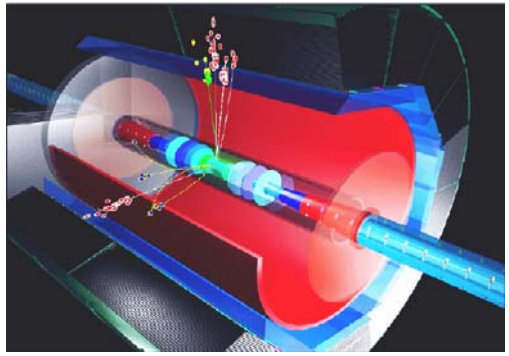
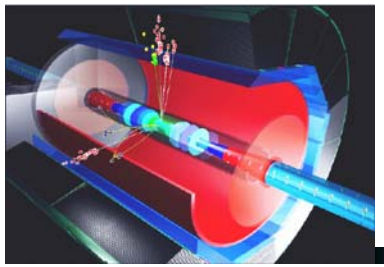


Worldwide Linear Collider Calorimeter R&D Test Beam Effort

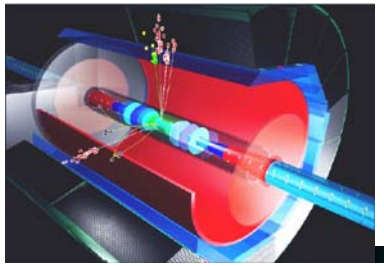
Felix Sefkow
DESY
CALICE Collaboration

LCWS 2004, Paris
April 22, 2004



Outline

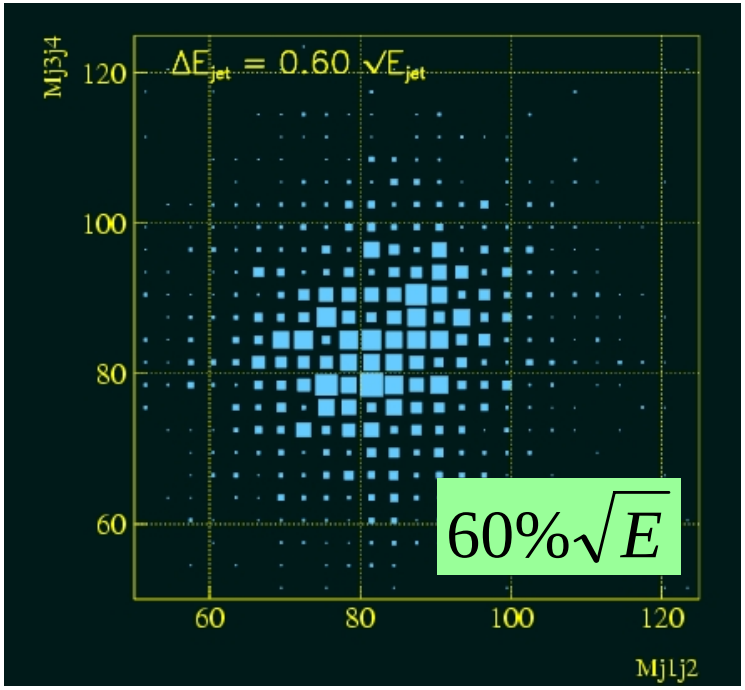
- Calorimeter R&D challenges
- Test beam requirements
- Past and present activities
- Preparations for the next steps



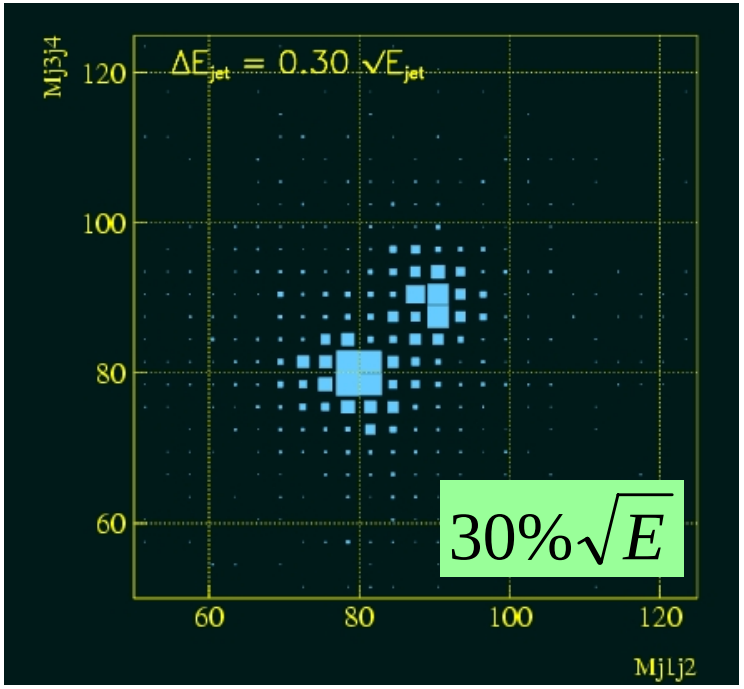
LC calorimetry challenge

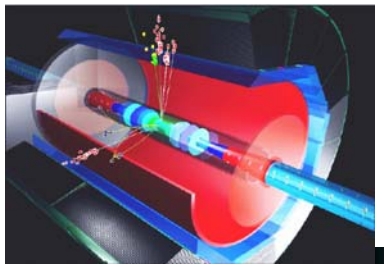
- **Jet energy resolution**: separate W and Z in their hadronic mode
- Dijet masses in $e^+e^- \rightarrow WW\nu\bar{\nu}$, $e^+e^- \rightarrow ZZ\nu\bar{\nu}$

LEP-like detector



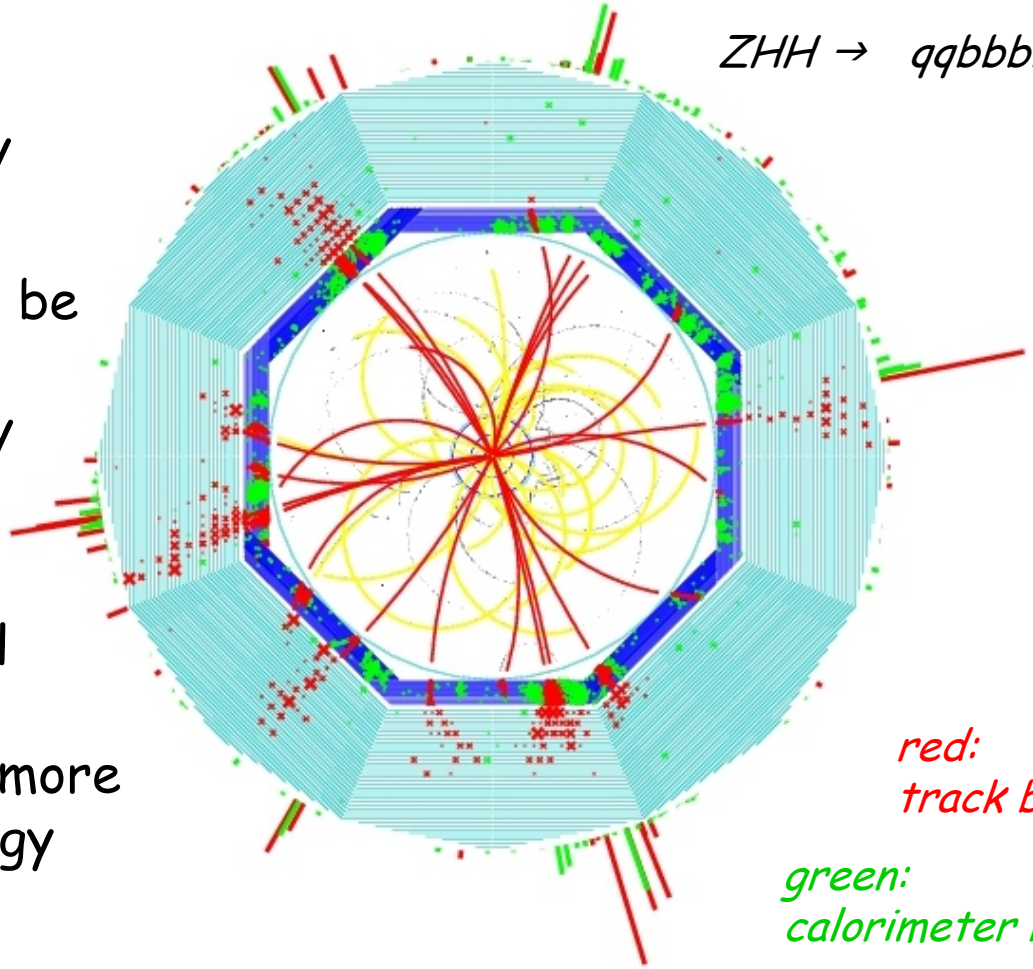
LC design goal

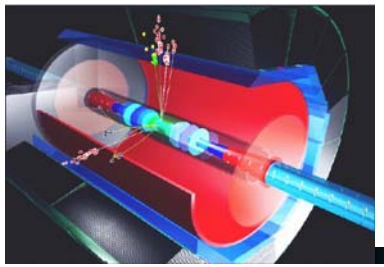




Particle flow

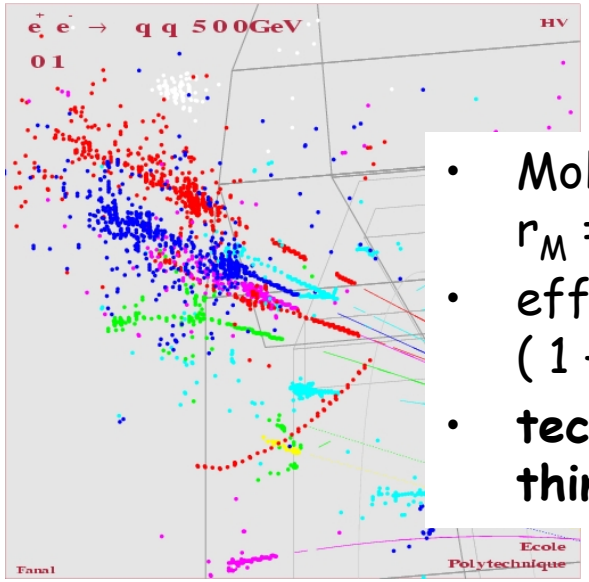
- Maximum tracking – minimum calorimetry
- Each particle should be reconstructed and measured separately
- For the jet energy measurement spatial resolution / particle separation power is more important than energy resolution





Calorimeter design

- small Moliere radius
- high granularity



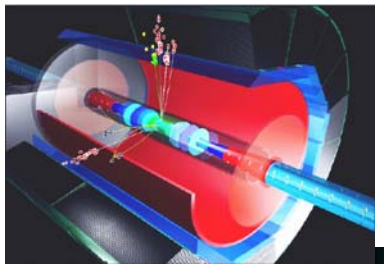
- Moliere Radius for W: r_M = 0.9cm
- effectively a factor (1 + Gap / 2.5mm) more
- **technology challenge: thin readout gap**

- "large" radius and length

Cost:
need ~3000 m²
expect 2$/ cm² Silicon in 2010
still ECAL = 50% of total detector

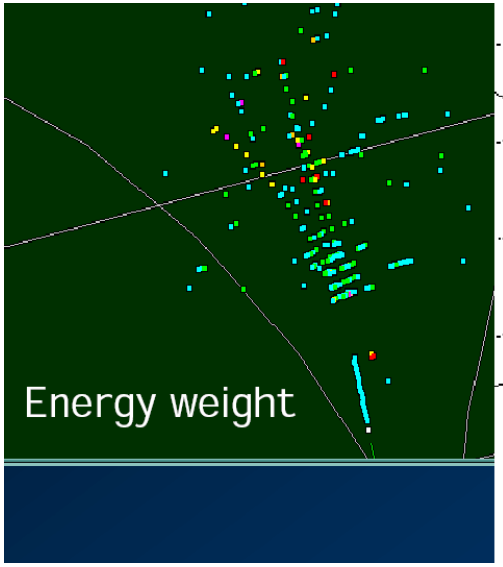
- large magnetic field
- "no" material in front

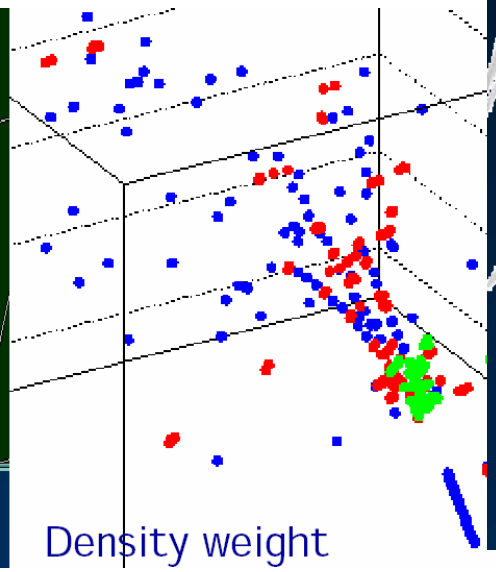
follow alternative options: scintillator or hybrid

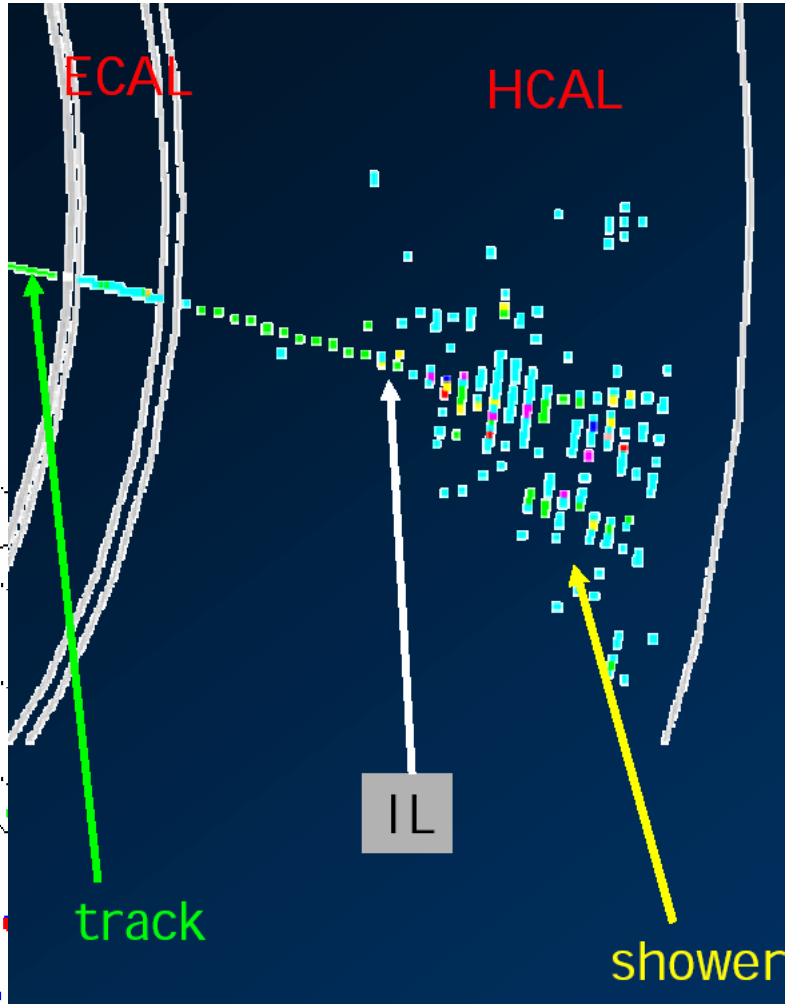


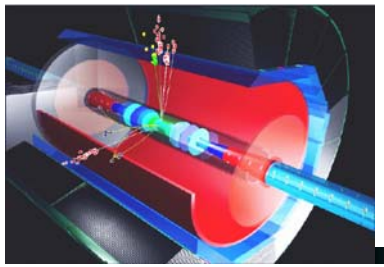
Hadron calorimeter concepts

- The HCAL must be imaging, too
- Readout options:
  - Analogue: classical scintillator – but pushing the granularity
  - Digital: radically imaging; counting hits



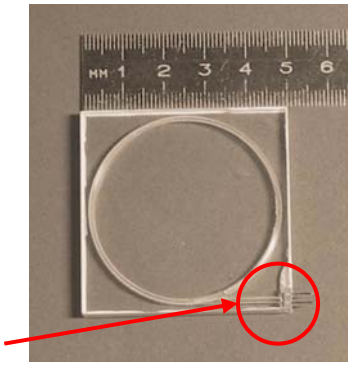






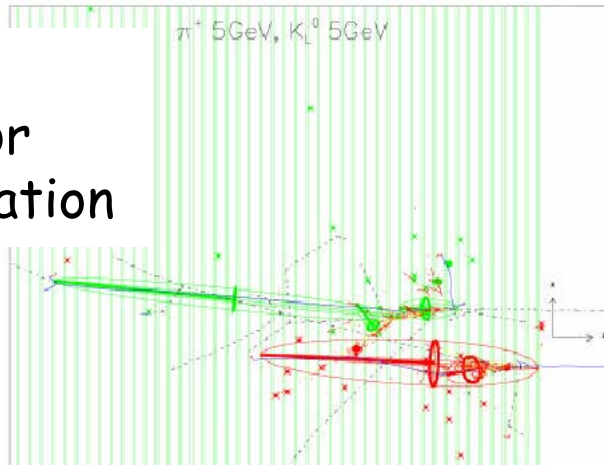
High granularity

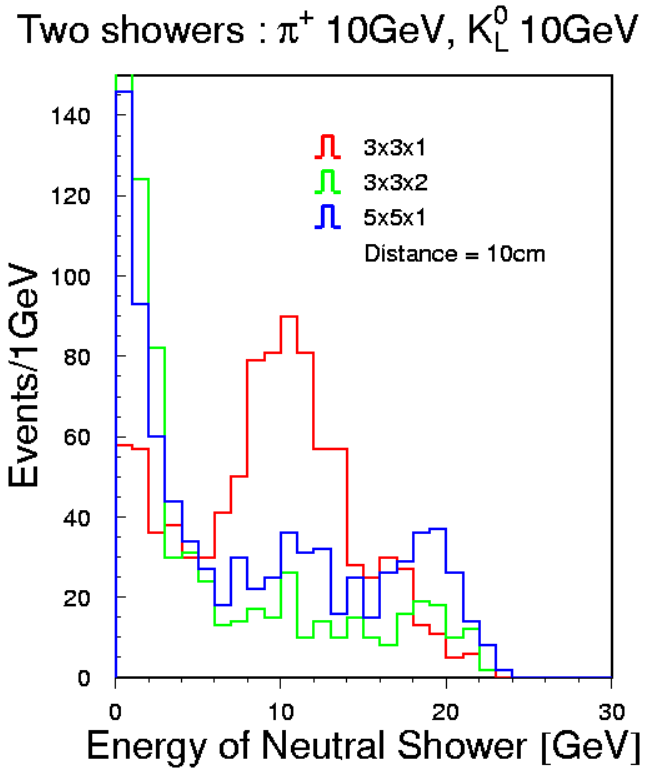
- new photodetectors allow individual readout of smallest scintillator tiles



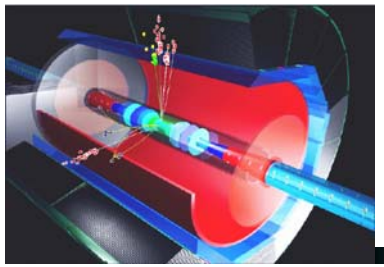
Si Photo-Multiplier

- optimize granularity for shower separation





(A.Raspareza)



Calorimeter R&D challenges

ECAL:

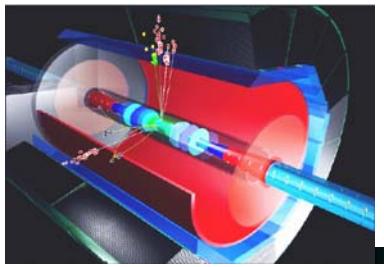
- Optimize overall detector geometry
- SiW: thin sampling layer technology
- alternatively: (hybrid) sampling structure
- photon reconstruction / separation

HCAL:

- Pattern recognition of shower "trees"
- large area chambers, low cost electronics
- novel readout technologies

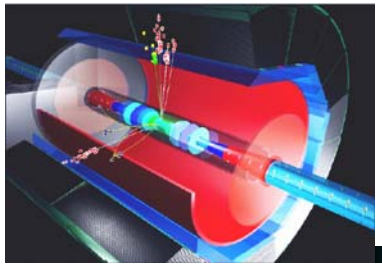
PFLOW:

- need fully developed algorithms to evaluate basic design configurations



Goals of the test beam program

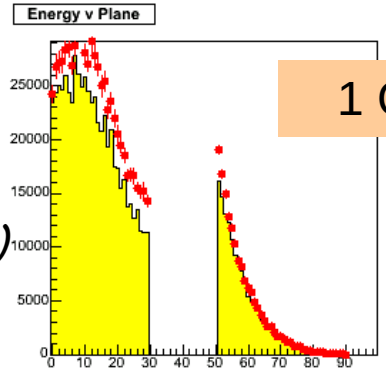
- **Technologies**: demonstrate the feasibility
- **Algorithms**: tune particle separation, PFLOW with real data
- **Simulations**: test and validate or improve hadronic shower models
  - together with well-measured hadronization of W or Z boson, optimize overall detector for jet reconstruction
  - even better, but more ambitious: collect a shower library
  - **Note**: this can ***not*** be done with existing coarse granularity data

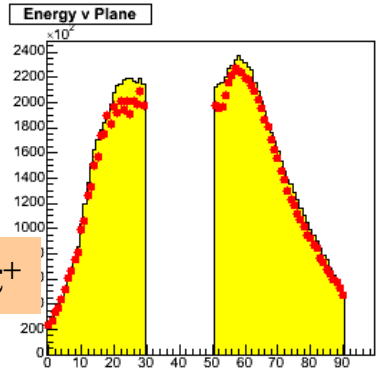


Required sensitivity

- 10'000 particles, compare Geant 3 (histo) vs. Geant 4 (points)

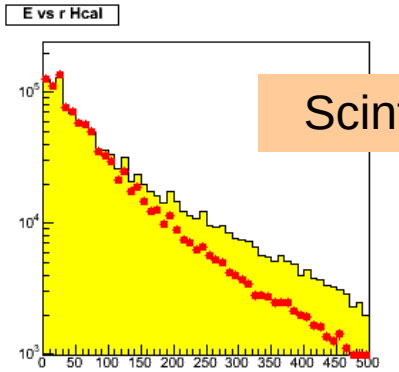
longitud. (ECAL+HCAL)

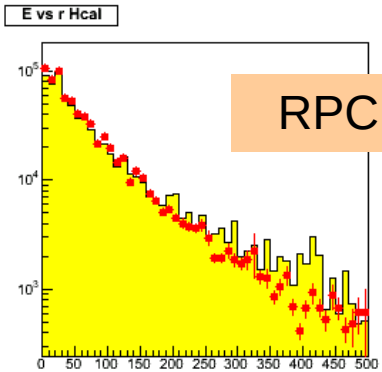




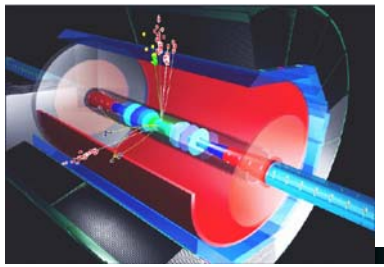
(study by D.Ward)

transverse in HCAL



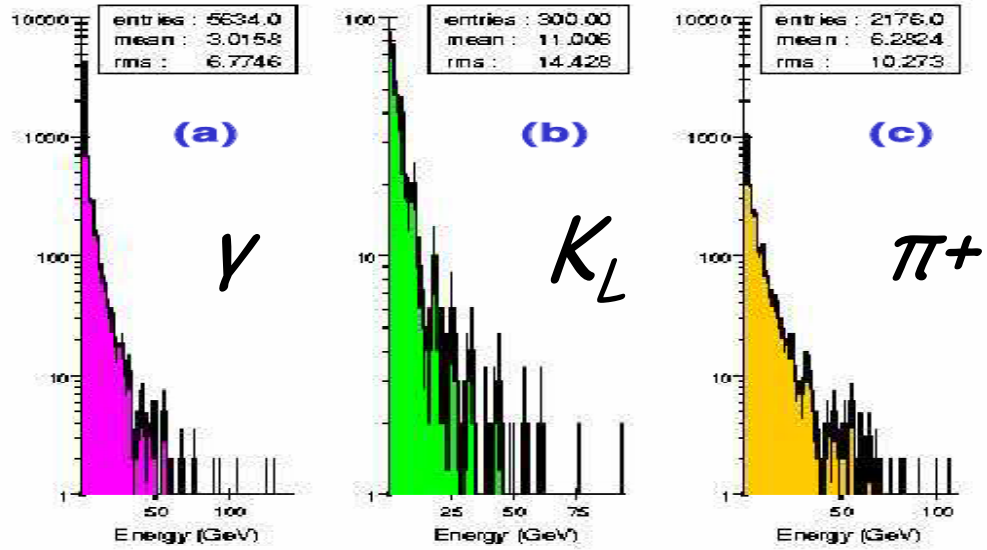


- differences vary with energy, particle type, detector material,…

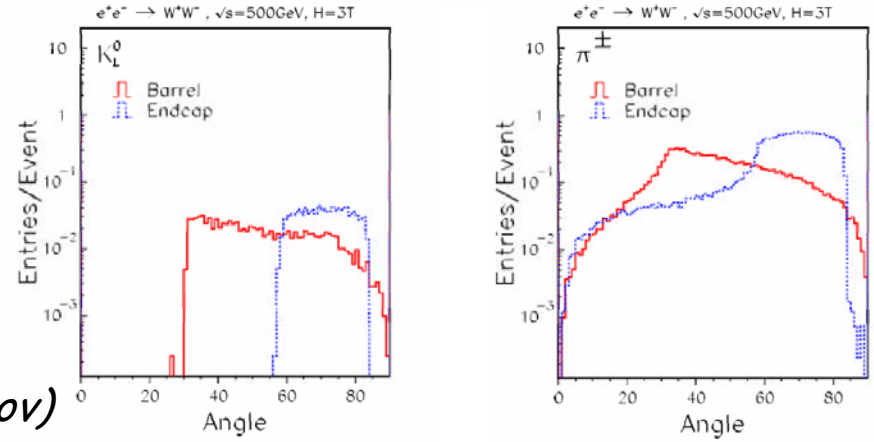


Energies and angles

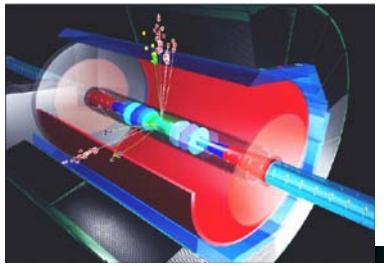
- mean energies around 10 GeV
- but need 5-50 GeV
- better 1-100 GeV



- 90 degrees never occurs!



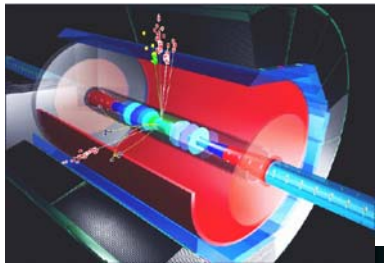
(V.Morgunov)



More beam requirements

- Electrons and photons, pions and protons, muons
- energy spread <2%
- rate ~1kHz (<100 Hz for RPCs)
- tracking (need ~1mm: wire chambers or Si telescope)
- particle ID (Cerenkov)
- infrastructure (crane, cooling, gas, computing & network)
- space (6m wide)
- magnet? (4T @ DESY, cosmics only, for small ECAL or RPCs)

- several phases of running time
- $O(10^2)$ configurations * $O(10^4)$ events * $O(10^2)$ bins = 10^8 events = 1-10 days running time = several weeks real time each

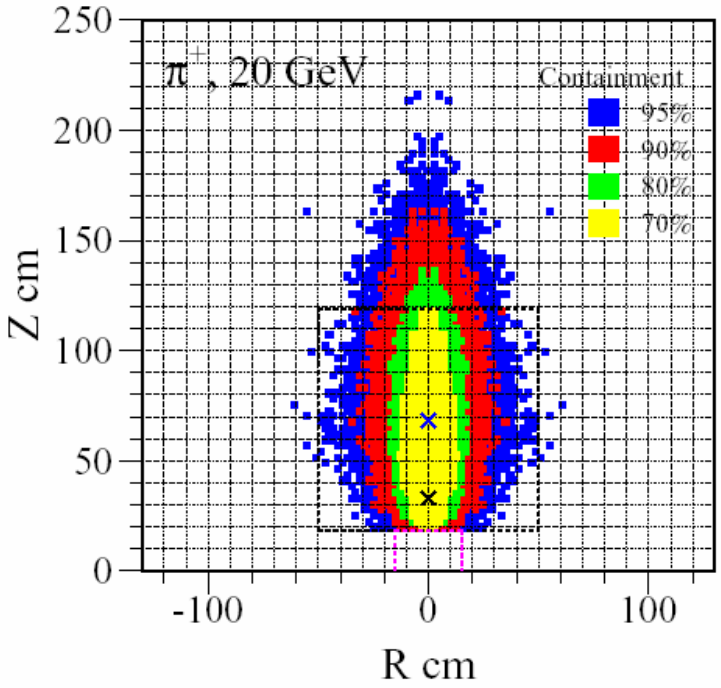


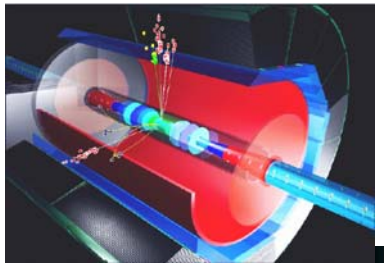
Test beam detector requirements

- a cubic metre size
- plus tail catcher to measure leakage
- possibilities for wide angular scans

- flexibility to test different configurations
  - with, w/o ECAL
  - different active media (scintillator, RPCs, GEMs)
  - different sampling structures, absorber thickness and types, and gap widths

- DAQ for few 10^4 or even few 10^5 ch.

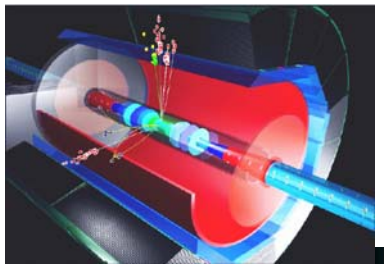




R&D groups worldwide

from world-wide testbeam draft

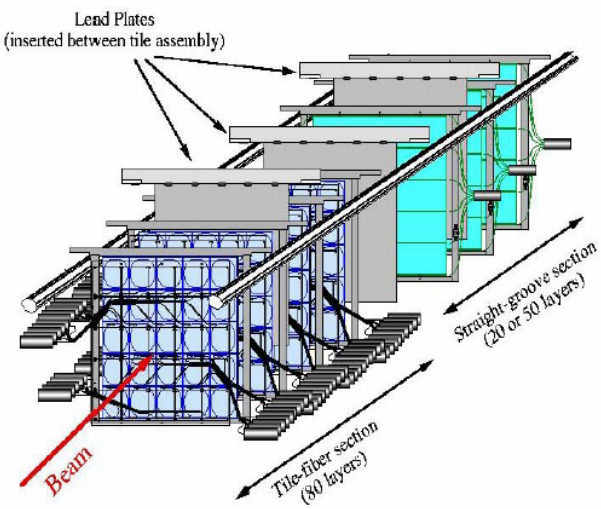
Calorimeter	Technology	Groups
Electromagnetic	Silicon-Tungsten	BNL, Oregon, SLAC
	Silicon-Tungsten	Britain, Czech, France, Korea, Russia
	Silicon-Tungsten	KNU, EWA
	Scintillator/Silicon-Lead	ANF, Padova
	Scintillator/Silicon-Tungsten	Kansas, Kansas State
	Scintillator-Lead	KEK, Kobe, Konan, Niigata, Shinshu, Tsukuba
	Scintillator-Tungsten	Colorado
Hadronic (analog)	Scintillator-Steel	DESY, Dubna, ITEP, LPI, MEPHI, Charles, IPAS
	Scintillator-Lead	KEK, Kobe, Konan, Niigata, Shinshu, Tsukuba
Hadronic (digital)	Gas Electron Multipliers-Steel	UTA
	Scintillator-Steel	NICADD
	Resistive Plate Chambers-Steel	IHEP (Russia), JINR
	Resistive Plate Chambers-Steel	ANL, Boston, Chicago, FNAL
Tail catcher	Scintillator-Steel	FNAL, NICADD
	Resistive Plate Chambers-Steel	INFN

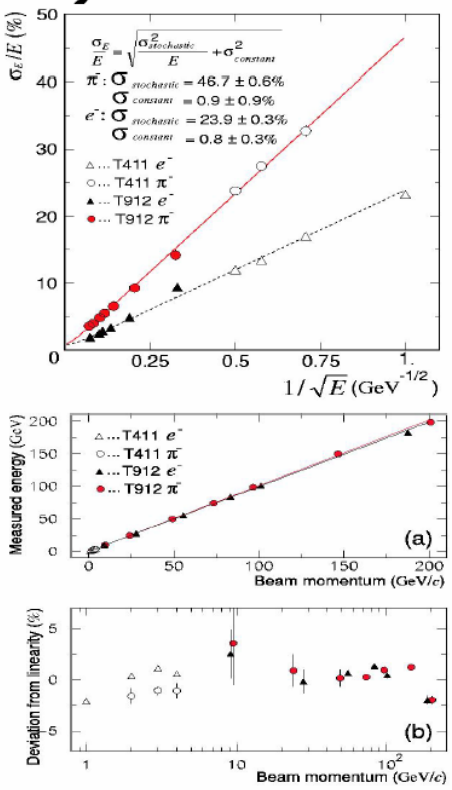


Previous studies: Asia

- long series, just finishing (spring 2004)
- example:
  - electrons and hadrons @ KEK and FNAL
- see calo session

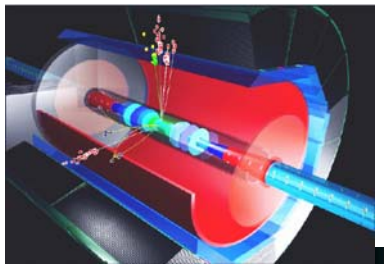
HCAL studies with test beam (1996-1999)





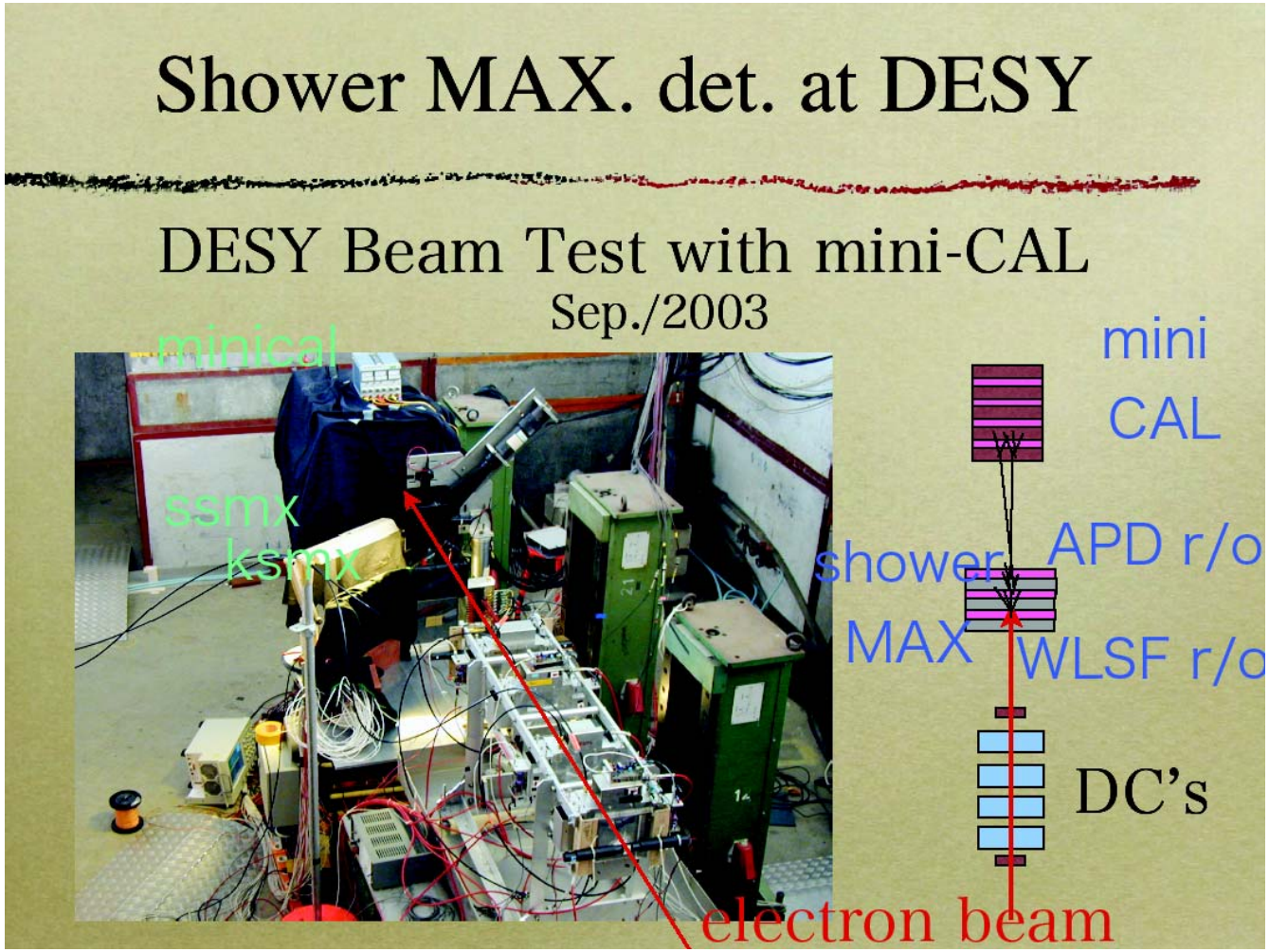
- Good energy resolution and linearity thanks to hardware compensation

(slide from Hiroyuki Matsunaga)

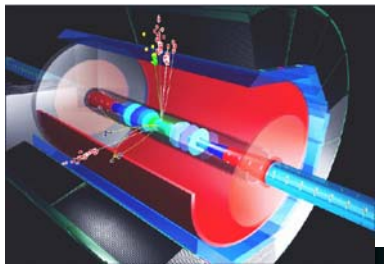


Joint European /Asian tests

- 6 GeV electrons

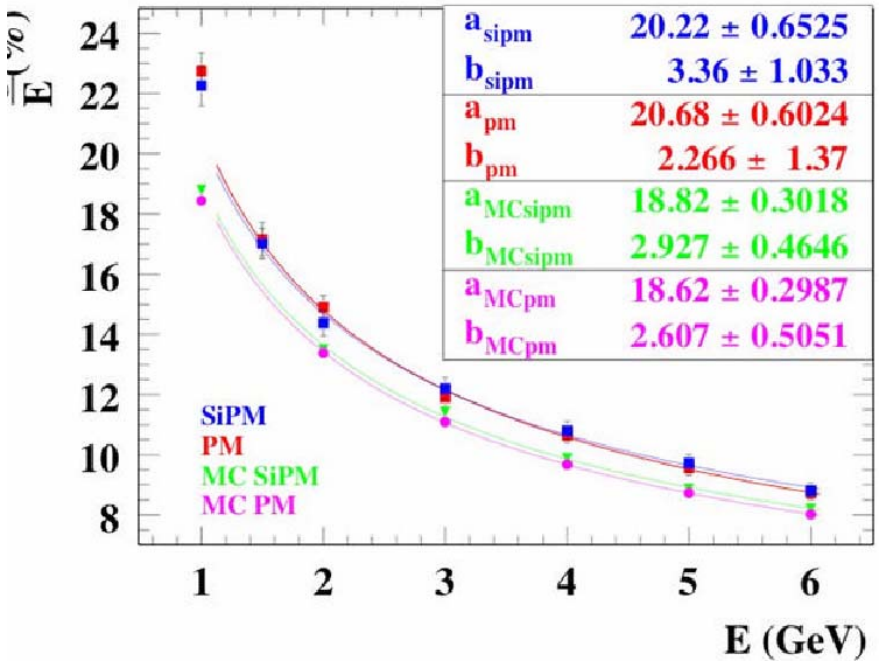


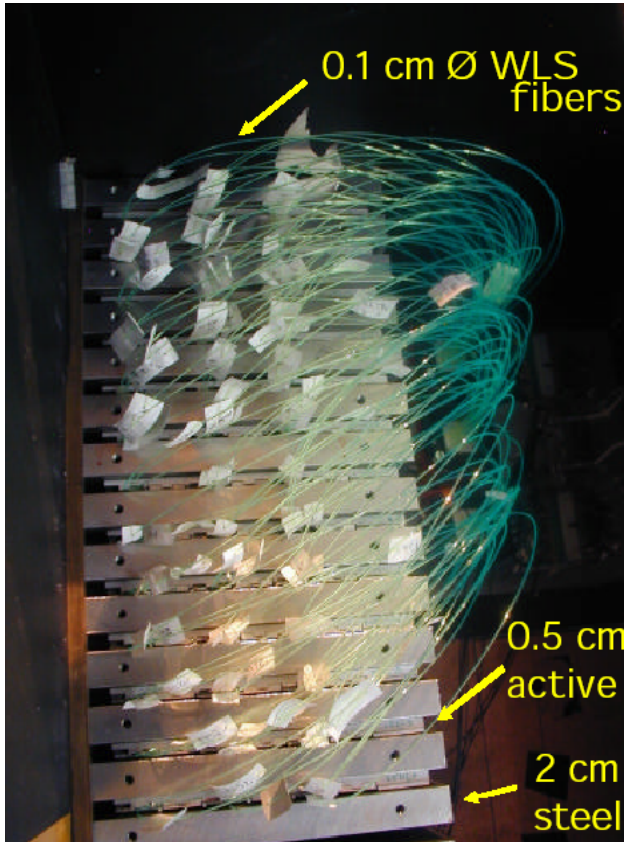
(slide from Tohru Takeshita)

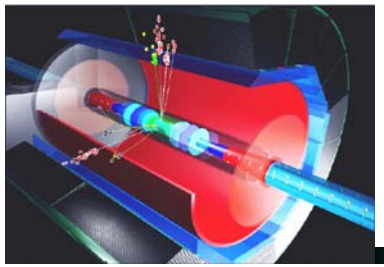


Scintillator HCAL (CALICE)

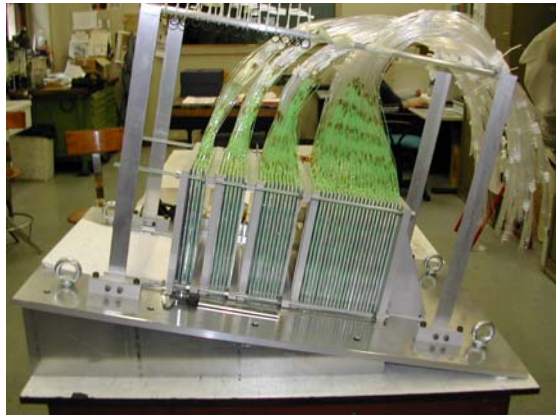
- pre-prototype, 50-100 channels
- Compare different photodetectors: SiPMs, MA-PMs and APDs (underway)
- see calo session



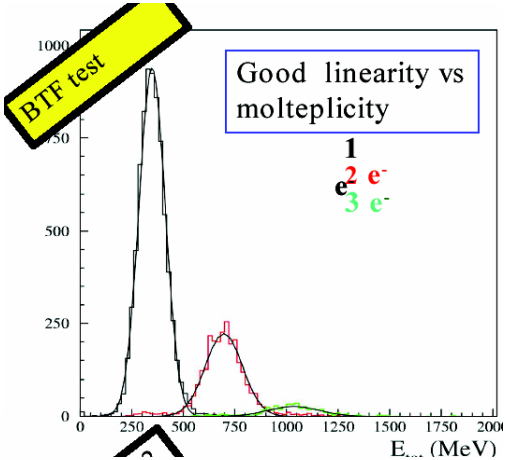


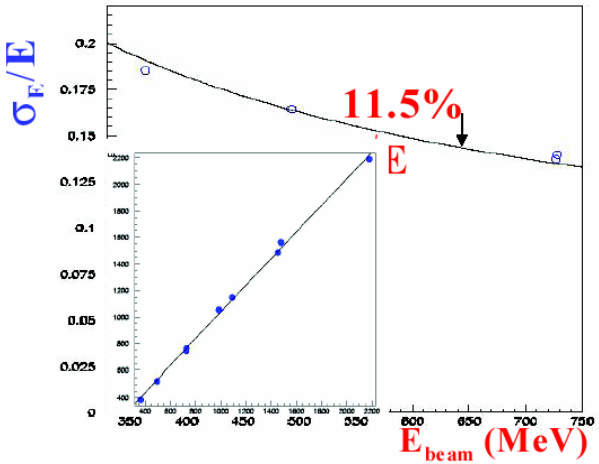


Hybrid ECAL (Italy)

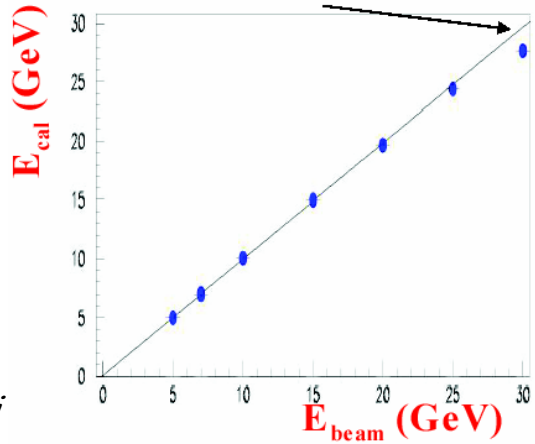


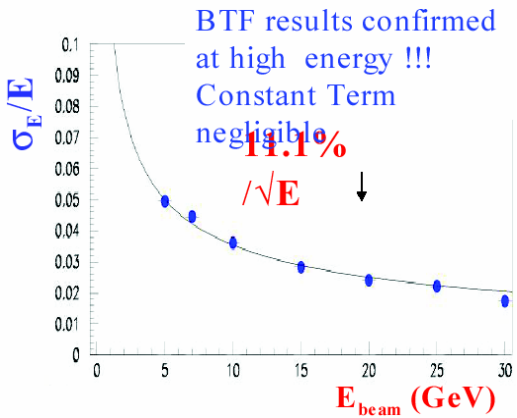
LCcal collaboration



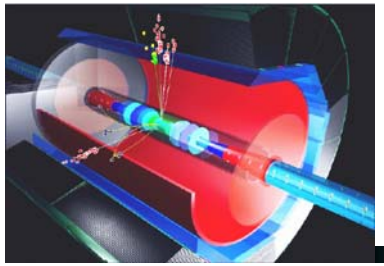


- at Frascati
- and CERN





S.Miscetti

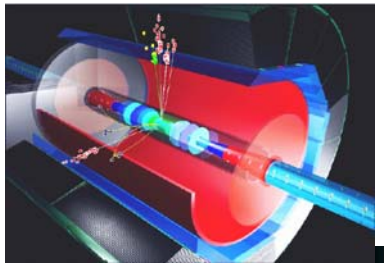


Plans in Asia, US, Europe

- Asian groups were planning to finalize ECAL tests in spring 2004
- report at this conference
- further plans being discussed

- US groups plan to start with ECAL options at SLAC in 2005,
- all HCAL options till 2008

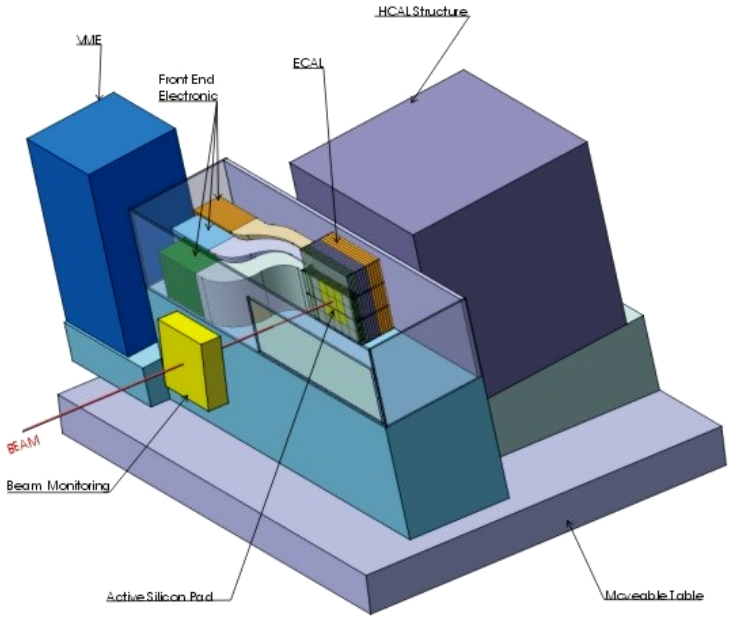
- Forward calorimeter groups plan
  - high intensity e beam at Frascati 2005-06
  - high energy e beam > 2008 (CERN?)

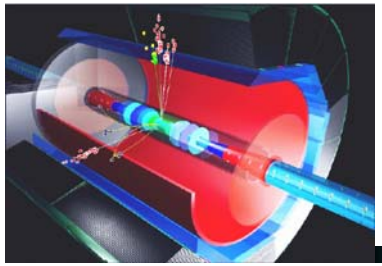


CALICE plans

164 Physicists, 28 Institutes, 9 Countries: 3 Regions

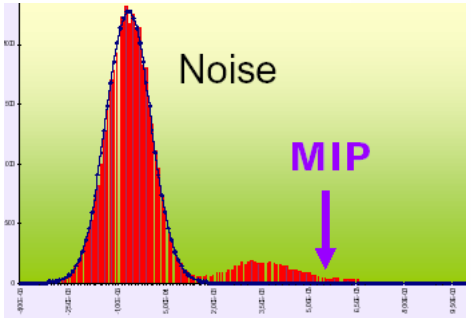
- CALICE prepares beam test series in 2005-06
- ECAL and HCAL together, different options
  - SiW ECAL
  - HCAL with scintillators, RPCs or GEMs

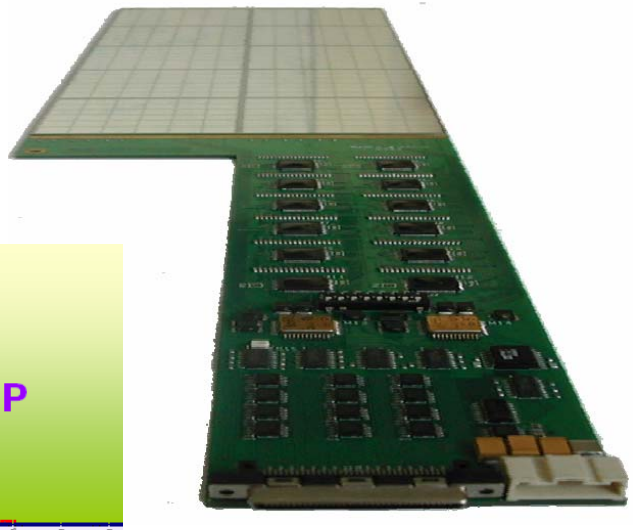




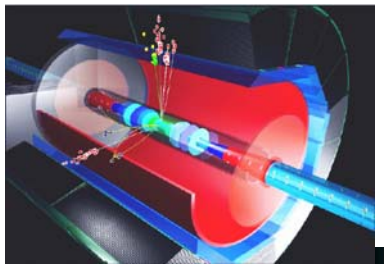
ECAL preparations

- PCB with Si sensors and VFE being commissioned with DAQ in Paris these days





- LAL,LLR,LPC,PICM
- Imperial College, UCL, Cambridge, Birmingham, Manchester, RAL
- ITEP,IHEP,MSU
- Prague (IOP-ASCR)
- SNU,KNU

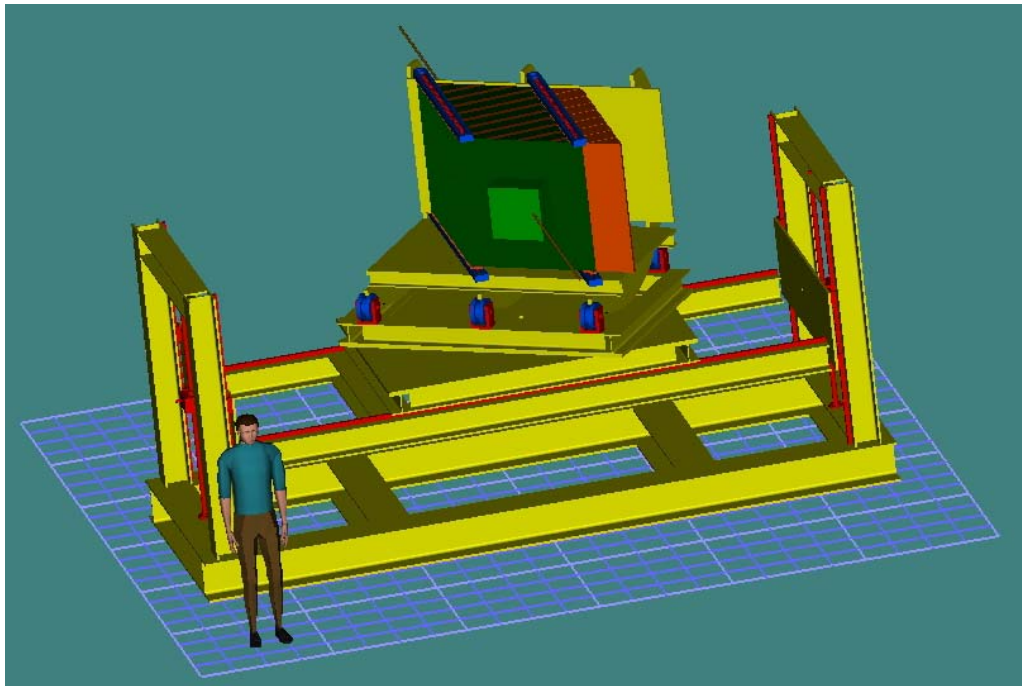


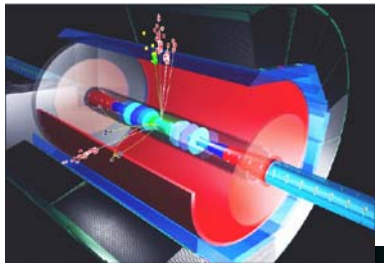
HCAL preparations

- cubic metre prototype (based on scintillator minical experience) presently moving from design to construction phase
  - high granularity to test analogue and (semi-)digital options

- flexible mechanical structure (stack and moving table)
  - being built at DESY

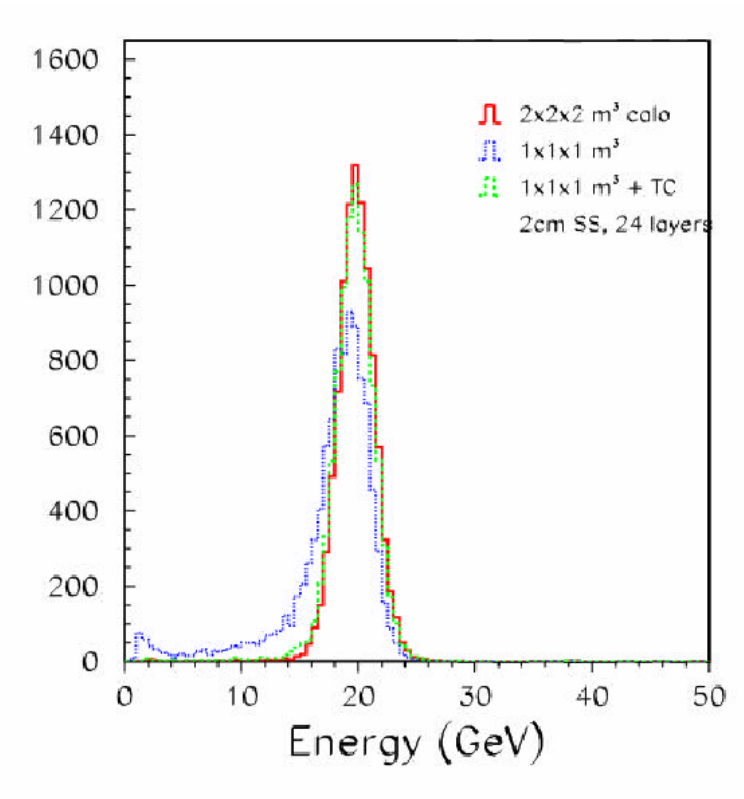
- square metre RPCs and GEMs in preparation (US, Russia)



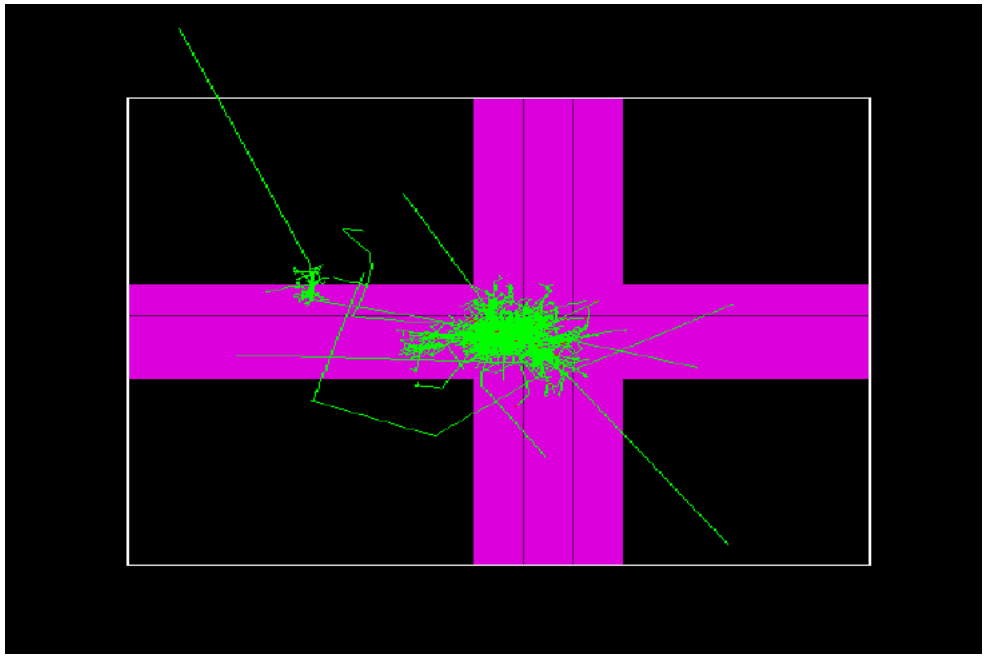


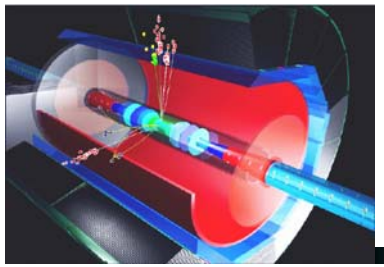
Tail Catcher

- HCAL inside coil is thin – need to recover 10-20% for 20 GeV pion
- scintillator strip tail catcher / muon system being prepared



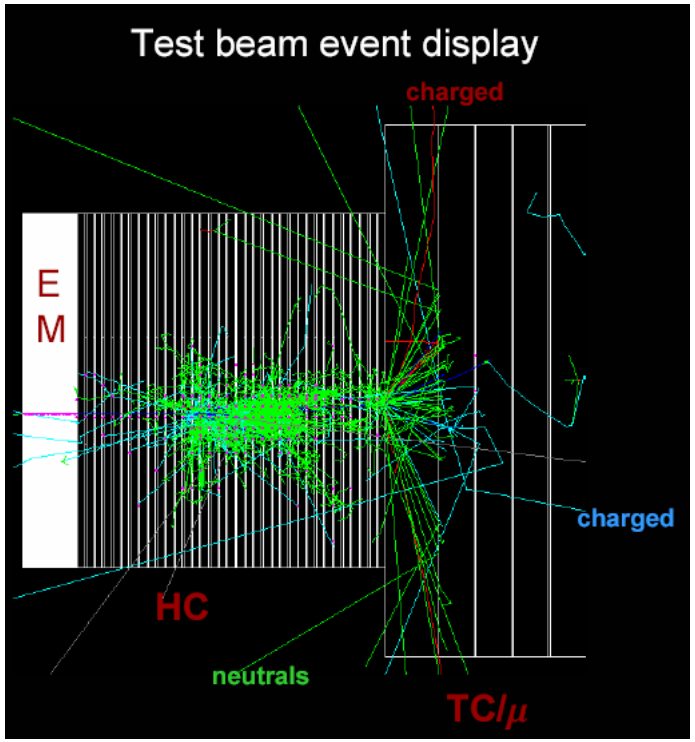
(NIU, with DESY)

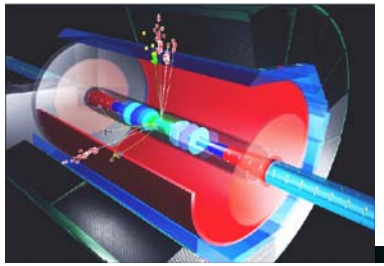




DAQ, software

- ECAL and HCAL (8-10'000 channele each) are aiming at using unified (ECAL) DAQ system
  - conceptual solutions for HCALfront end electronics exist
- common testbeam simulation and reconstruction framework
  - effort centred at DESY, NIU, and Paris



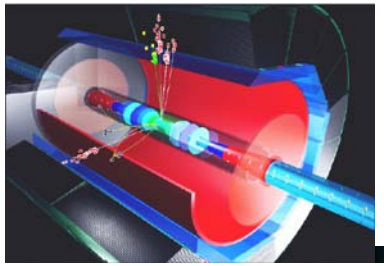


Schedule, near, medium term

- start with ECAL end 2004 at DESY
- then integrate (scintillator) HCAL with ECAL

- goal: move both to hadron beam in 2005
  - and high energy e beam, …
- vary readout options: 2006 +
- possible scenario:

Year	Calorimeter	Beam time request
2005	ECAL (CALICE)	3 weeks (electrons)
	Analog HCAL	4 weeks (hadrons, muons)
2006	Digital HCAL (RPCs)	4 weeks (hadrons, muons)
	ECAL + Analog HCAL + Tail catcher	5 weeks (hadrons)
	ECAL + Digital HCAL + Tail catcher	5 weeks (hadrons)
	ECAL (US)	3 weeks (electrons)
2007	ECAL + Analog HCAL + Tail catcher	5 weeks (hadrons)
	ECAL + Digital HCAL + Tail catcher	5 weeks (hadrons)
	Digital HCAL (different active media)	8 weeks (hadrons, muons)
2008	ECAL + Digital HCAL + Tail catcher	5 weeks (hadrons, muons)



Conclusion

- R&D proto-collaborations work:
- prototype construction in task sharing mode ongoing
- common systems (mechanics, DAQ, tail catcher), infrastructure and software

- clock is running for basic design choices in few year's time
- first round in 2005

- FNAL and Protvino beam facilities both meet basic calorimeter requirements
- practicability to be checked: need to further sharpen our plans