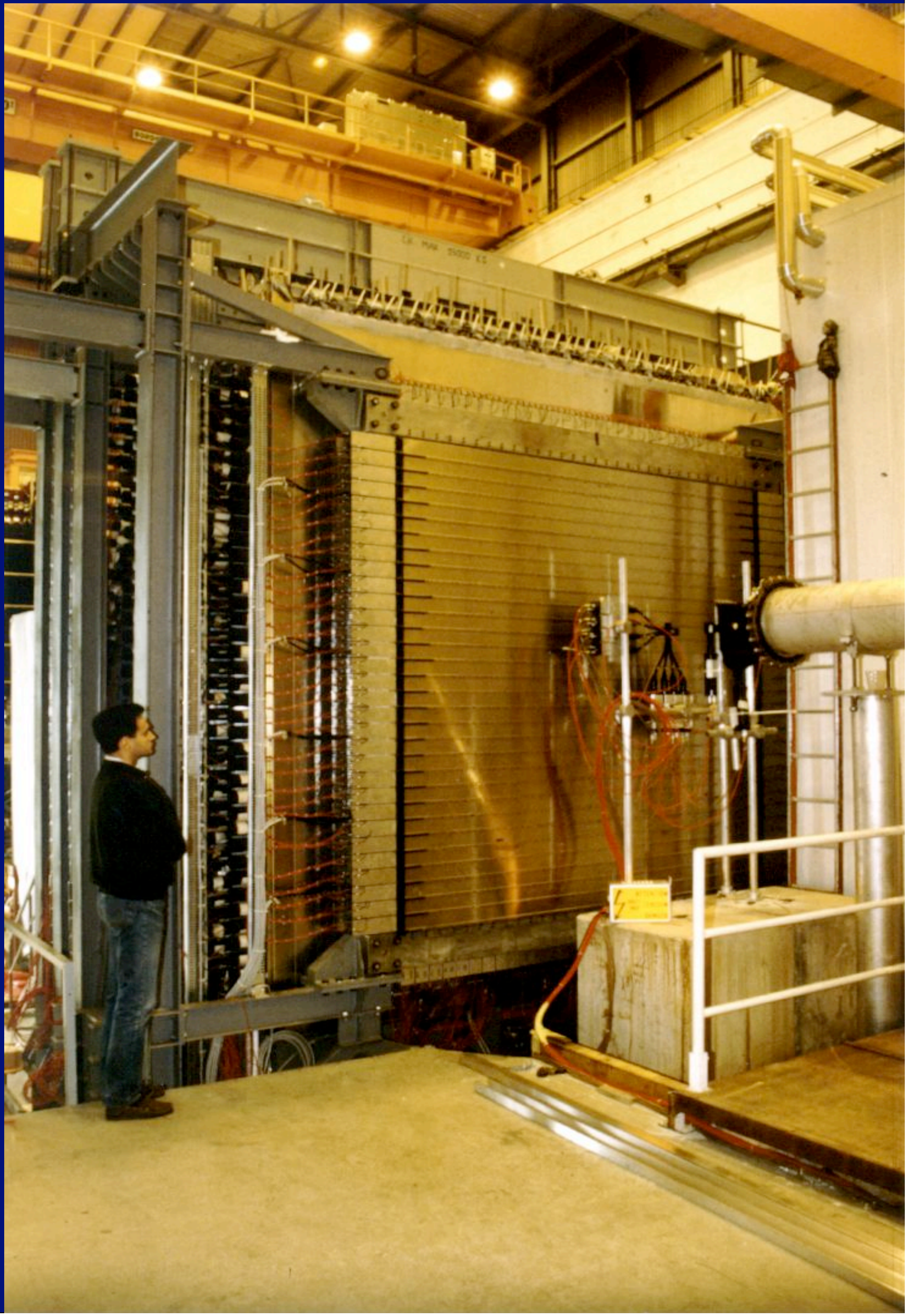
SPACAL and RD1 projects at CERN (1988-1992)





First application of the SPACAL technique to an experiment: EM + HAD calorimeter

CHORUS experiment at CERN (1992-1996)



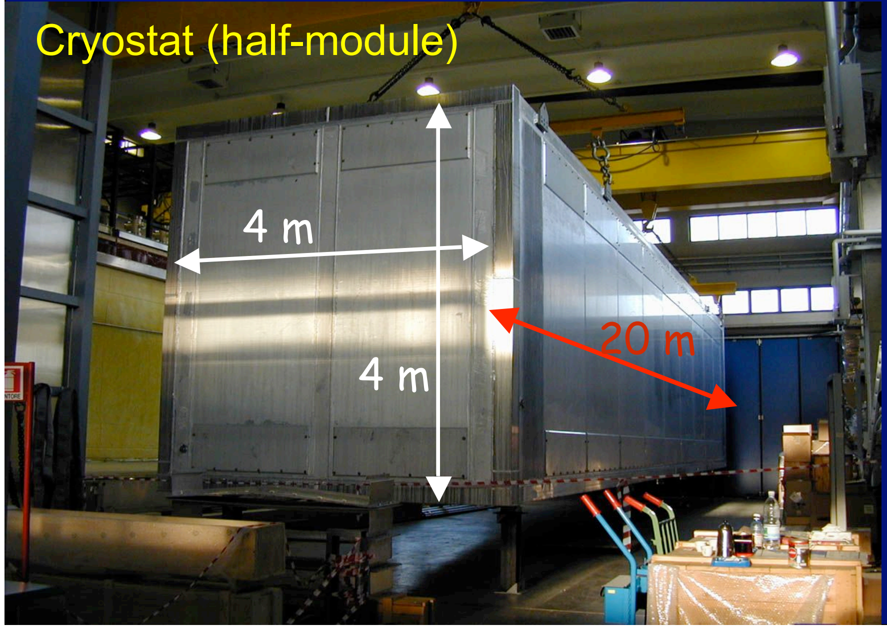
achievement: high hadronic energy resolution for kinematical pre-selection of ν interactions

Large mass (~ kton) liquid Argon TPC for high space resolution imaging-calorimetry of rare events (neutrino and astroparticle)

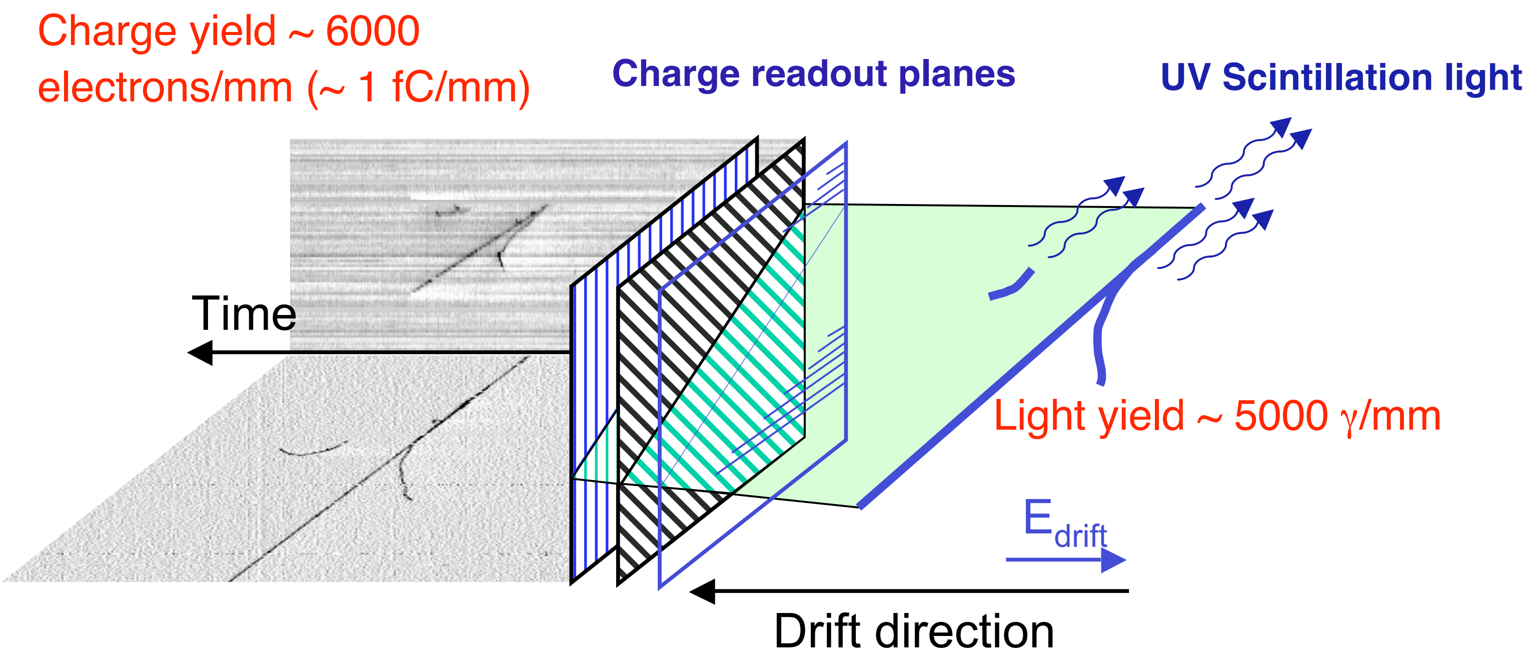
ICARUS R&D project at INFN (in progress)

achievement: working technology for high-mass underground observatories;
excellent imaging-calorimetric performance

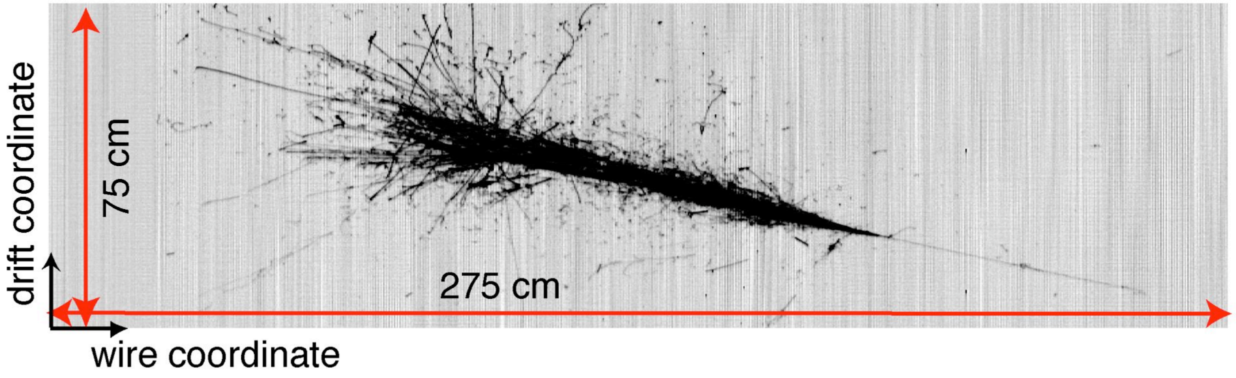
300 ton module

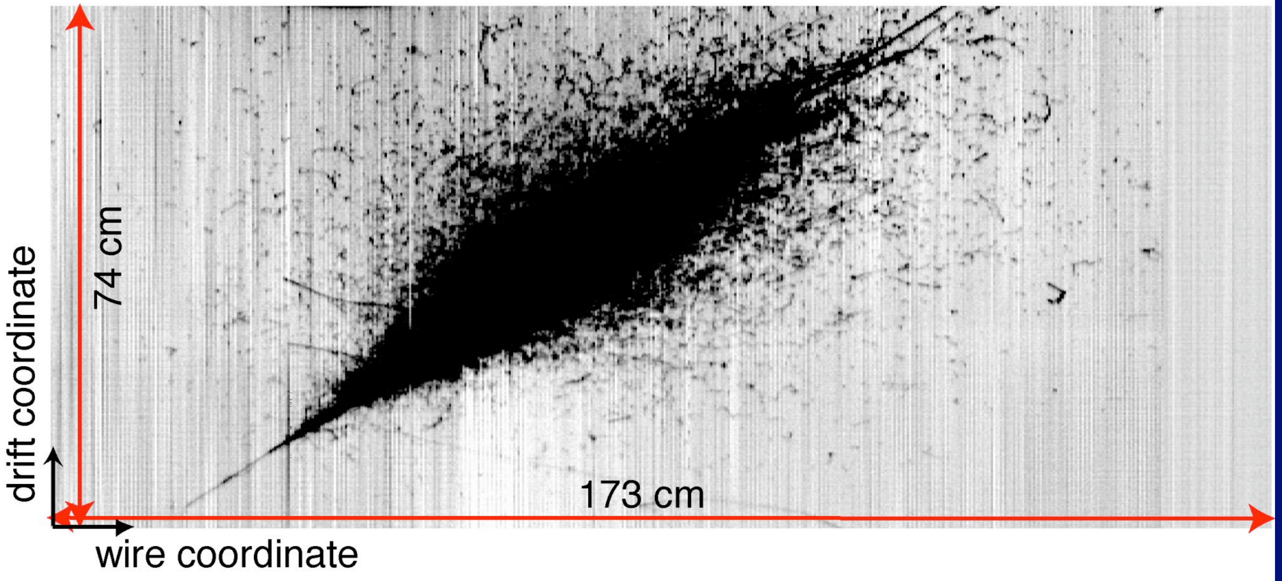


LAr TPC working principle



Cosmic-events in a 300 ton detector module


Run 308 Event 7 Collection view


Run 308 Event 332 Collection view

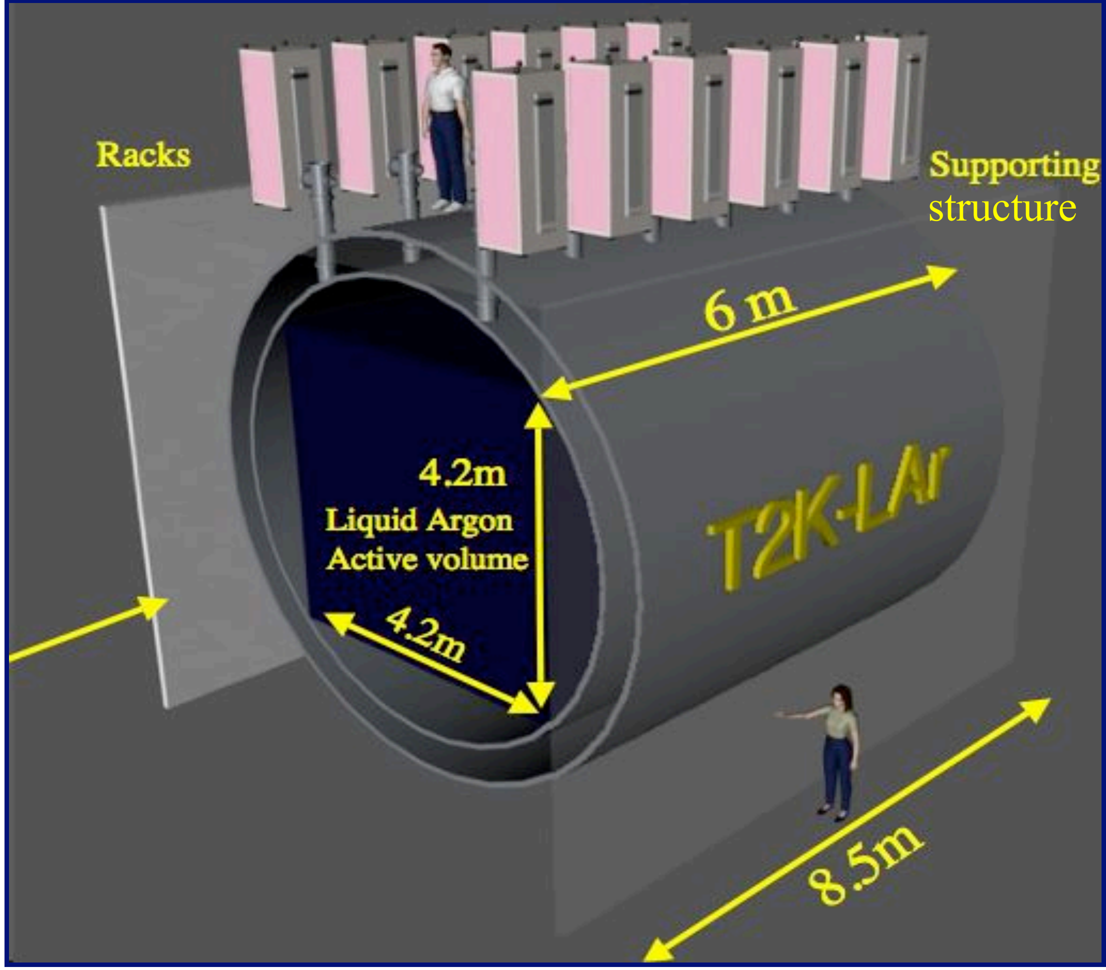
ν interaction in a

50 liter prototype

Application of the LAr TPC technique for a fine-grained calorimeter for the near station of a neutrino oscillation experiment

Neutrino physics: the calorimeter is “The detector”

T2K experiment in Japan



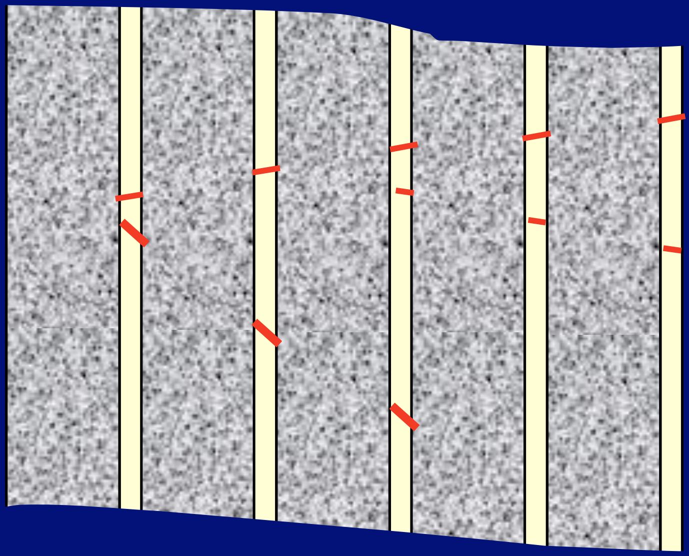
Outlook: low energy-threshold measurement of ν interactions for beam normalization and BG determination;
high-accuracy study of low-energy ν events

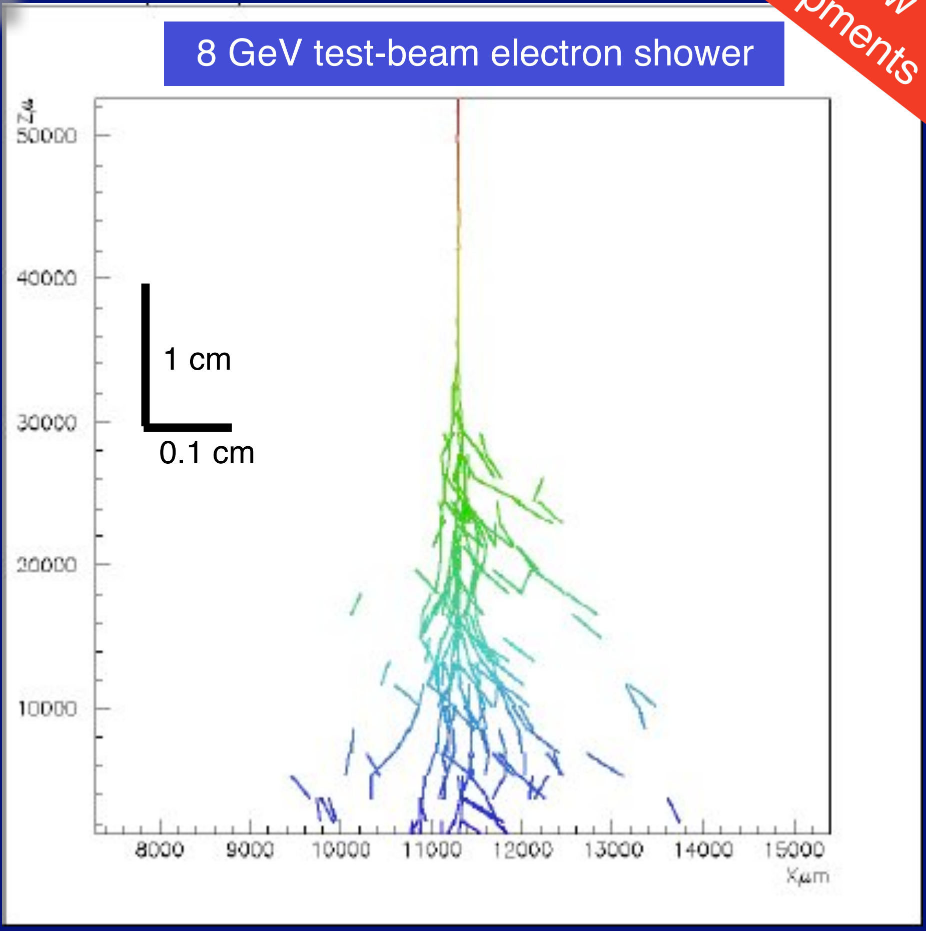
Re-birth of the nuclear emulsion film technique for extremely fine-grained and compact calorimeters for the detection and kinematical analysis of short lived particles. Only possible thanks to analogous advances in the automatic scanning technology

An 'old' technique re-discovered thanks to new technological developments

Achievements: detailed event topology; energy measurement e.g. by micro-track counting; particle ID by dE/dX and multiple scattering measurement; large detector mass feasible (~kton)

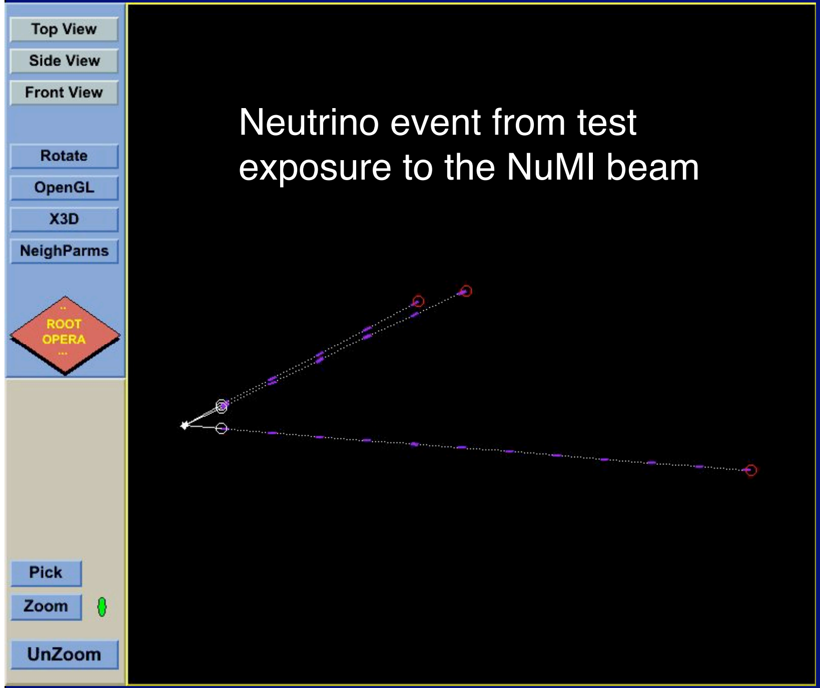
ECC concept: emulsion film/ lead sandwich with fine sampling calorimeter (~ 0.2 X_0)





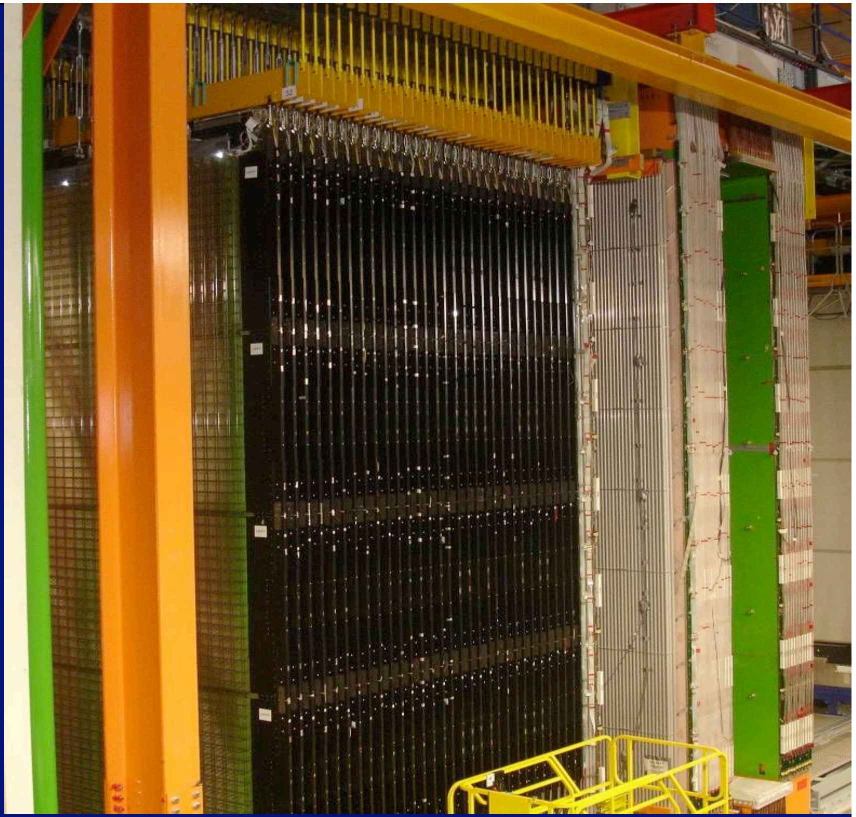
8 GeV test-beam electron shower

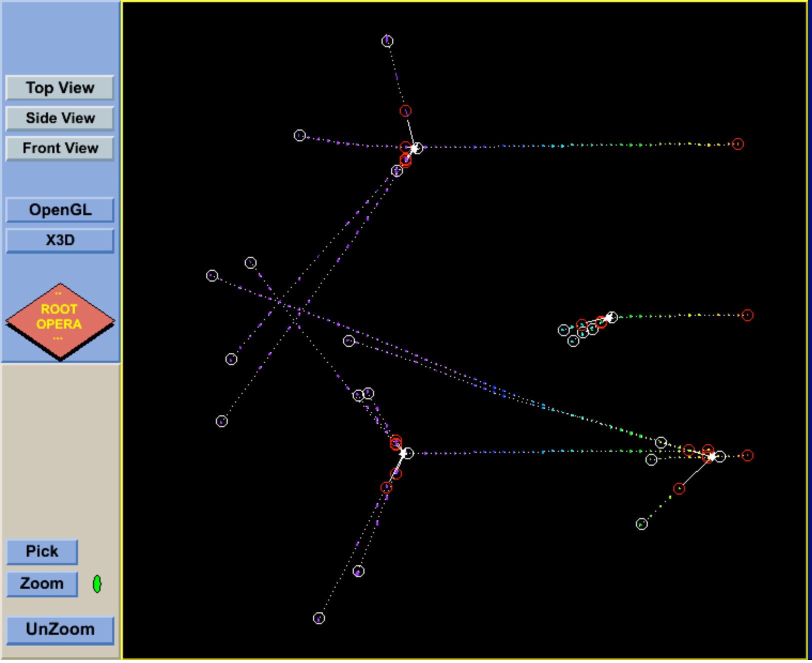
OPERA experiment at Gran Sasso Lab (CNGS ν beam)



Neutrino event from test exposure to the NuMI beam

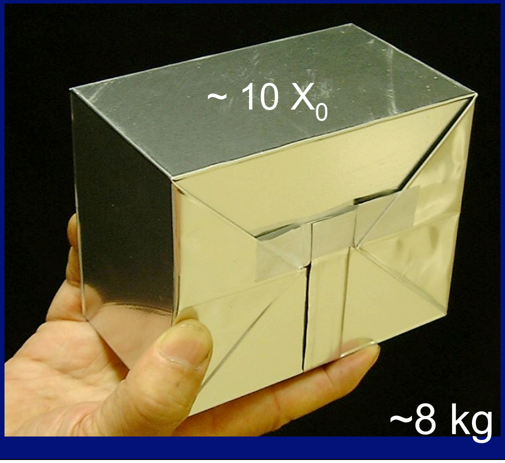
The OPERA detector at LNGS





8 GeV test-beam pion interactions

Elementary calorimeter ‘module’: the brick



~ 10 X_0

~8 kg

Some considerations

The present trend in calorimetry might be understood by looking at the contributed paper list of CALOR06:

- **27** on LHC calorimetry
- **13** on calorimeter technology/methods/simulations
- **11** on ILC calorimetry
- **8** on astroparticle/neutrino calorimeters
- **7** on running calorimeters
- **1** on calorimeters in medicine

Can we draw any conclusion ?

In my opinion the progress of calorimetry is mainly determined by two different approaches:

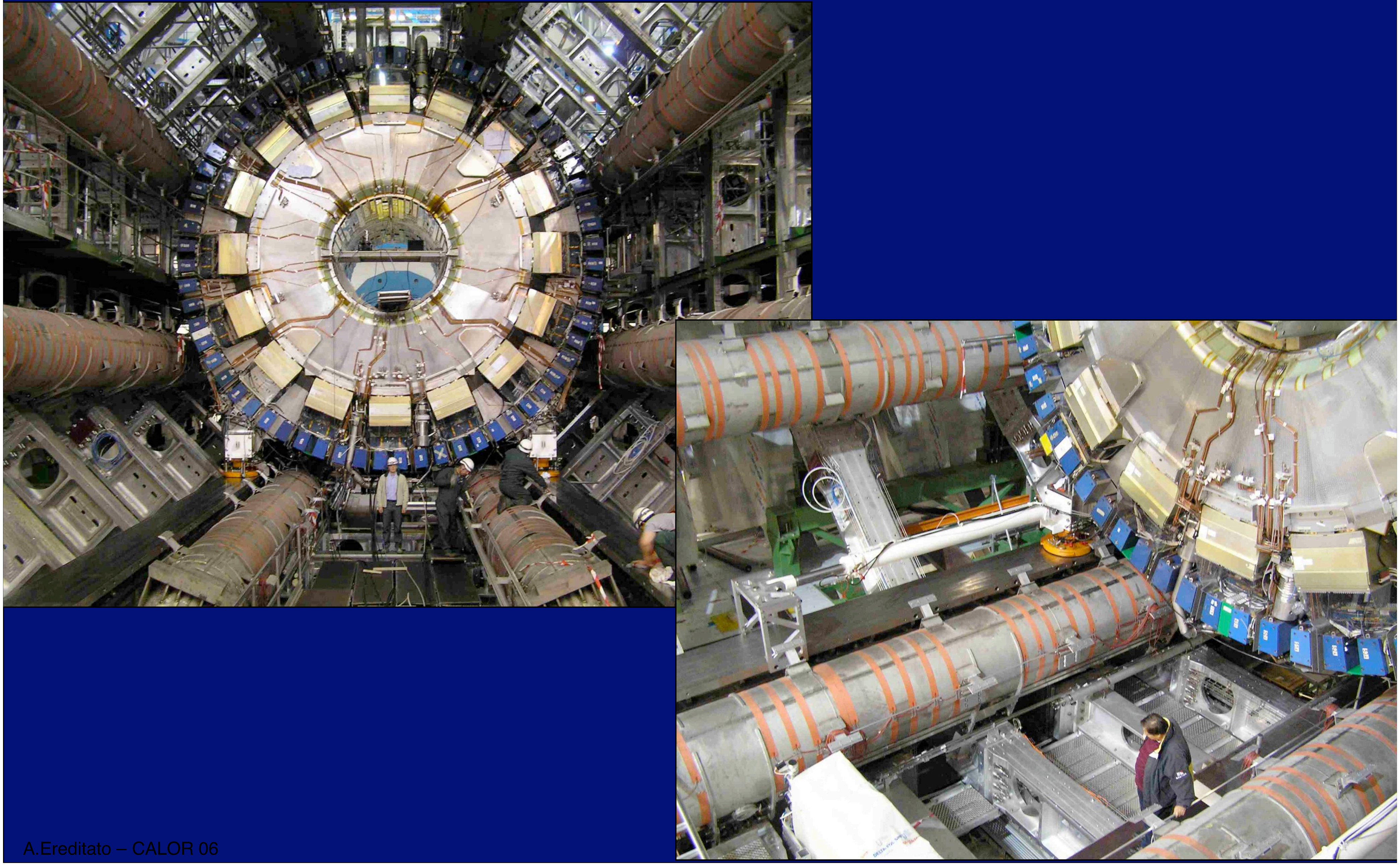
- the intellectual, curiosity-driven R&D studies on new techniques and new methods, often originated from a better understanding of the underlying physics mechanisms
- the challenge represented by ‘the next to come’ frontier experiments (energy, luminosity, dimensions/mass, etc.)

Today, I wish to pay here a tribute to all colleagues (very busy) in following the second approach. Take as an example:

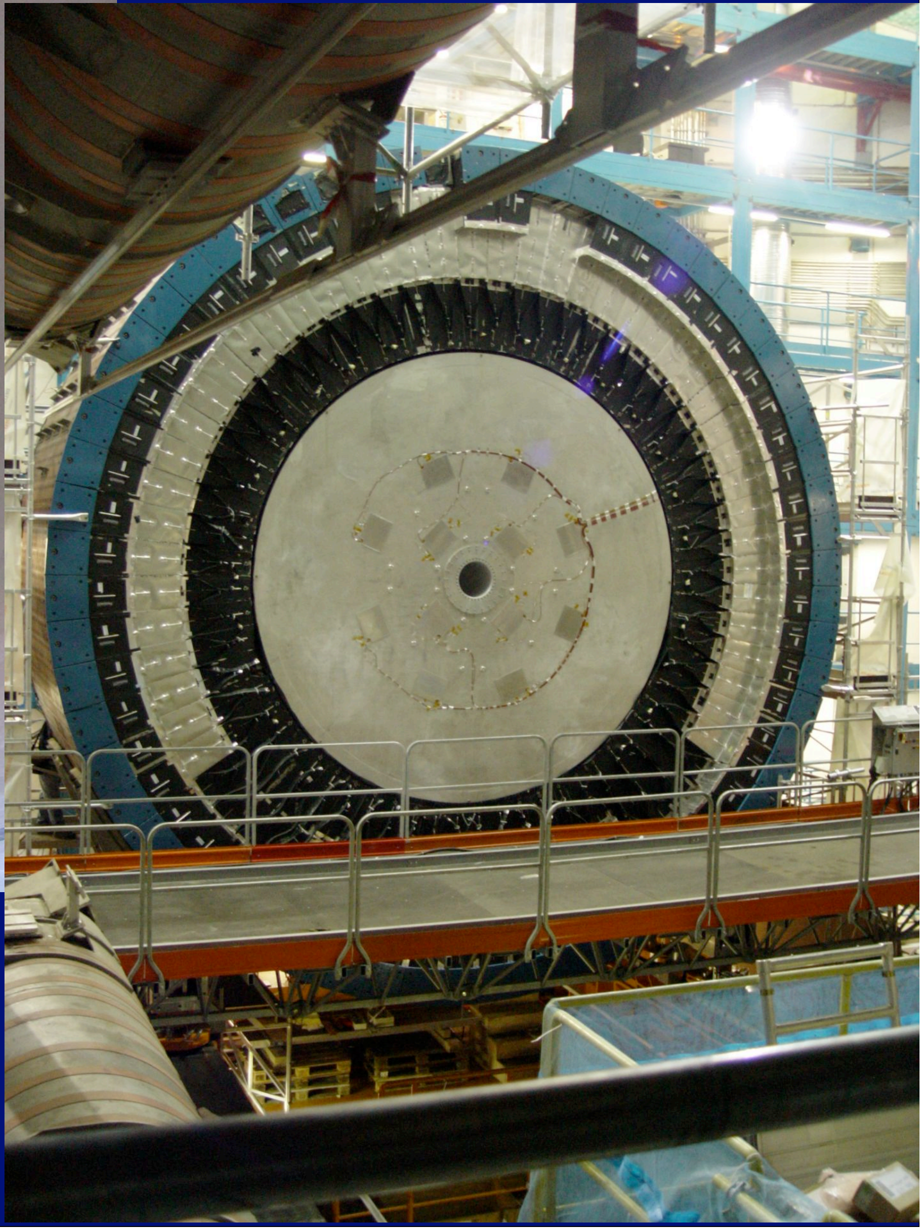
- the long standing effort to build and operate LHC calorimeters
- the intense activity around the design & prototyping of future ILC detectors

State-of-the-art calorimeter systems: LHC detectors

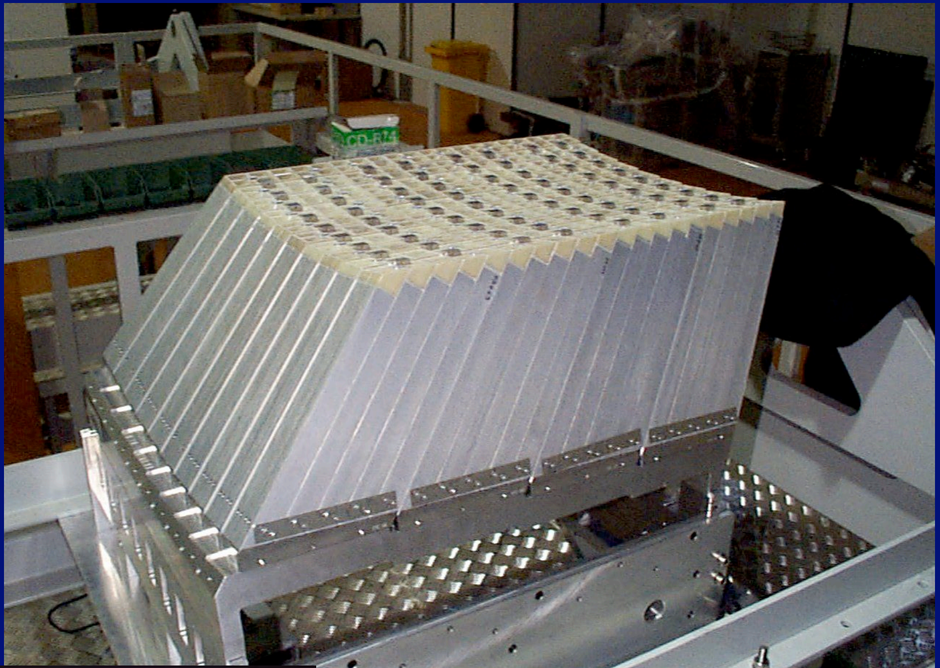
Outstanding example: the alignment of the ATLAS barrel LAr ECAL



Lowering the LAr end-cap ECAL in the ATLAS pit



The challenge of the large PbWO CMS ECAL



Not-exhaustive list of (met) challenges for LHC calorimetry

- energy, position, angular resolution
- hermeticity and coverage
- radiation hardness/tolerance
- uniformity and stability of response, calibration
- high rate, signal pile-up
- suitable electronics to exploit the detector performance
- long term operation
- very long production phases, engineering and integration issues
- keep cost within budget !

Get a flavor of the complexity of the enterprise ?

Available online at www.sciencedirect.com
SCIENCE DIRECT
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Nuclear Instruments and Methods in Physics Research A 558 (2006) 388–418
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A
www.elsevier.com/locate/nima

Review

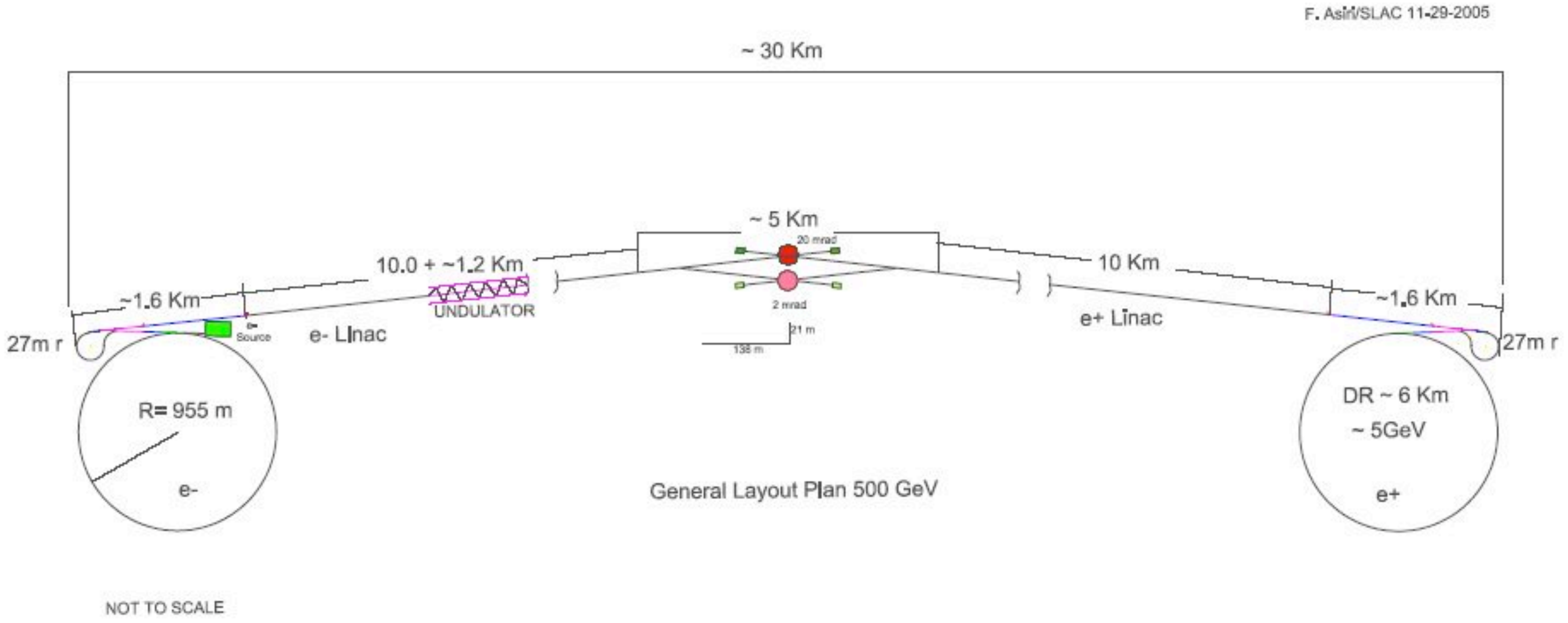
Construction, assembly and tests of the ATLAS electromagnetic barrel calorimeter

B. Aubert[a,1,2], B. Beaugiraud[a,1,2], J. Colas[a,1,2], P. Delebecque[a,1,2], L. Di Ciaccio[a,1,2], M. El Kacimi[a,1,2,3], P. Ghez[a,1,2], C. Girard[a,1,2], M. Gouanère[a,1,2], D. Goujdami[a,1,2,3], A. Jeremie[a,1,2], S. Jézéquel[a,1,2], R. Lafaye[a,1,2], N. Massol[a,1,2], P. Perrodo[a,1,2], H. Przysiezniak[a,1,2], G. Sauvage[a,*,1,2], J. Thion[a,1,2], I. Wingerter-Seez[a,1,2], R. Zitoun[a,1,2], Y. Zolnierowski[a,1,2], R. Alforque[b], H. Chen[b], J. Farrell[b], H. Gordon[b], R. Grandinetti[b], R. Hackenburg[b], A. Hoffmann[b], J. Kierstead[b], J. Koehler[b], F. Lanni[b], D. Lissauer[b], H. Ma[b], D. Makowiecki[b], T. Muller[b], S. Norton[b], V. Radeka[b], D. Rahm[b], M. Rehak[b], S. Rajagopalan[b], S. Rescia[b], K. Sexton[b], J. Sondericker[b], I. Stumer[b], H. Takai[b], A. Belymam[c,1,4], D. Benchekroun[c,1,4], C. Driouichi[c,1,4], A. Hoummada[c,1,4], M. Hakimi[c,1,4], M. Knee[d], R. Stroynowski[d], B. Wakeland[d], V. Datskov[e], V. Drobin[e], M. Aleksa[f], J. Bremer[f], T. Carli[f], M. Chalifour[f,5], J.L. Chevalley[f], F. Djama[f,6], L. Ema[f], C. Fabre[f], P. Fassnacht[f], F. Gianotti[f], A. Gonidec[f], J.B. Hansen[f,7], L. Hervas[f], T. Hott[f], C. Lacaste[f], C.P. Marin[f], P. Pailler[f], A. Pleskatch[f,8], D. Sauvage[⊕], G. Vandoni[f], V. Vuillemin[f], H. Wilkens[f], S. Albrand[g,1,4], B. Belhorma[g,1,4], J. Collot[g,1,4], P. de Saintignon[g,1,4], D. Dzahini[g,1,4], A. Ferrari[g,1,4], J. Fulachier[g,1,4], M.L. Gallin-Martel[g,1,4], J.Y. Hostachy[g,1,4], G. Laborie[g,1,4], F. Ledroit-Guillon[g,1,4], P. Martin[g,1,4], J.F. Muraz[g,1,4], F. Ohlsson-Malek[g,1,4], S. Saboumazrag[g,1,4], S. Viret[g,1,4], R. Othegraven[h], C. Zeitnitz[h], D. Banfi[i], L. Carminati[i], D. Cavalli[i], M. Citterio[i], G. Costa[i], M. Delmastro[i], M. Fanti[i], L. Mandelli[i], M. Mazzanti[i], F. Tartarelli[i], E. Augé[j], S. Baffioni[j], J. Bonis[j], W. Bonivento[j,9], C. Bourdarios[j], C. De la Taille[j], L. Fayard[j], D. Fournier[j], G. Guilhem[j], P. Imbert[j], L. Iconomidou-Fayard[j], G. Le Meur[j], M. Mencik[j], J.-M. Noppe[j], G. Parrour[j], P. Puzo[j], D. Rousseau[j], A.-C. Schaffer[j], N. Seguin-Moreau[j], L. Serin[j], G. Unal[j], J.-J. Veillet[j], F. Wicek[j], D. Zerwas[j], F. Astesan[k], W. Bertoli[k], B. Canton[k], F. Fleuret[k], D. Imbault[k], D. Lacour[k], B. Laforge[k], Ph. Schwemling[k,**], E.M. Abouelouafa[l,1,4], A. Ben Mansour[l,1,4], R. Cherkaoui[l,1,4], Y. El Mouahhidi[l,1,4], H. Ghazlane[l,1,4], A. Idrissi[l,1,4], K. Bazizi[m], D. England[m], V. Glebov[m], T. Haelen[⊕], F. Lobkowicz[⊕], P. Slattery[m], J. Belorgey[n], N. Besson[n], M. Boonekamp[n], D. Durand[n], J. Ernwein[n], B. Mansoulié[n], F. Molinié[n], J.P. Meyer[n], P. Perrin[n], J. Schwindling[n], J.P. Taguet[n], H. Zaccone[n], B. Lund-Jensen[o,1], S. Rydström[o,1], Y. Tayalati[o,1,10], B. Botchev[p], G. Finocchiaro[p], J. Hoffman[p], R.L. McCarthy[p], M. Rijssenbeek[p], J. Steffens[p], M. Zdrazil[p], H.M. Braun[q]

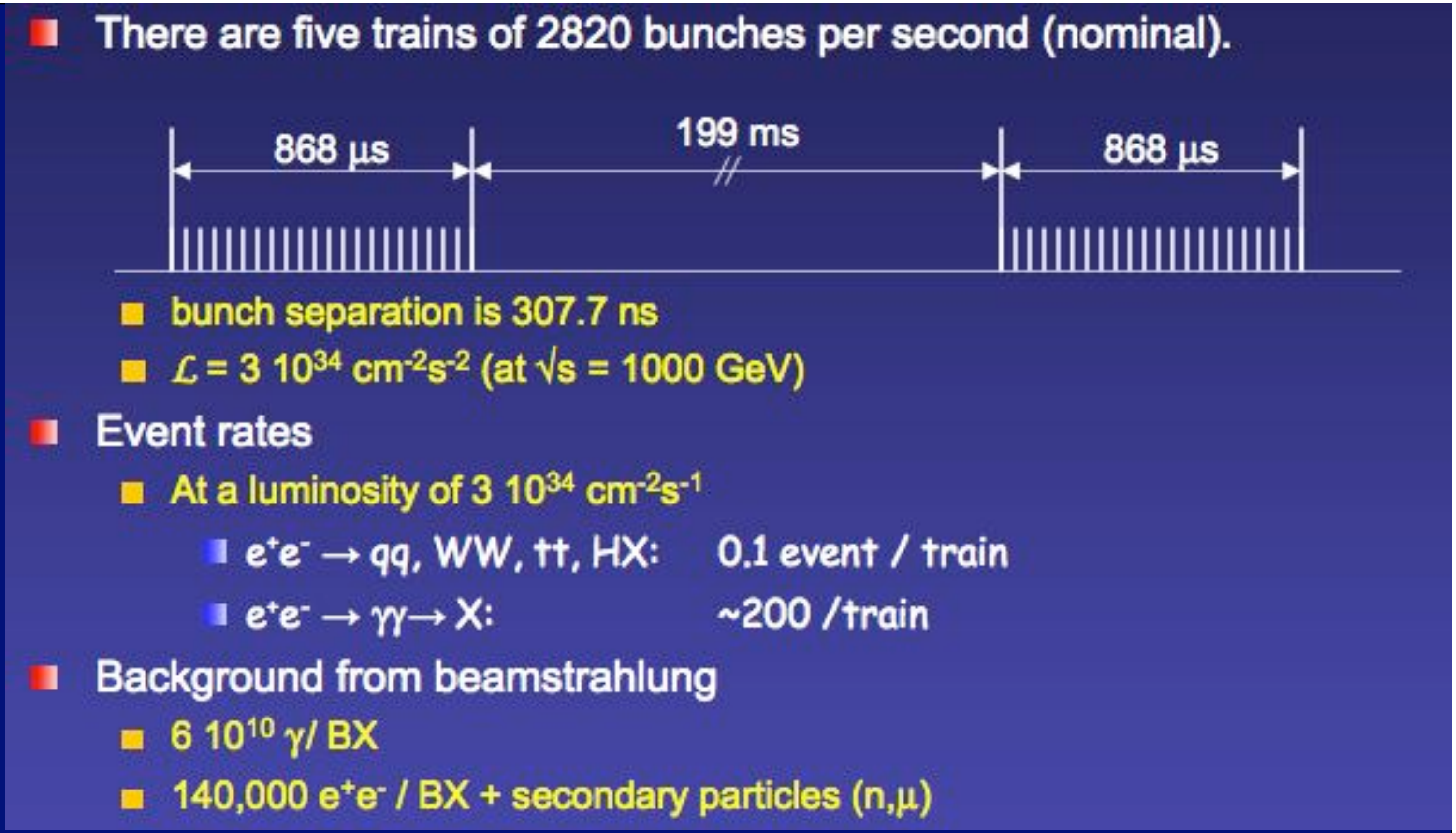
We are all eager to see how well the various LHC calorimeters will perform...

Many interesting talks at CALOR08 !

Tomorrow’s HEP calorimetry: the challenge of the ILC



The ILC



- There are five trains of 2820 bunches per second (nominal).
  - bunch separation is 307.7 ns
  - $\mathcal{L} = 3\ 10^{34}\ \text{cm}^{-2}\text{s}^{-2}$ (at $\sqrt{s}$ = 1000 GeV)
- Event rates
  - At a luminosity of $3\ 10^{34}\ \text{cm}^{-2}\text{s}^{-1}$
    - $e^+e^- \rightarrow qq, WW, tt, HX$: 0.1 event / train
    - $e^+e^- \rightarrow \gamma\gamma \rightarrow X$: ~200 /train
- Background from beamstrahlung
  - $6\ 10^{10}\ \gamma$/ BX
  - 140,000 e^+e^- / BX + secondary particles (n,μ)

Bunch crossing identification: Si for tracker or ECAL ?

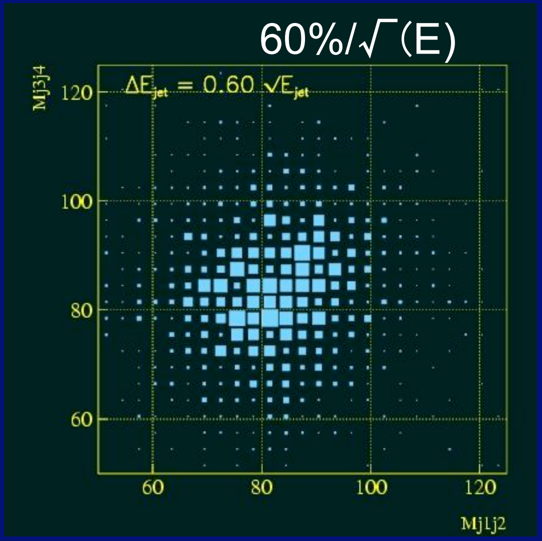
- E_{cm} from 200 to 500 GeV with possibility to perform energy scan
- Integrated luminosity: 500 fb^{-1} in 4 years
- Energy stability better than 0.1%
- About 80% electron polarization
- Possible upgrade to 1 TeV

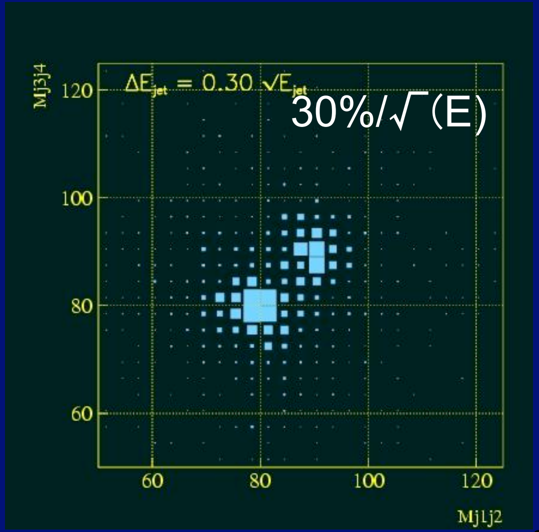
Requirements for ILC calorimetry

- energy resolution for single particles (e/γ and hadrons)
- energy resolution for jets
- linearity (1-100 GeV)
- hermeticity (no cracks)
- operation in strong magnetic field

Benchmark: separate WW and ZZ in multi-jet events

(anything new w.r.t. the LHC ?)


60%/√(E)


30%/√(E)

ILD detector requirements, as compared to LHC detectors

Inner vertex layer	3-6 times closer to IP
Vertex pixel size	1/30
Vertex materials	1/30
Materials in tracker	1/6
Track momentum resolution	1/10
EM cal granularity	1/200 (!?)

Jet energy resolution (physics): $dE/E \sim 0.3 / \sqrt{E(GeV)}$

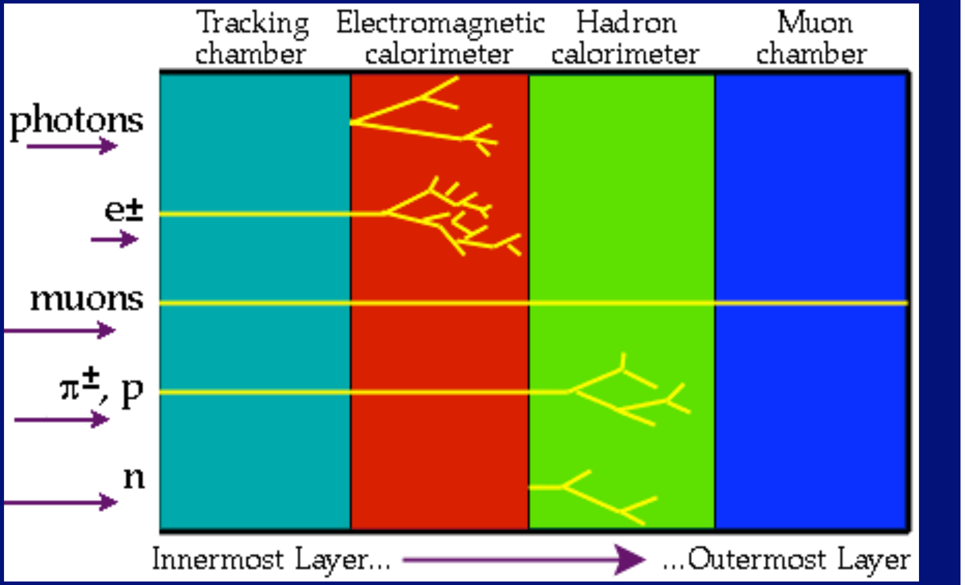
Hermeticity (BG vetoing and missing E): down to $\theta \sim 5\text{-}10$ mrad

High energy resolution for hadrons

Compensation?

Well studied and well established experimentally (ZEUS, SPACAL, JLC)

Particle energy flow ?



Exploit tracker+ECAL+HCAL to reconstruct the energy (momentum) of each individual particle:

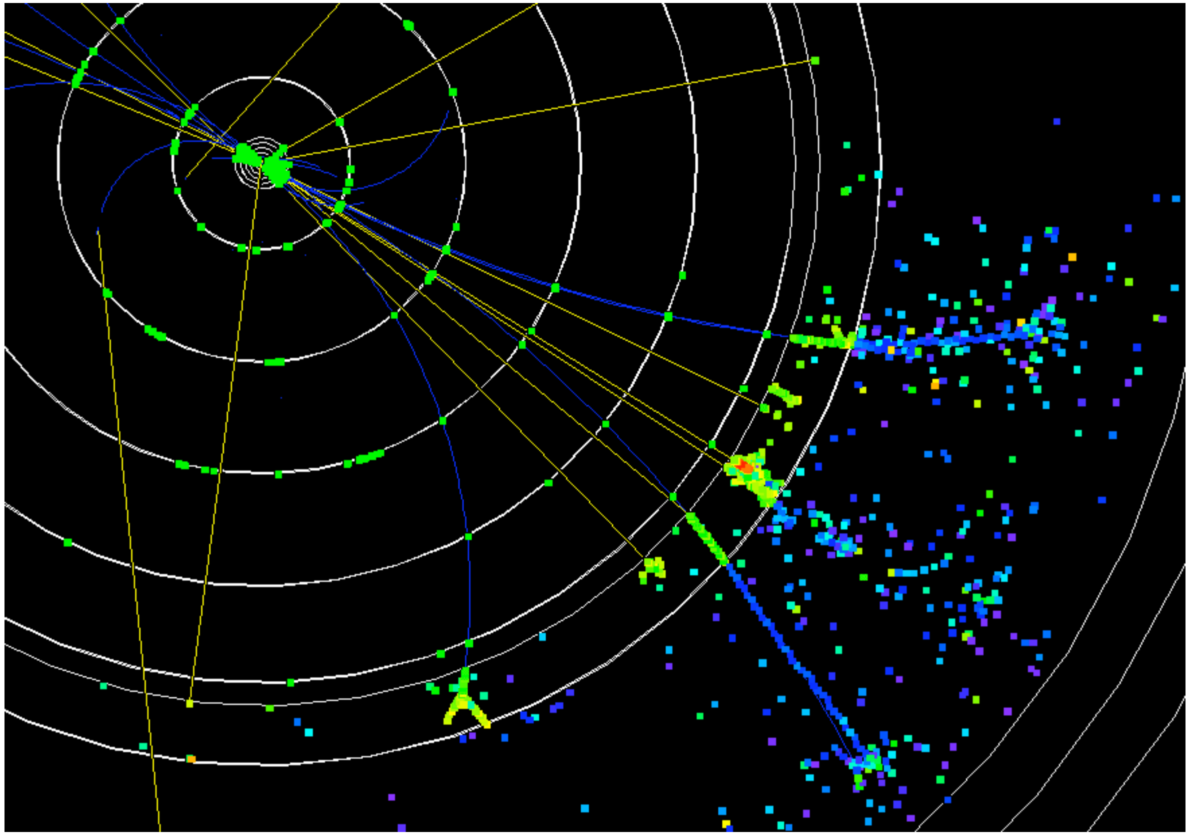
Tracker: momentum of charged particles (~ 65 % of Etot)

ECAL: energy of photons (~ 25 % of Etot)

HCAL: energy of neutral hadrons (~10% of Etot)

Particle flow analysis (PFA) determines the design of the calorimeters

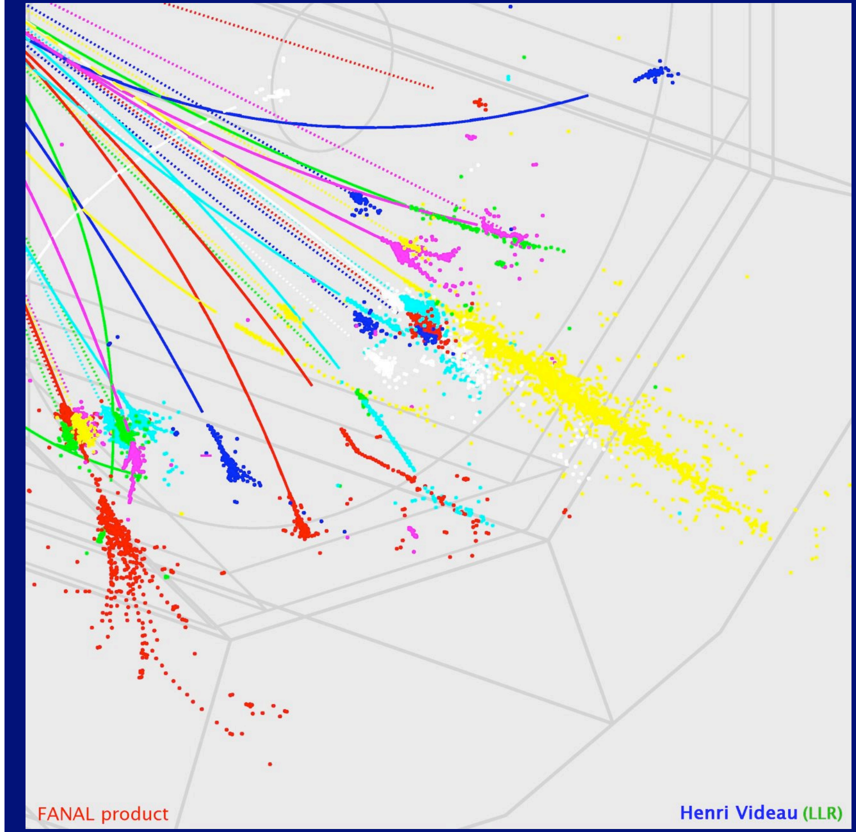
Calorimeters drive the design of the apparatus **(ECAL ~ HCAL~ $50-100 M)** and more than at the LHC, they constitute the heart of the apparatus



Goal: measure the energy of each individual particle -> need extremely high longitudinal and transverse segmentation (high absorber density)

Particle flow concept (1)

1. Use high performance tracker to measure the momentum of charged pions and kaons
2. Use ECAL only for photons. Try not to have hadrons showering in ECAL (longitudinal segmentation)
3. Use HCAL only for neutral hadrons. Fine segmentation to separate their clusters from those from charged hadrons (cluster suppression)



The PFA concept is attractive but in order to have a really working (and powerful) tool one will need:

- **to perform extensive simulation studies**
- **to confirm the actual feasibility of the hardware**
- **to prove that it works by beam test results**

(tests in CDF: $0.85\sqrt{E} \to 0.65\sqrt{E}$)

…and (let me be provocative)

- **to make sure that it is really what one needs by proving that it is not an expensive overkill !**

Particle flow concept (2)

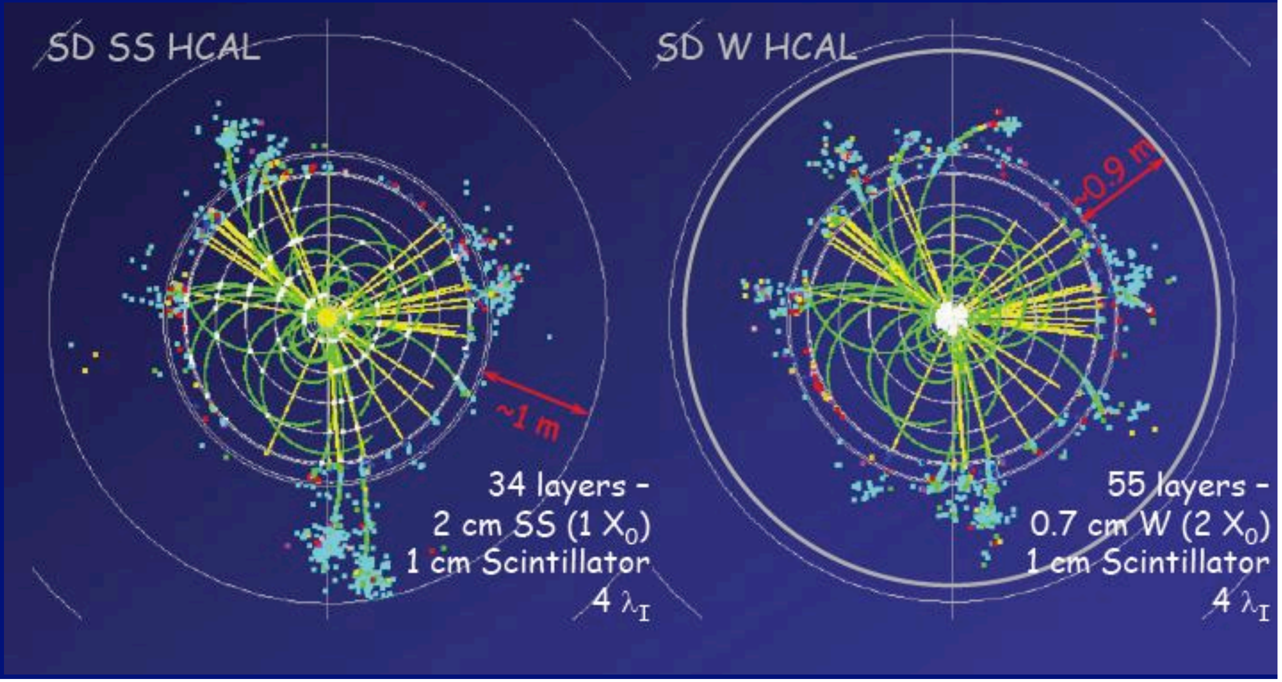
$E_{jet} = \Sigma\,|P|_{ch} + \Sigma\,E_{\gamma} + \Sigma\,E_{neut}$

$\sigma^2_{Ejet} = \sigma^2_{ch} + \sigma^2_{ph.} + \sigma^2_{\gamma} + \sigma^2_{method}$

Remarks:

1) Small contribution from neutral hadrons: modest HCAL energy resolution?
2) σ^2_{method} is important and might affect the merits of the method:
   - discrimination between separate energy clusters
   - track-cluster association
3) Strong B field required to bend charged-particle tracks
4) Fine segmentation (volume) for ECAL and HCAL
5) Large ECAL inner radius (particle separation), small R_M (small clusters) and large λ_{int}/X_0
6) ‘Digital’ HCAL ?

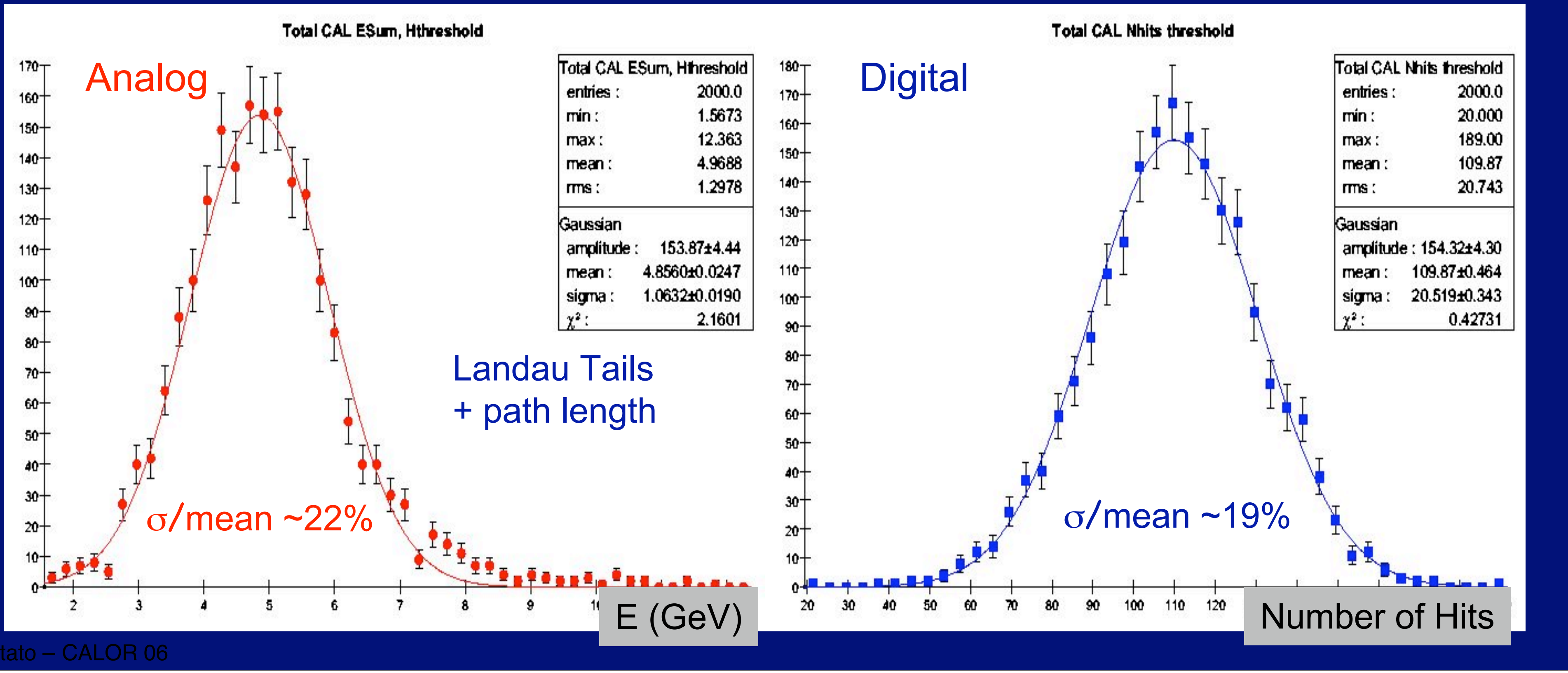
Stainless steel vs Tungsten →



Digital HCAL instead of analog readout:

- Very fine granularity and segmentation (~1cm, ~50 layers)
- The large number of channels is balanced by single-bit R/O
- Hit counting to estimate Etot
- Get rid of Landau fluctuations (is then digital better than analog?)

Question: is this the end of hadron calorimetry or it is just a peculiar application to meet the ILC experimental requirements ?



Analog

σ/mean ~22%

Landau Tails
+ path length

E (GeV)

Digital

σ/mean ~19%

Number of Hits

From theory to real calorimeters: R&D and design studies

Detector options:

ECAL	**HCAL**
Silicon-Tungsten	**Scintillator-Steel (analog)**
Scintillator/Silicon-Lead	**Scintillator-Lead (analog)**
Scintillator/Silicon-Tungsten	**GEM-S.Steel (digital)**
Scintillator-Lead	**RPC-S.Steel (digital)**
Scintillator-Tungsten	**Scintillator-S.Steel (digital)**
	Scintillator-Lead-S.Steel (digital)

General requirements:

- dense absorber material for both ECAL and HCAL
- if PFA adopted: Si as baseline ECAL option ?
- neutron detection in HCAL (if PFA): hydrogen in the active medium ?
- gaseous active medium might be suitable for large radius HCAL detectors

Large collaborations are clustering around detector proposals

ILC detector proposals

Silicon Detector - SiD: the goal is a calorimeter with the highest granularity, made of a Tungsten absorber and Silicon detectors. To make the detector affordable, a relatively small inner calorimeter radius of 1.3 m is chosen. Shower separation and good momentum resolution are achieved with a 5 T magnetic field and very precise Silicon detectors for charged-particle tracking. The fast timing of the Silicon tracker makes SiD a suitable detector to fight backgrounds.

Large Detector - LDC: derived from the detector described in the technical design report for TESLA, uses a somewhat larger radius of 1.7 m. It also features a Silicon-Tungsten calorimeter, possibly with a coarser granularity. For charged-particle tracking, a large time-projection chamber (TPC) is planned to allow efficient and redundant particle reconstruction. The larger radius is needed to achieve the required momentum resolution.

GLD detector: choose a larger radius of 2.1 m to take advantage of a shower separation just by distance. It uses a calorimeter with even coarser segmentation and gaseous tracking similar to the LDC. Moderate 3 T B field.

Example: SiD detector

Physics requirements (nearly common to any other experiment proposals)

- Two-jet mass resolution comparable to the widths of W/Z for an unambiguous identification of the final states

- Excellent flavor-tagging efficiency and purity (for b, c and s quarks)

- Momentum resolution adequate to reconstruct recoil-mass to dimuons with resolution better than the beam-energy spread

- High hermeticity to precisely determine the missing momentum

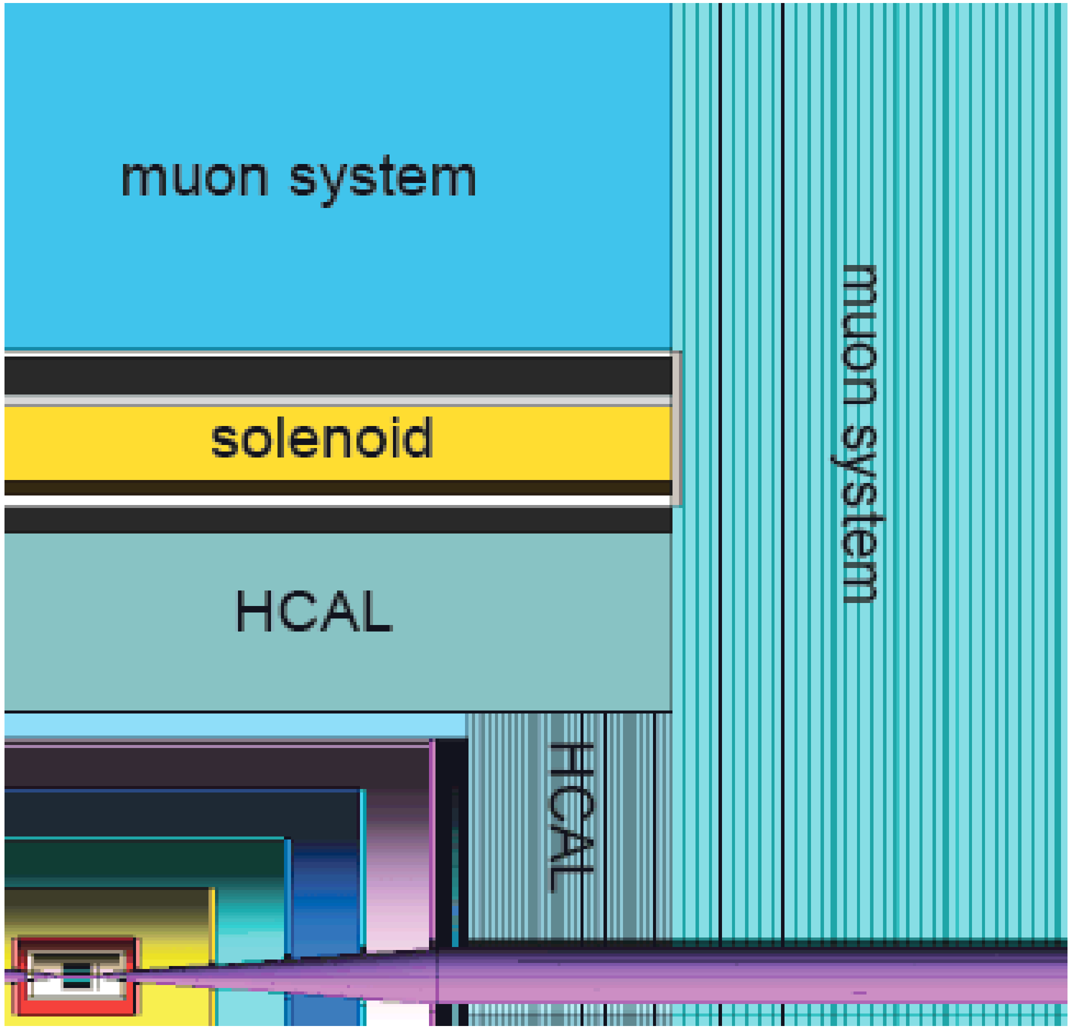
- Good timing resolution to tag bunch-crossings to suppress BG in calorimeter and tracker

- Very forward calorimetry that resolves each bunch in the train for veto capability

SiD Design features

- **Jet energy resolution goal is $30\%/\sqrt{E}$.**
- **Choose a dense, highly segmented,** SiW ECAL and HCAL.
- High magnetic field **limits radius and cost of calorimeters and solenoid and maintains BR^2 ($B = 5$ Tesla)**
- Si strip tracker **for excellent momentum resolution and robust performance ($\Delta p_t/p_t^2 \leq 5 \times 10^{-5}$ GeV^{-1})**
- VX Tracker **at minimum possible radius with max Ω ($\Delta\delta = 5 \oplus 10/p\sin^{3/2}\theta$ μm)**
- Instrumented flux return **for muon identification**

SiD detector implementation

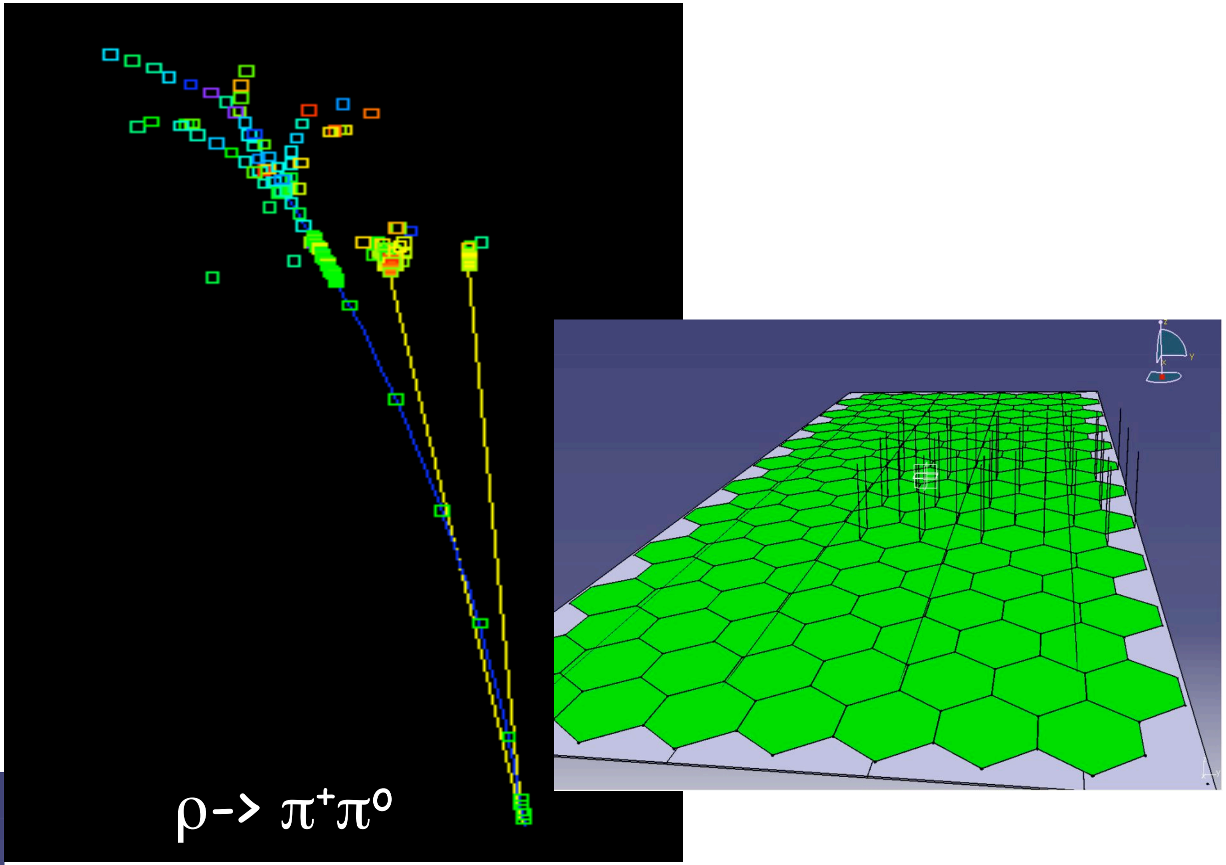


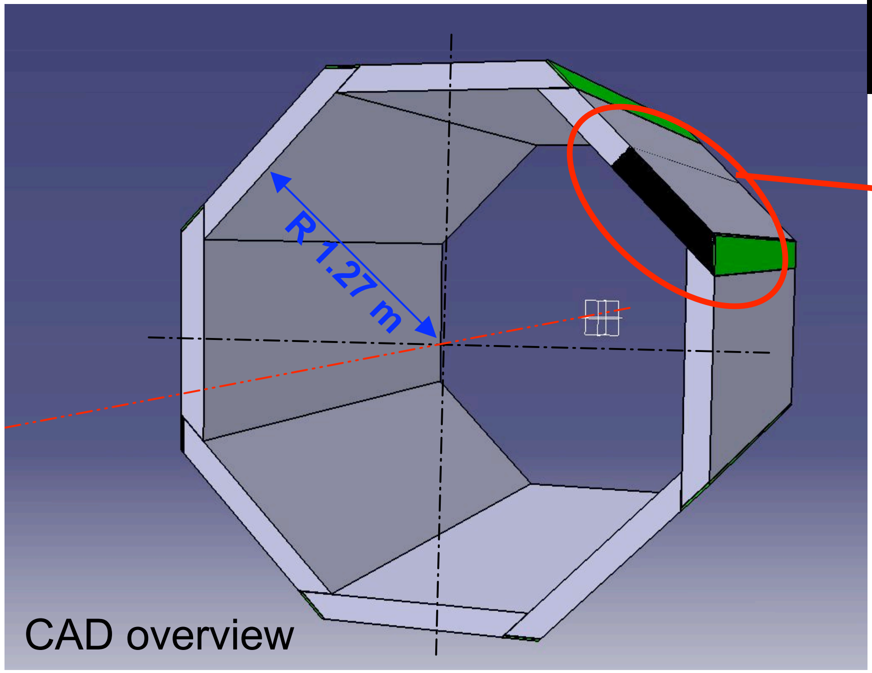
- 5 layer pixel VXT
- 5 layer Si tracker with endcaps
- Si/W ECAL and HCAL inside the coil
- 5T field solenoid
- Instrumented flux return for muon detection

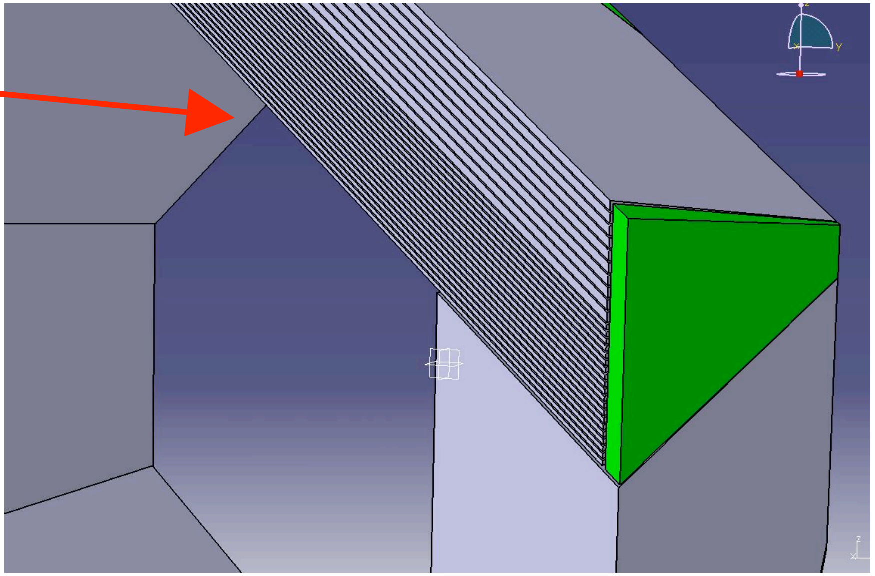
Compact detector: 12 x 12 x 12 m^3

ECAL

- 20 layers x 2.5 mm thick W
  10 layers x 5 mm thick W
- ~ 1mm Si detector gaps
- Tungsten $R_{M\ eff}$= 12 mm
- Highly segmented Si pads 12 mm^2



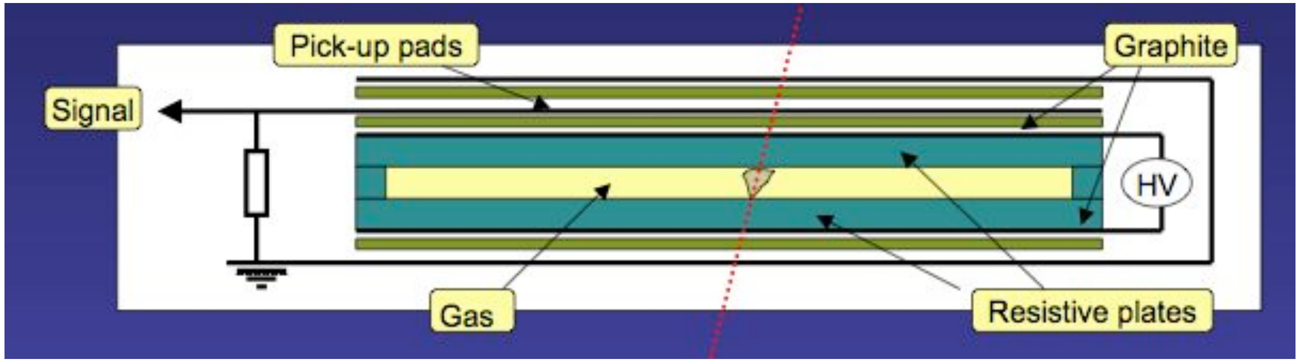




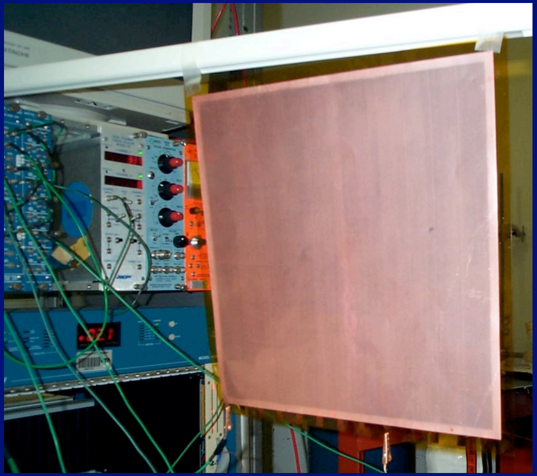
HCAL

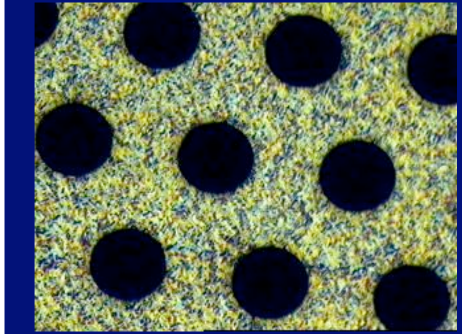
	Scintillator	GEMs	RPCs
Technology	**Proven (SiPM?)**	**Relatively new**	**Relatively old**
Electronic readout	**analog (multi-bit) or semi-digital (few-bits)**	**digital (single-bit)**	**digital (single-bit)**
Thickness (total)	**~ 8 mm**	**~8 mm**	**~ 8 mm**
Segmentation	**3 x 3 cm^2**	**1 x 1 cm^2**	**1 x 1 cm^2**
Pad multiplicity for MIPs	**Small cross talk**	**Measured at 1.27**	**Measured at 1.6**
Sensitivity to neutrons	**Yes**	**Negligible**	**Negligible**
Recharging time	**Fast**	**Fast ?**	**Slow (20 ms/cm^2)**
Reliability	**Proven**	**Sensitive**	**Proven (glass)**
Calibration	**Challenge**	**Depends on efficiency**	**Not a concern (high efficiency)**
Assembly	**Labor intensive**	**Relatively straight forward**	**Simple**
Cost	**Not cheap (SiPM?)**	**Expensive foils**	**Cheap**

RPC (baseline ?)



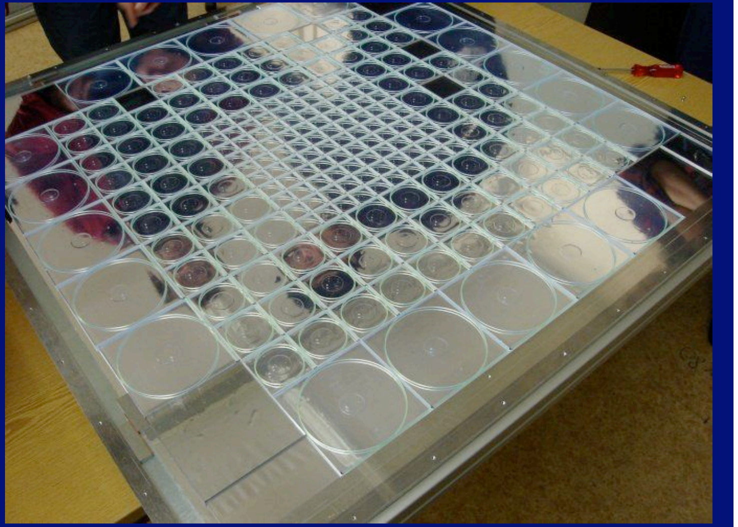
HCAL readout options



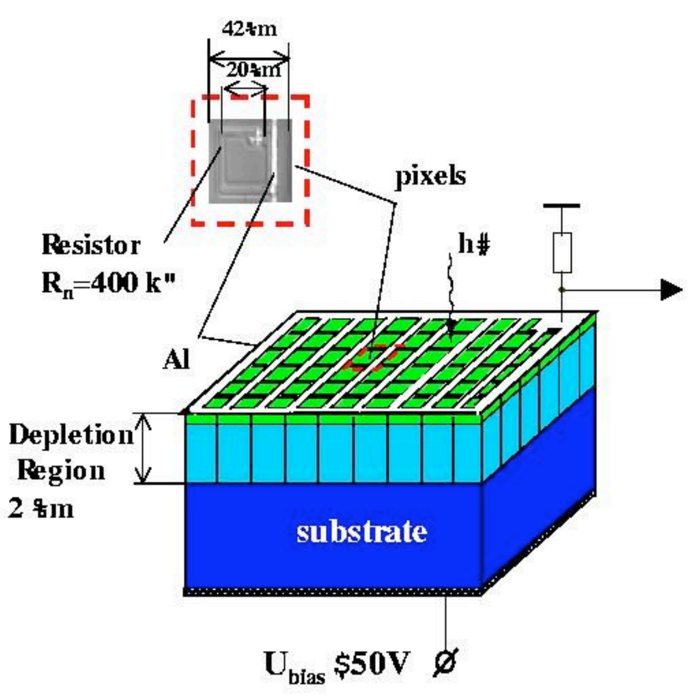


GEM (dig)

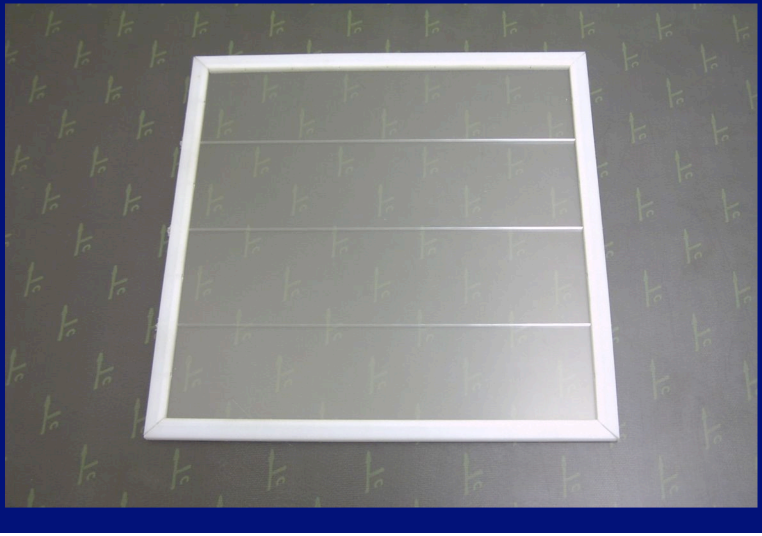
Scintillators
(analog)



SiPMT



RPC (dig)



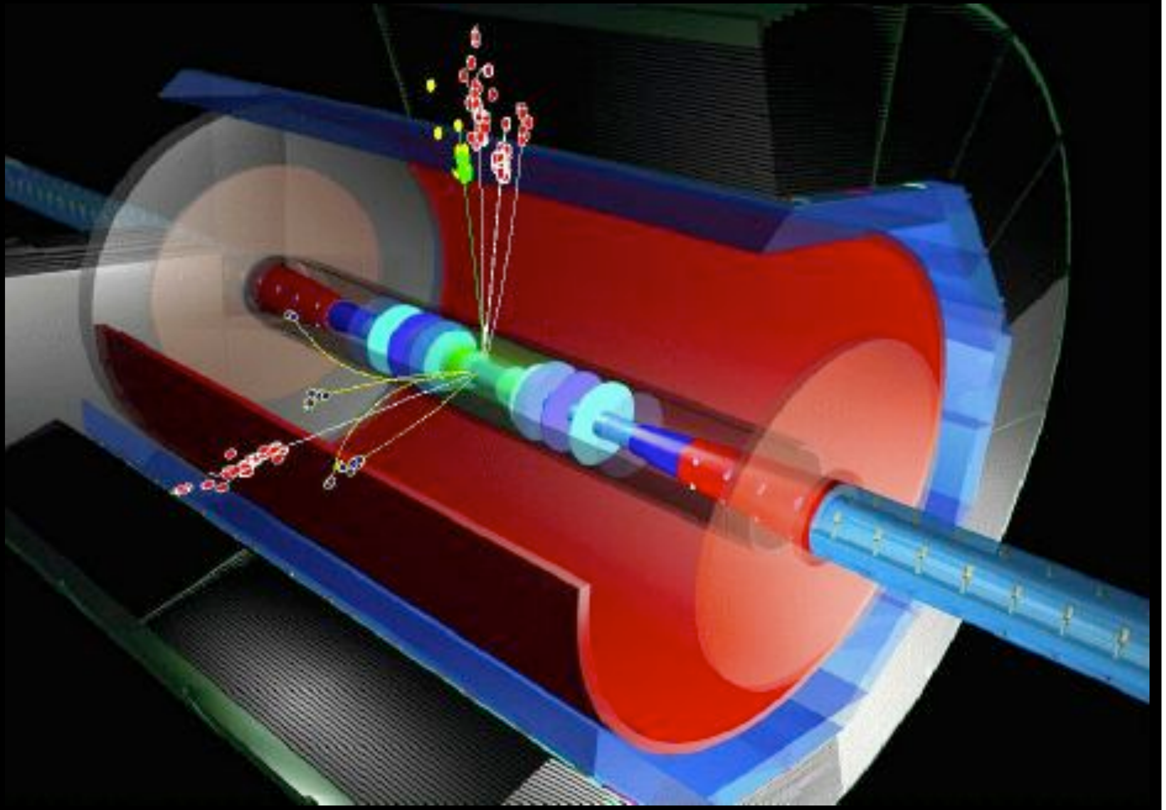
LDC detector

Concept:

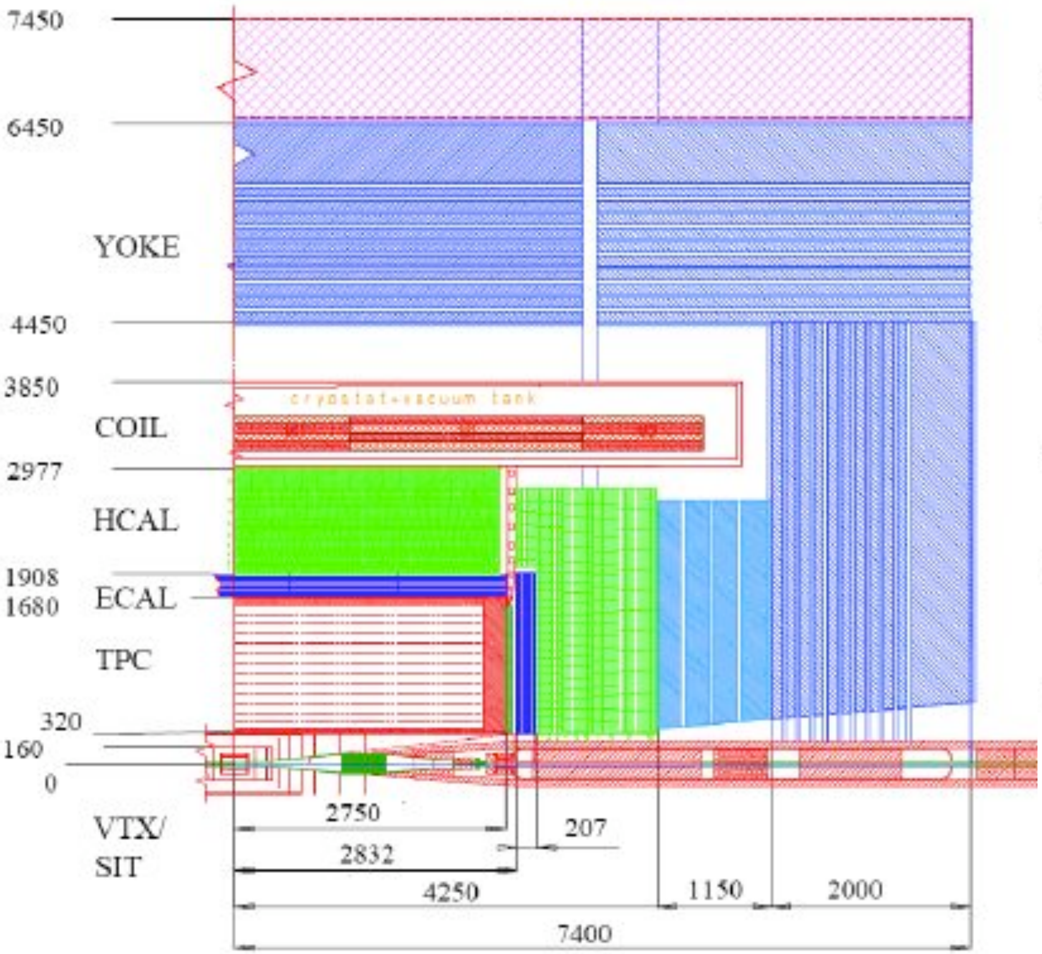
Large gas tracking detector (TPC) backed by a high-granularity calorimeter

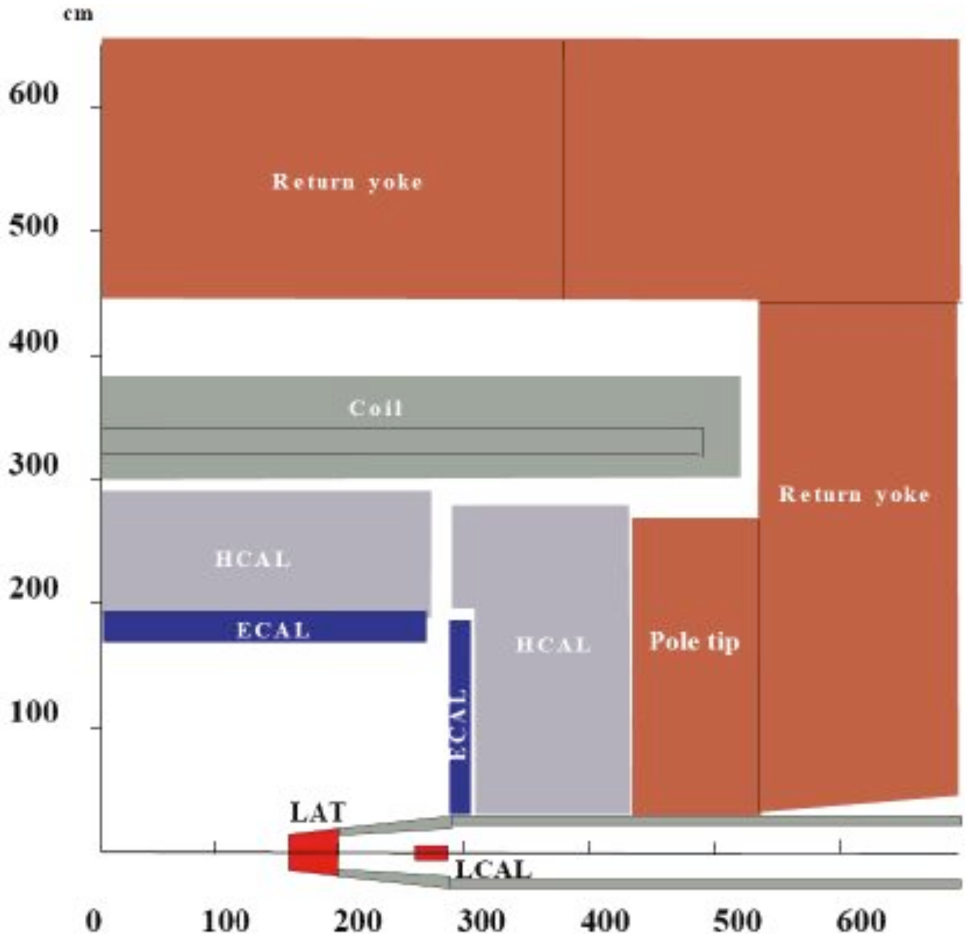
(evolution of the original TESLA design)

Key role of the TPC



LDC detector

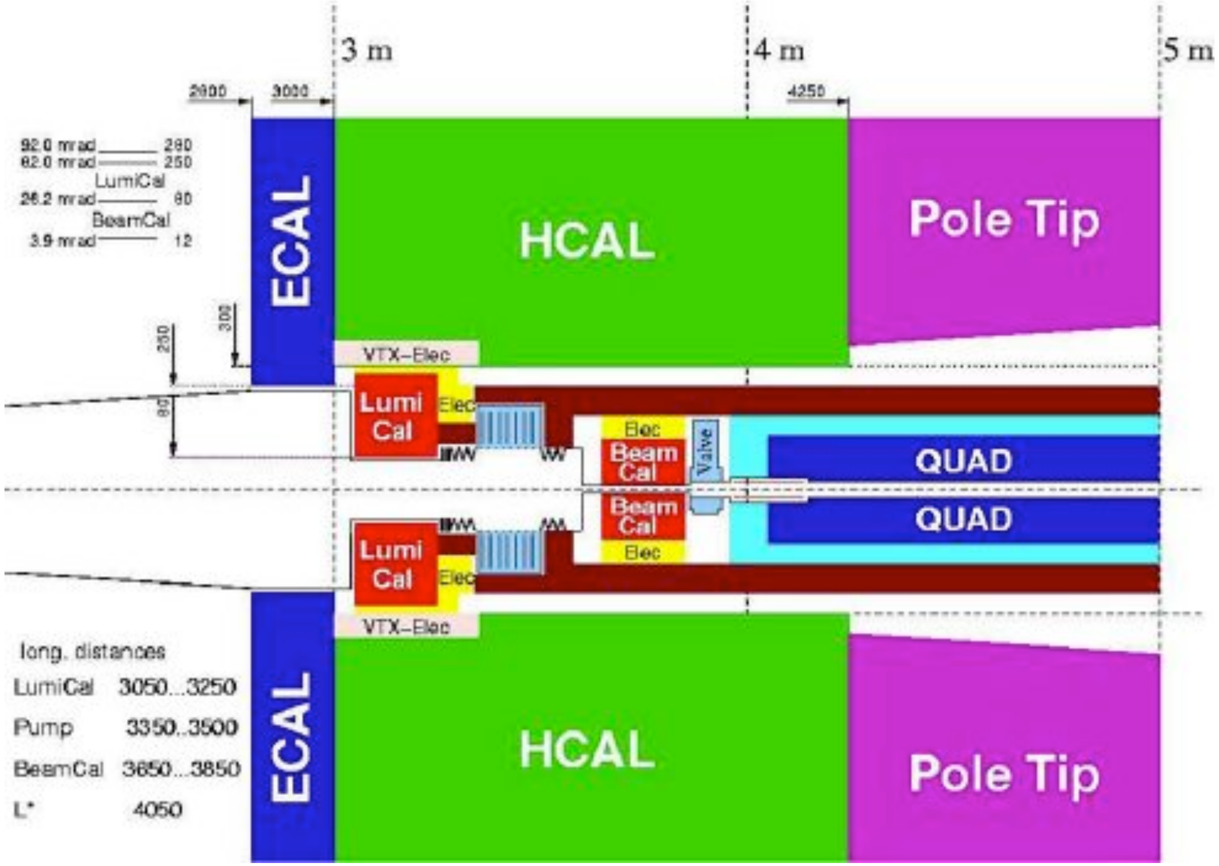




LDC calorimetry

- Si-W ECAL in barrel and end cap (ECAL)
- Steel-Scint. or steel-RPC barrel and end cap (HCAL)
- 4T superconducting coil
- Instrumented iron return yoke with RPC (MUON)

Example: forward calorimeter: TESLA design scaled to high B field



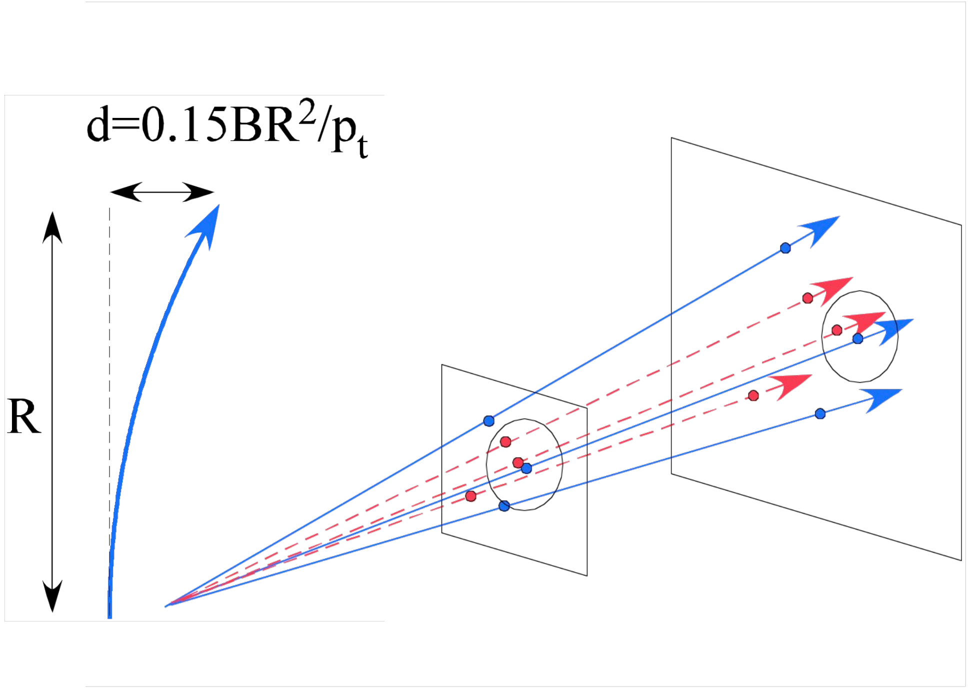
long. distances	
LumiCal	3050...3250
Pump	3350..3500
BeamCal	3650...3850
L*	4050

GLD detector concept

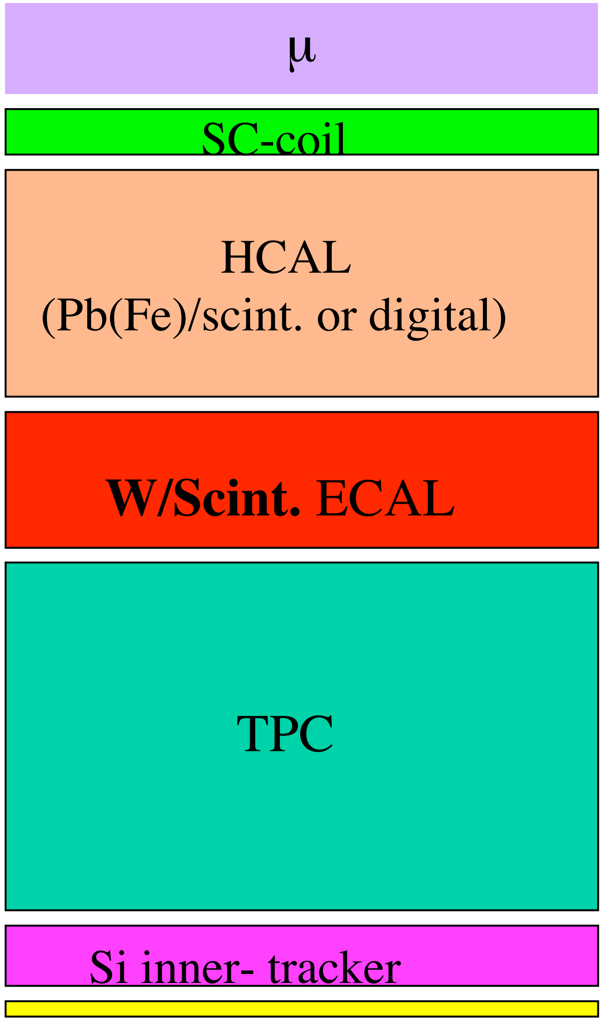
Fine segmentation of CAL intrinsically limited by R_M (W/Scint 1.8 cm, Pb/Scint 2.5 cm)

High B field can spread hits, but might be unefficient for dense jets

Therefore, adopt a large ECAL radius **(large detector)** with a few cm^2 granularity



GLD detector


μ

SC-coil

HCAL
(Pb(Fe)/scint. or digital)

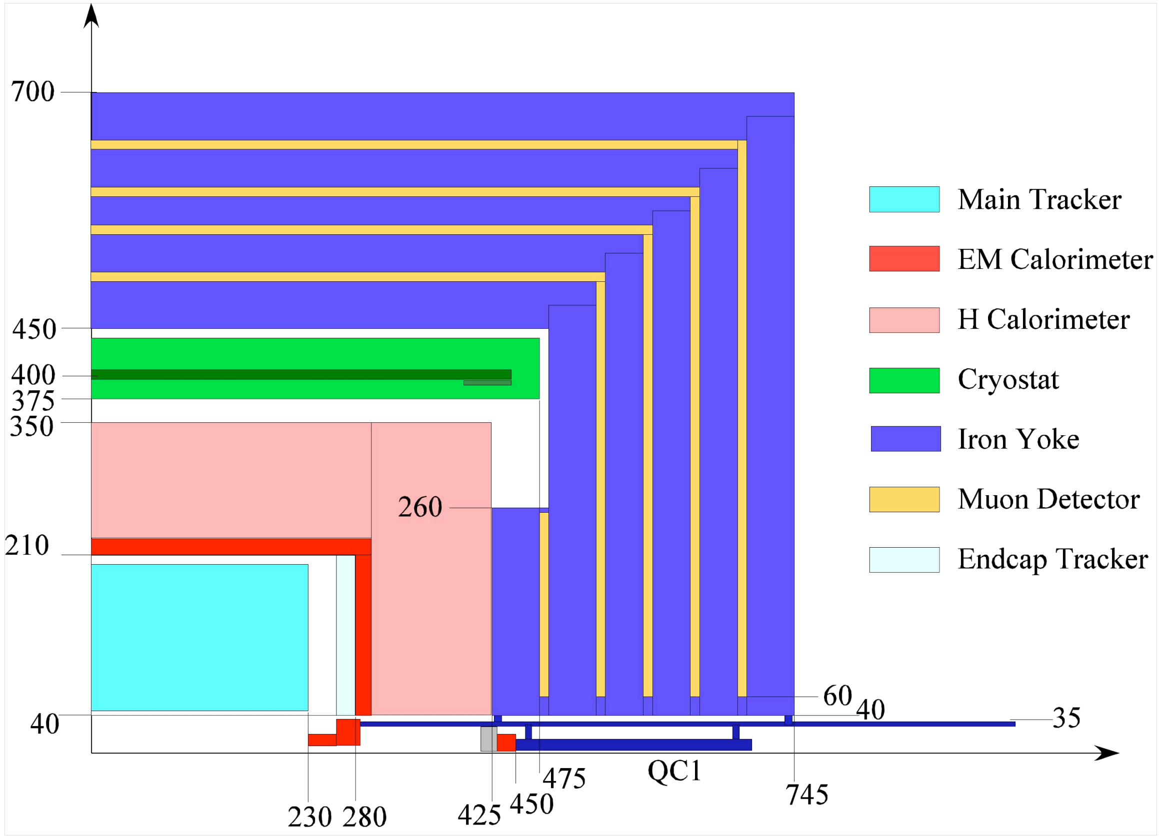
W/Scint. ECAL

TPC

Si inner- tracker

VTX: fine pixel-CCD

- large TPC (tracking)
- W-scintillator ECAL (cost!) with large radius
- moderate B field



Pros and cons of a large detector

ADVANTAGES

Good jet PFA measurement (better cluster separation and charge particle separation at the entrance of ECAL due to large BL^2)

Easier pattern recognition (more hits)

Good momentum resolution for charged particles (large $BL^2 \sqrt{n}$)

Good dE/dx measurement for charged particles

Smaller relative volume of the dead space

DISADVANTAGES

Larger solenoid (lower magnetic field) hence larger VTX inner radius

Calorimeter volume increases ($\sim L^2$) --> need cheap calorimeter options

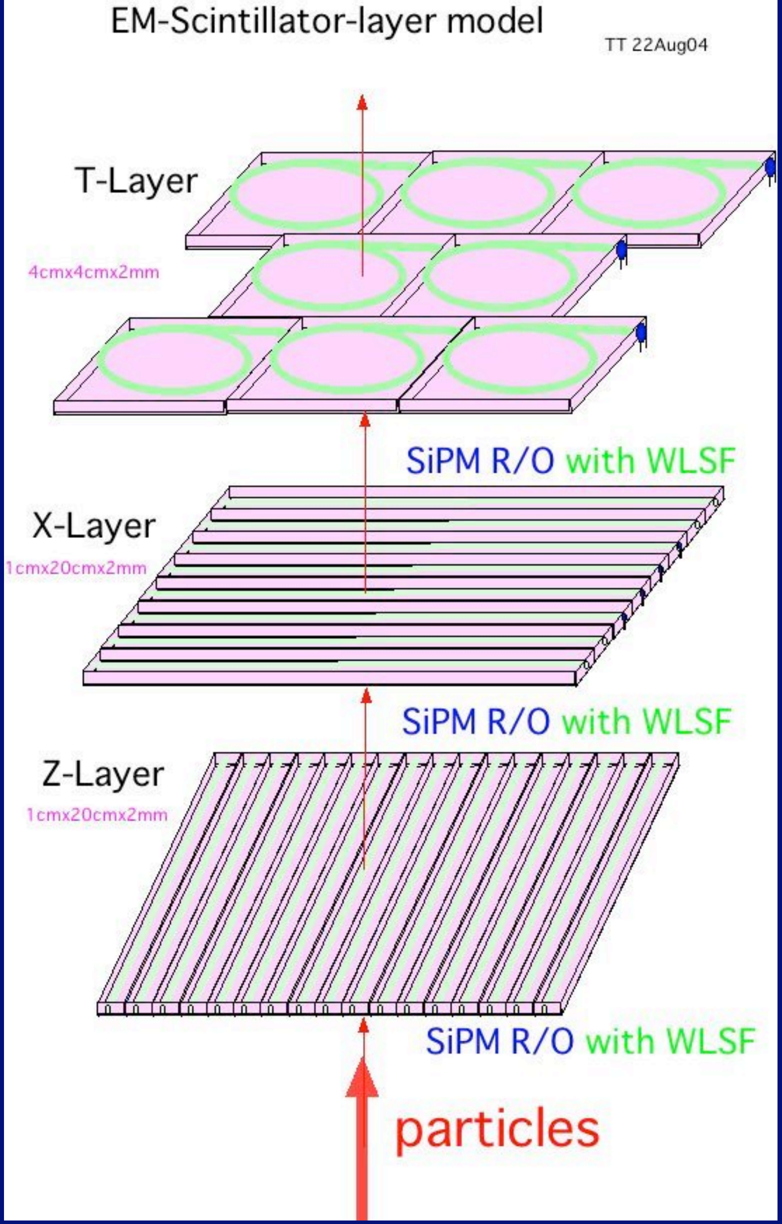
GLD ECAL scintillator option

3 mm W + 2 mm scintillator + 1 mm gap
33 layers, ~28 X_0, ~1 λ, R_M~18 mm

Readout: WS fiber + MPC (Multipixel Photon Counter)

4 x 4 cm^2 tiles and 1 cm wide strips

Option: very fine segmentation with Si for the first few X_0



HCAL: compensating/scintillator ?

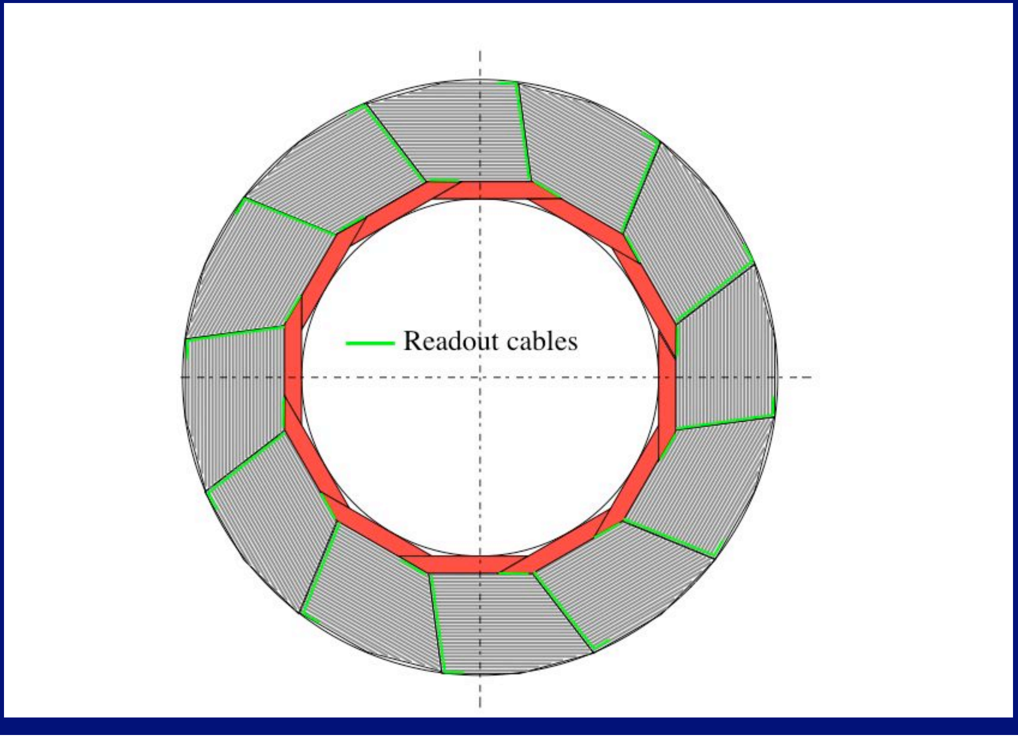
50 layers

20 mm Pb + 5 mm scintillator + 1 mm gap (6 λ) : compensating

WS fiber + MPC (SiPM) readout

4 x4 cm^2 tile and 1cm wide strips

Alternative option: digital readout



CONCLUSIONS (?)

This is the introductory talk: as a conclusion let me ask a few questions that I hope will be answered at CALOR 06

Is calorimeter theory completely understood ?

Are there new promising techniques ?

Astrop

What

I wish you a nice and fruitful conference!

Electronics, software, calibration: adequate to meet the future challenges ?

ILC calorimetry, the next big enterprise. How to assess the PFA issue ?

What is the best (performing, affordable, cost effective) solution for ILC ECAL/HCAL ?

Specific ILC questions: material in front of the calorimeter ? how much do we rely on MC ? beam tests ? how relevant will be ‘association confusion’ ?…

I look forward triggering an interesting discussion !