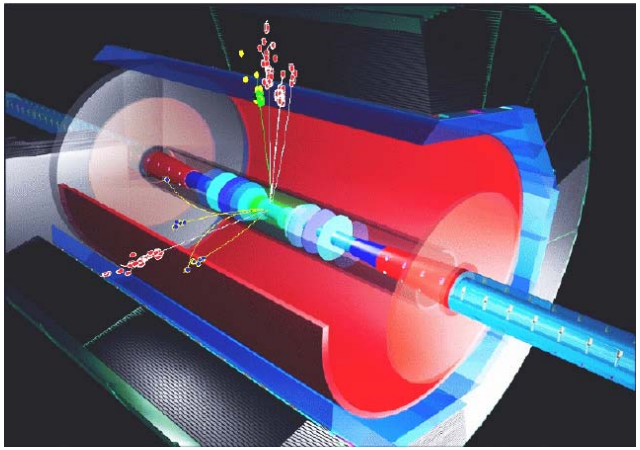
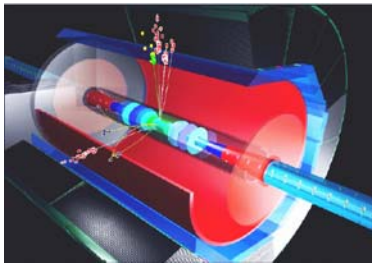


The scintillator HCAL testbeam prototype

Felix Sefkow
DESY
CALICE collaboration

LCWS 05 at Stanford
March 18-22, 2005

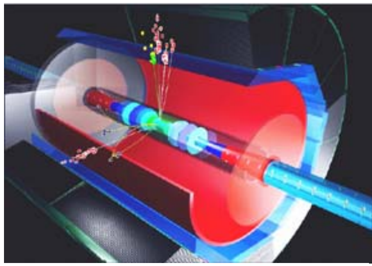


This talk

includes material from

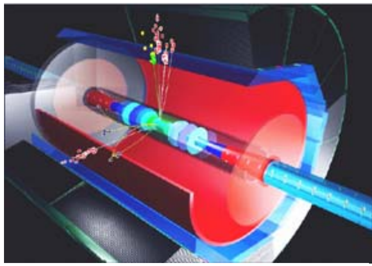
Mikhail Danilov (ITEP, Moscow)

who had to cancel his contribution to this conference due to delays in visa procedures



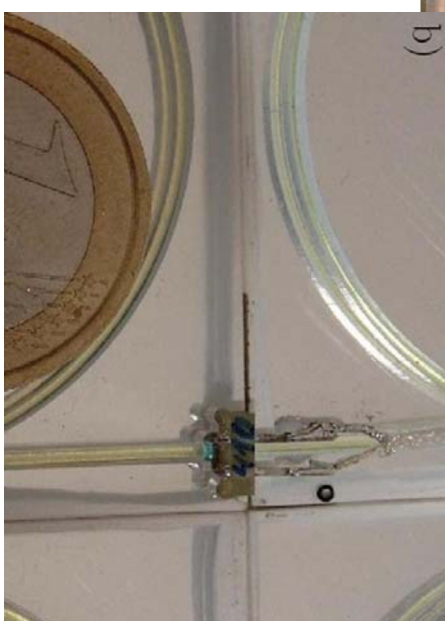
Outline

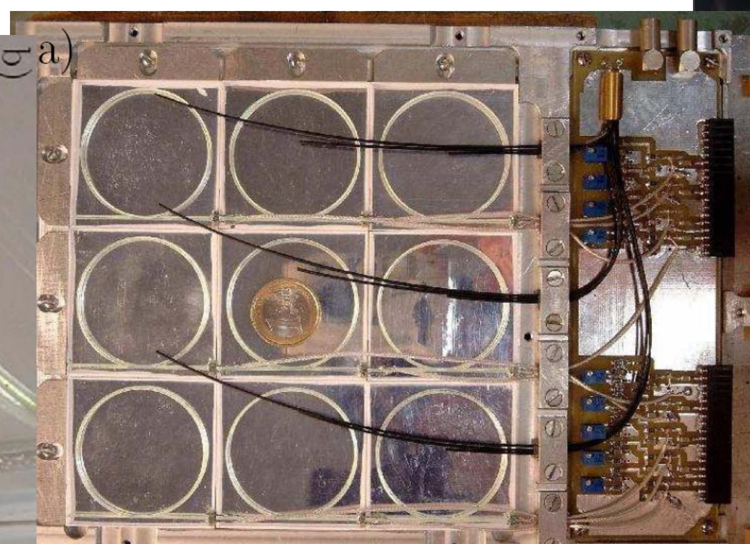
- The “Minical” experience, final results
- The testbeam prototype, goals and design considerations
- Readout electronics, SiPMs and scintillators, mechanics
- **More talks by J.Blazey, E.Garutti, G.Martin, J.Cvach and R.Poeschl**

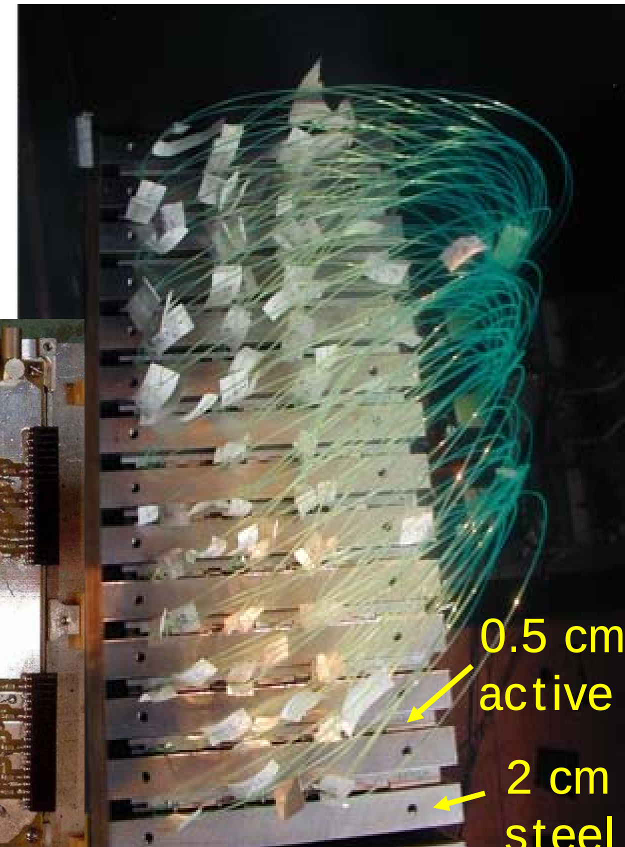


The “minical” pre-prototype

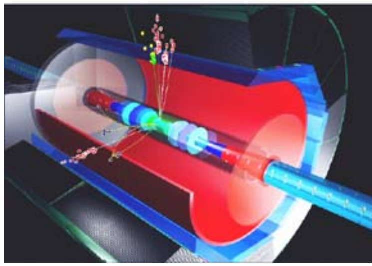
- DESY 6 GeV e beam 2003-2004
- 108 scintillator tiles (5x5cm)
- Readout with Silicon PMs on tile, APDs or PMTs via fibres







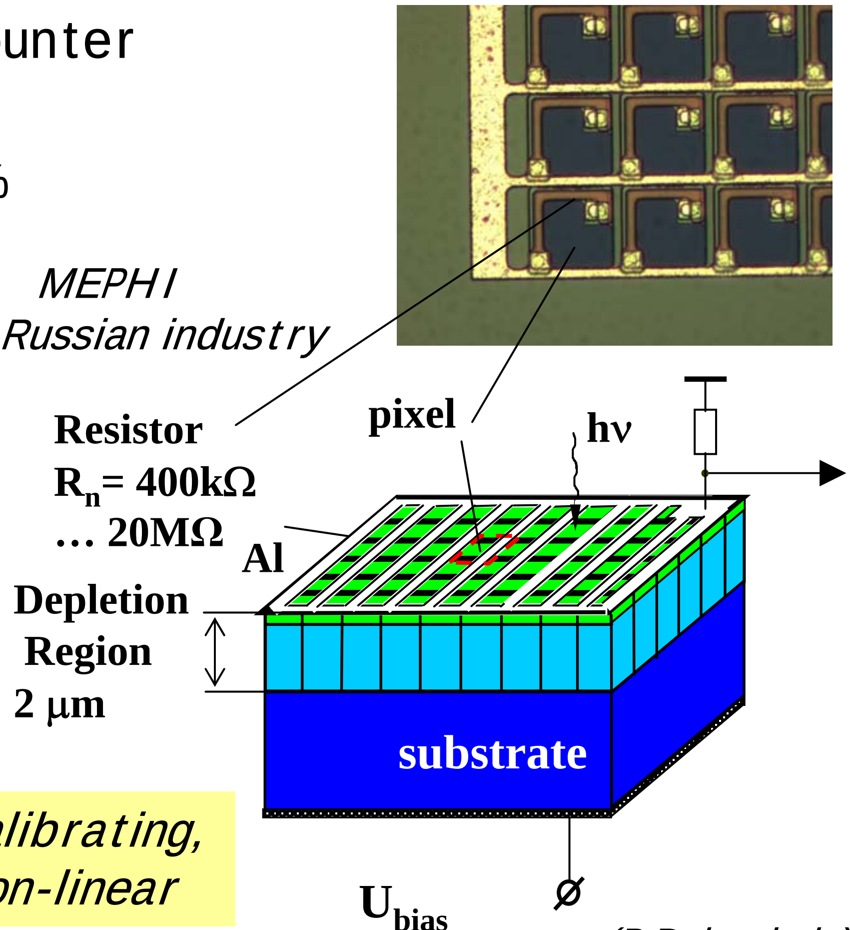
DESY, Hamburg U, ITEP, LPI, MEPHI, Prague



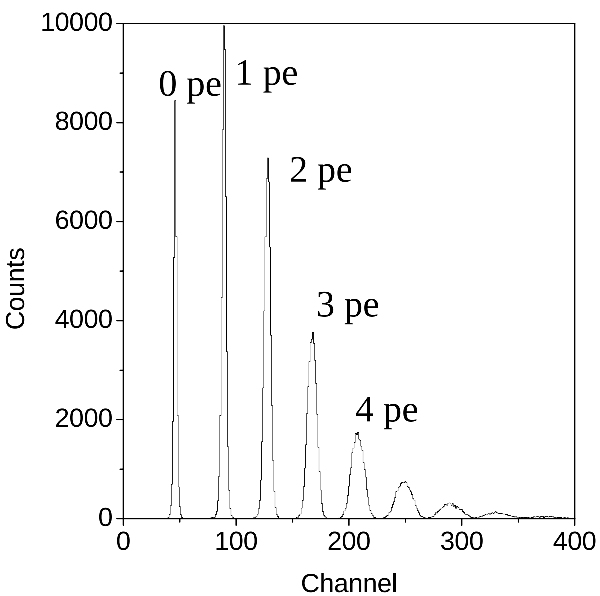
The Silicon Photomultiplier

- A pixilated solid state Geiger counter
  - 1000 pixels on 1mm^2
  - Gain ~ 10**6, efficiency 10...15%
  - At 60 V typ. bias voltage

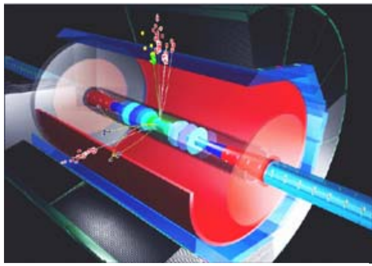
MEPHI
with Russian industry



(B.Dolgoshein)



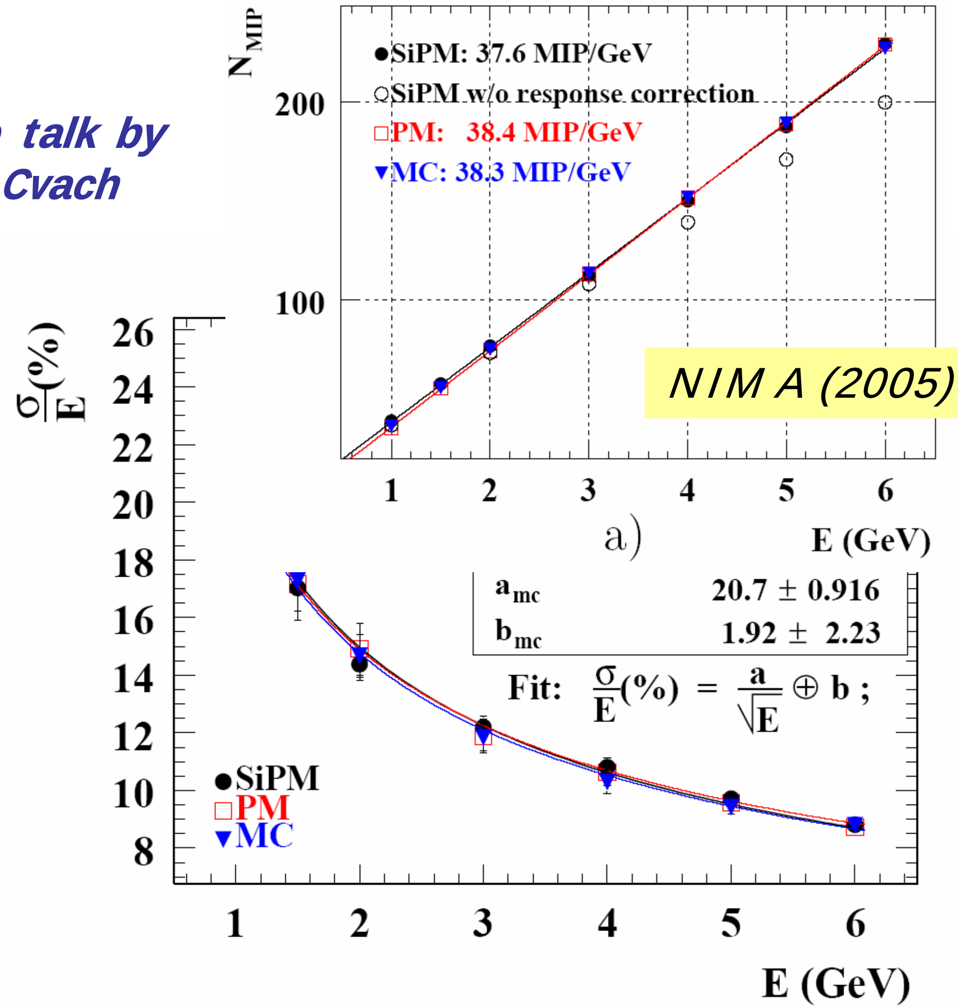
Auto-calibrating,
but non-linear

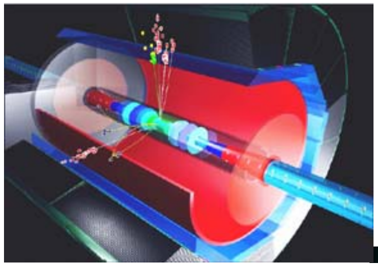


Testbeam results

- Resolution as good as with PM or APD*
- Non-linearity can be corrected (at tile level)
  - Does not deteriorate resolution
  - Need to observe single photon signals for calibration
- Well understood in MC
- Stability not yet challenged

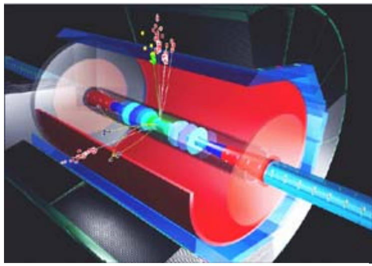
see talk by J.Cvach





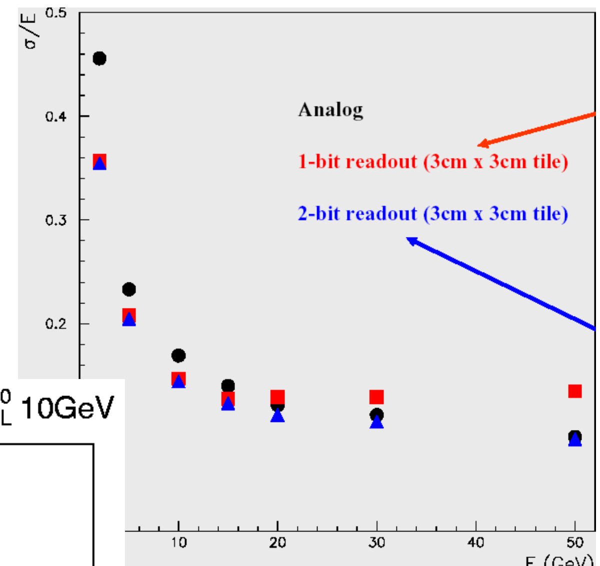
Minical conclusions

- The SiPM has been established as photo-sensor for calorimetric applications
- It opens up new possibilities for highly granular scintillator-based calorimeters

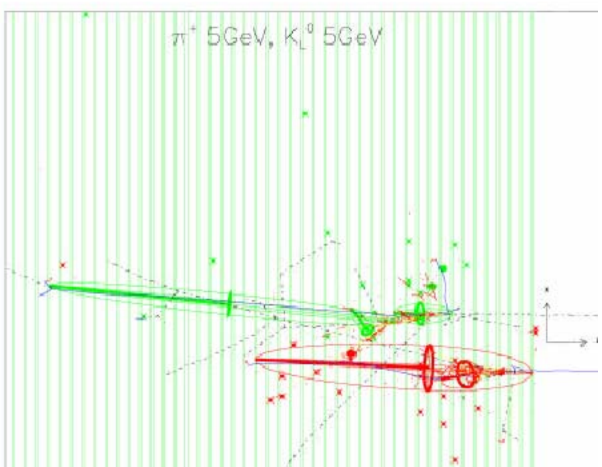


$1m^3$ Hadron beam prototype

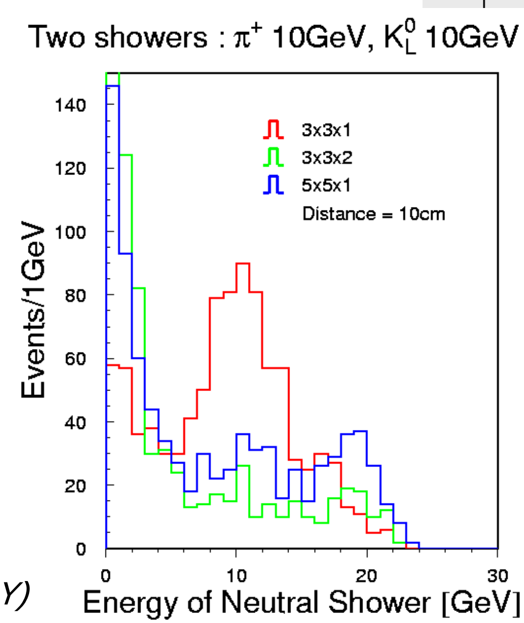
- Test the analog and semi-digital scintillator based HCAL concept
- High granularity core with 3cm tiles
- 8000 channels in total



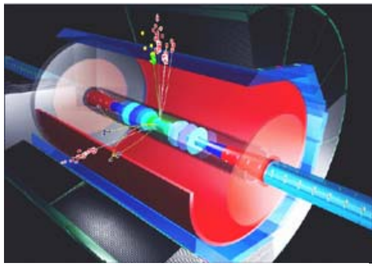
V.Zutshu (NIU)



A.Raspereza (DESY)

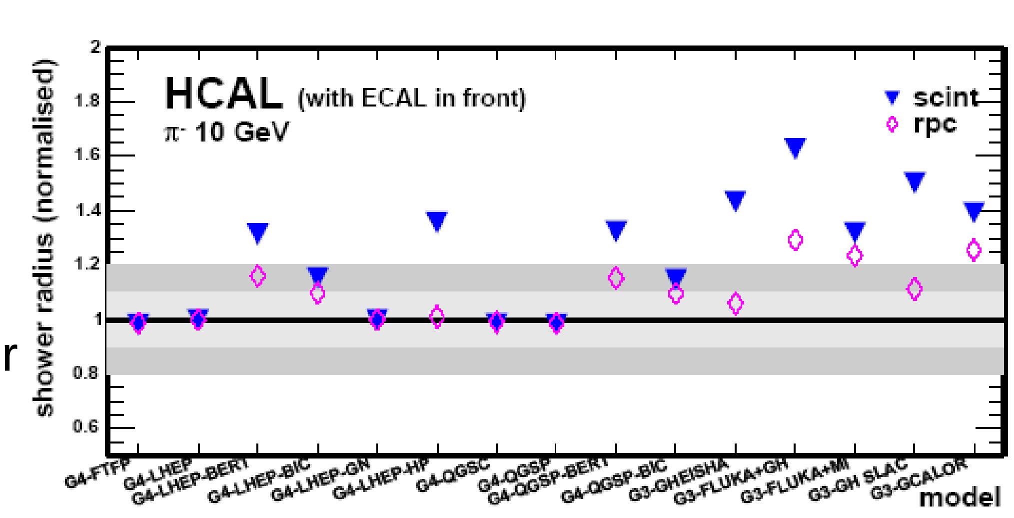


Reading every layer essential

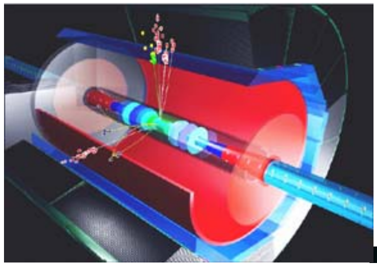


HCAL testbeam goals

- **Technology**: Gain large scale, long-term experience with a SiPM readout detector
  - Identify critical operational aspects to optimize photo-detector, electronics and calibration system
- **Physics**: Collect data samples **(~ 10^8 evts)** to
  - Explore hadron showers with unprecedented granularity
  - Validate hadronic shower models
  - Develop particle flow algorithms



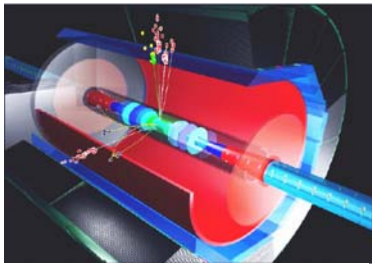
G.Mavromanolakis



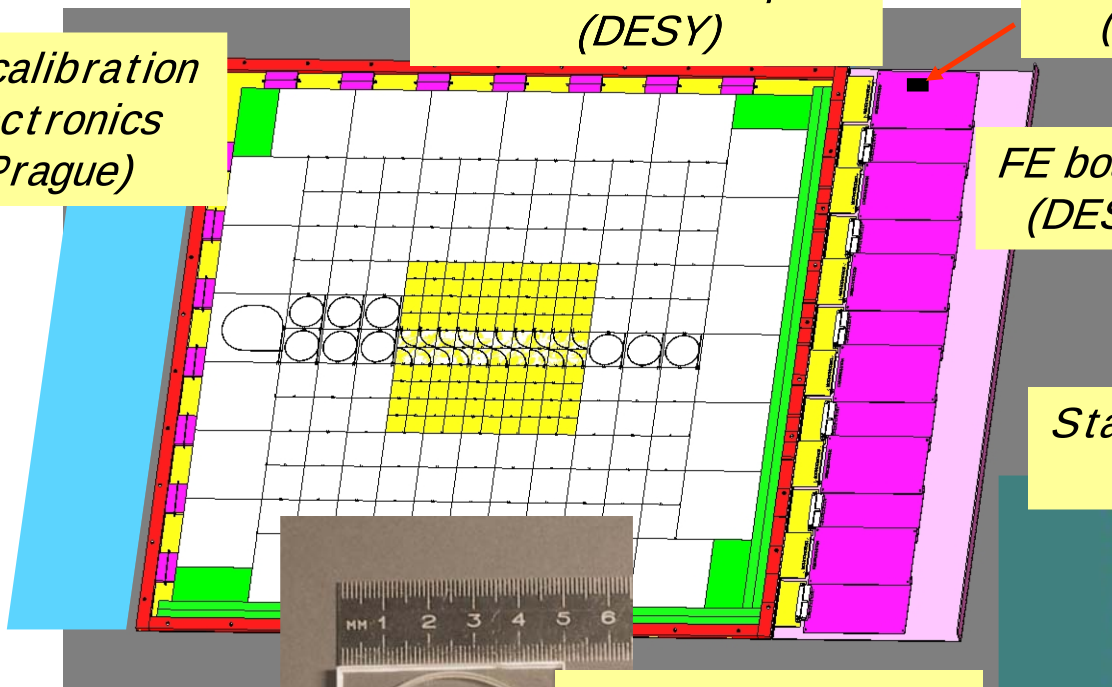
Prototype design challenges

- Design based on minical experience (SiPM, scintillator, cable) – but…
- Industrialize SiPM and tile production – scale by two orders of magnitude
- 8k channel bias supply and readout electronics for beam test with ECAL
- Versatile calibration & monitoring system
- Modular mechanical design

***NOT** a prototype for an ILC detector*



Collaborative effort



LED calibration electronics (Prague)

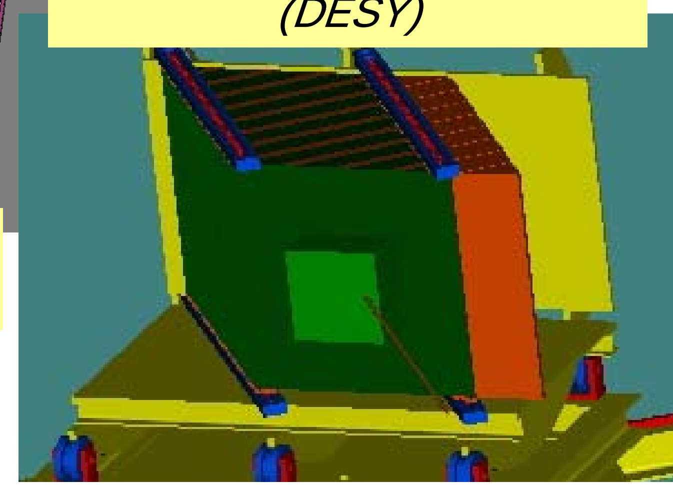
Cassettes, LED optics (DESY)

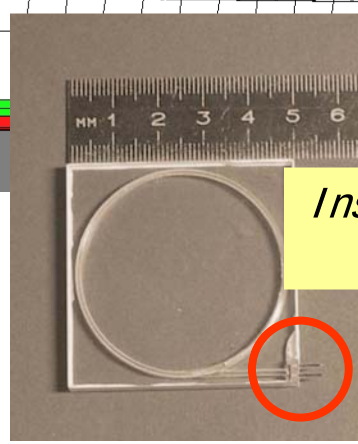
VFE ASICs (LAL)

FE boards (DESY)

DAQ (UK groups)

Stack, motion, Slow Control (DESY)

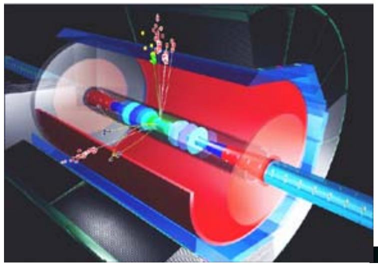




Instrumented tiles (ITEP)

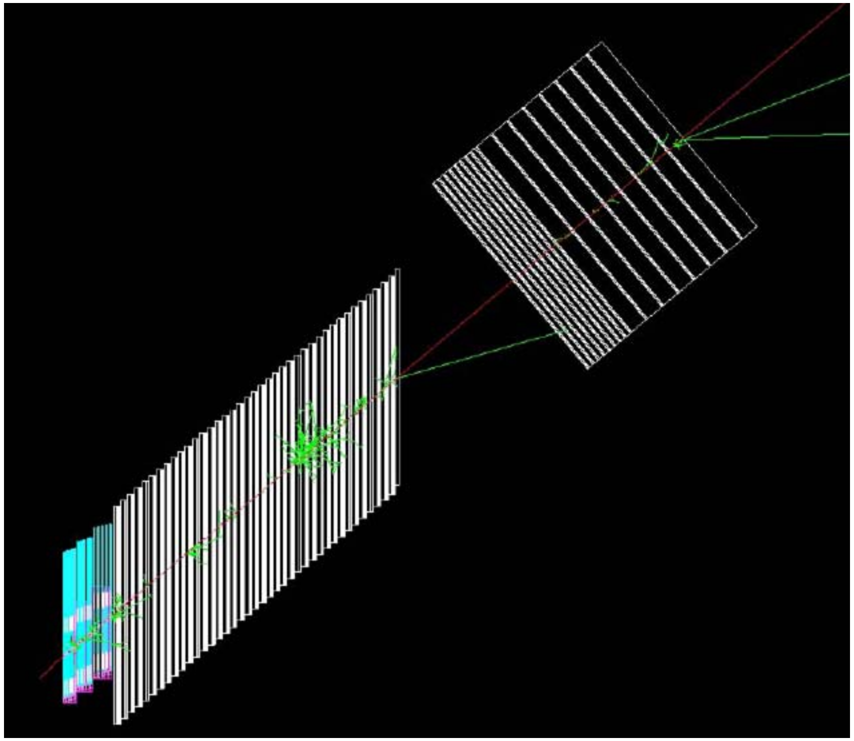
SiPMs (MEPHI)

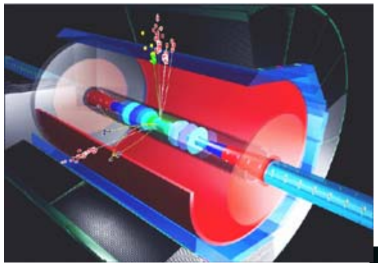
Commissioning (DESY, MEPHI, later: NIU, all)



Software

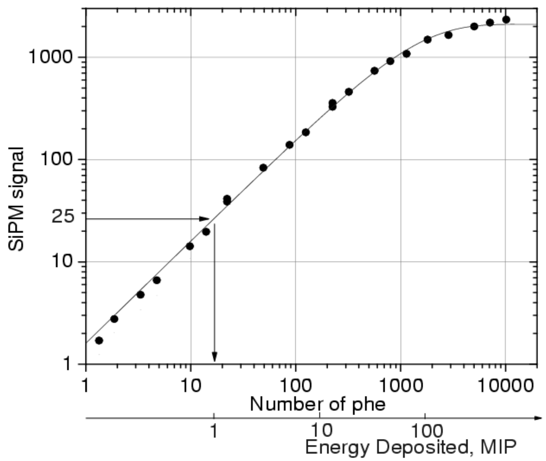
- No time to cover the software side
- Using the (inter-regional) LCIO data model
  - For physics studies and simulations
  - Also for calibration and conditions data
  - **See R.Poeschl's talk**

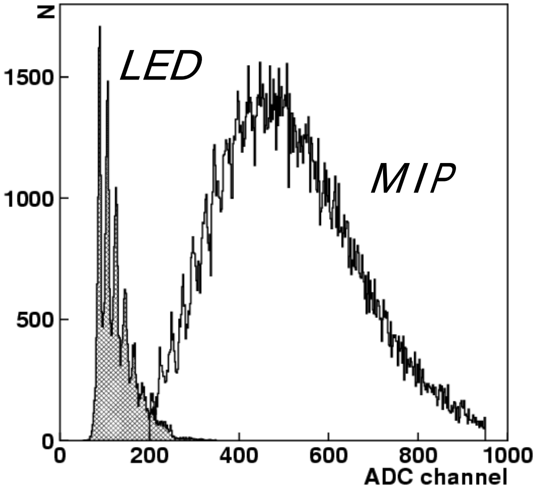


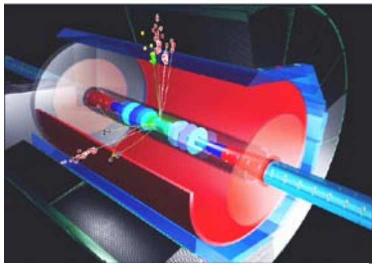


Calibrating & monitoring SiPMs

- Challenge: control a non-linear detector
- Energy scale is set by MIP response
- Non-linearity correction requires observation of single photo-electron signals
  - By-product: directly observe SiPM gain
- Temperature sensitivity (at g=10**6)
  - Gain 1.7 % / K, total signal 4.5% / K
- Redundant calibration and monitoring system
- **See talk by E.Garutti**

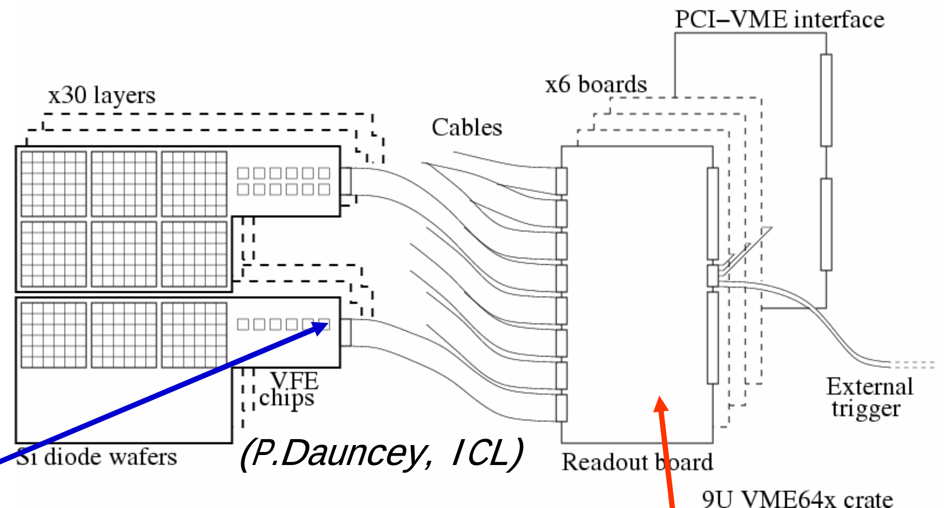






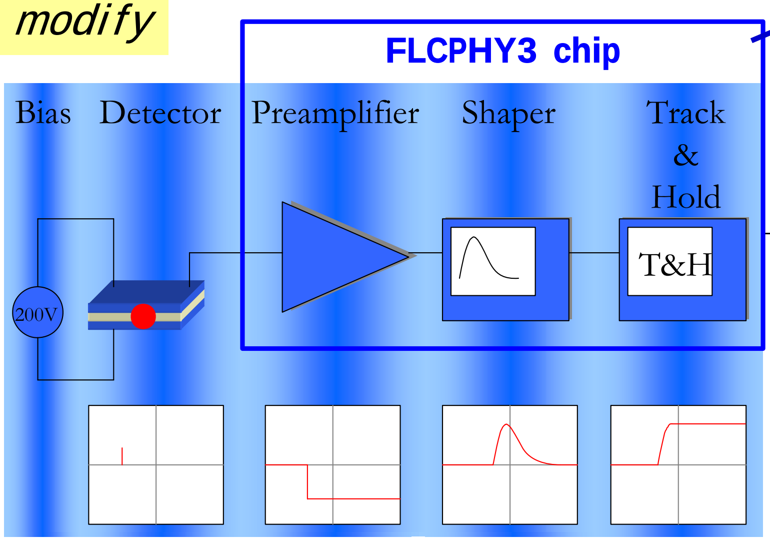
ECAL based electronics concept

- Similar number of analogue channels
- To eventually meet same rate and latency requirements



(P.Dauncey, ICL)

modify

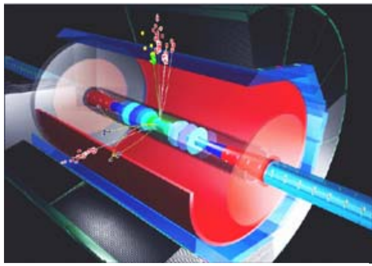


Ch. De la Taille, LAL

5 more

CERC (CALICE ECAL r/o card)

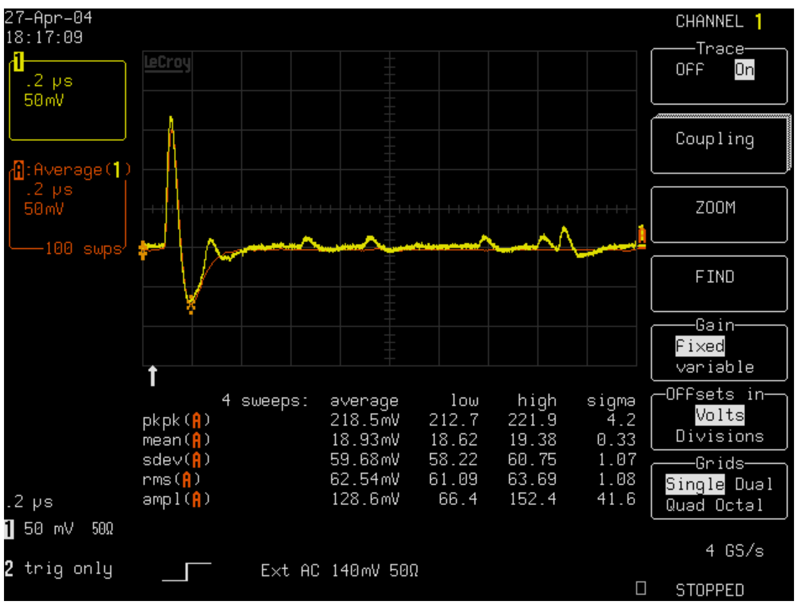
- 8x12 ADCs (16 bit)
- 8 MB memory (2k events)
- DAQ rate 1 kHz peak, 100Hz average
- 180 ns trigger latency

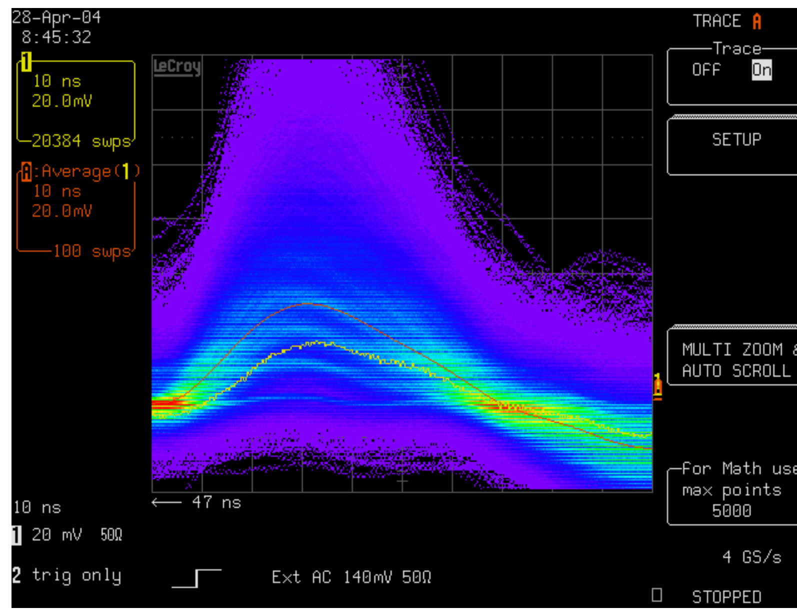


Slow and fast shaping

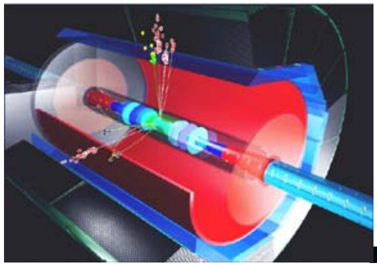
- With (slow) 180 ns shaping and single pixel noise rate of 2 MHz observation of single photon peaks hampered by pile-up
- Add fast shaping for calibration (no trigger latency required)

tests with SiPM minical cassette at LAL (during LCWS 04)

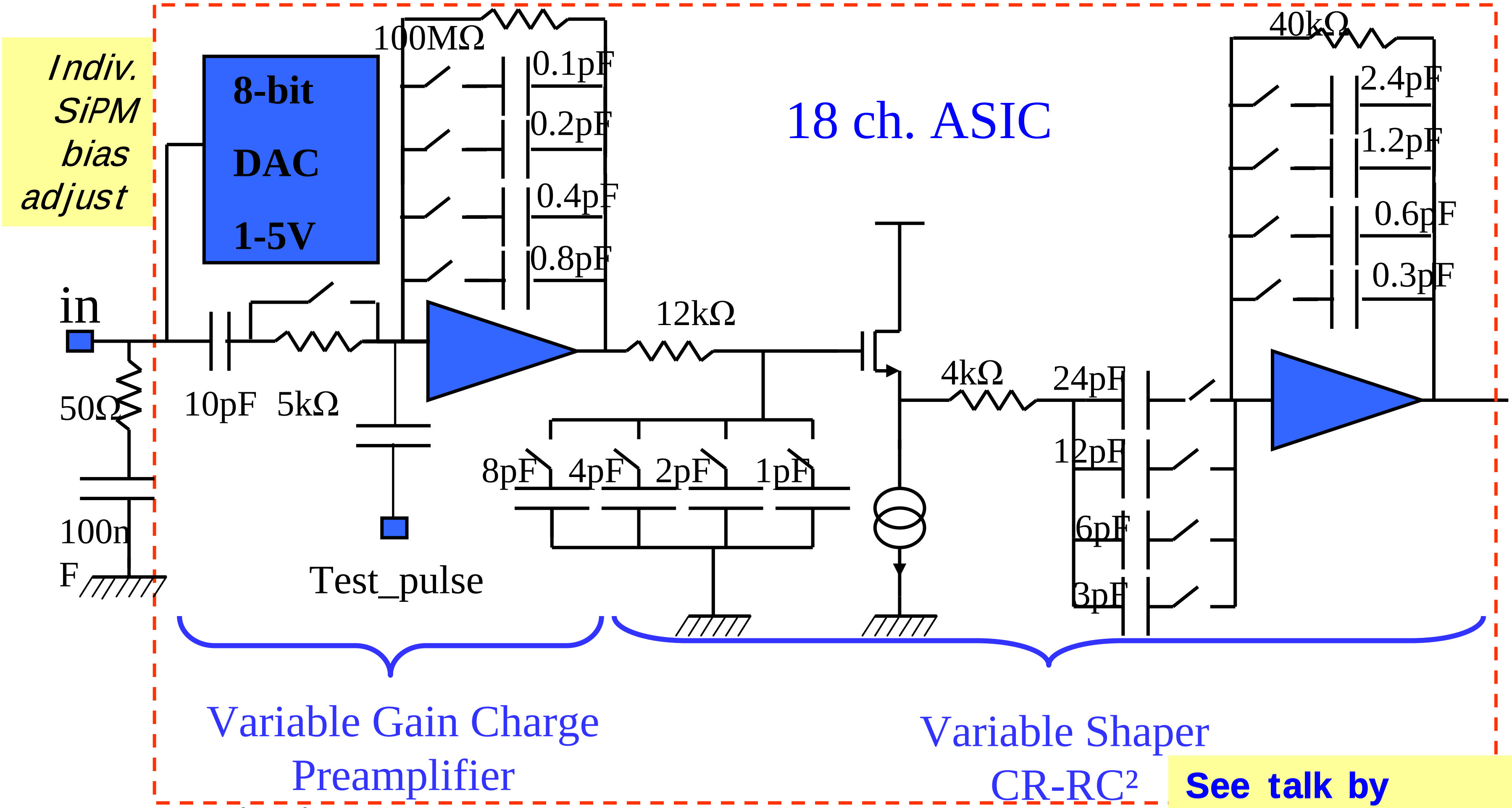




26ns peaking time

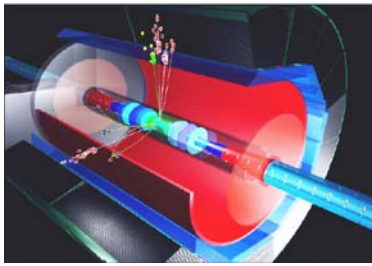


Front end chip ILC_SiPM

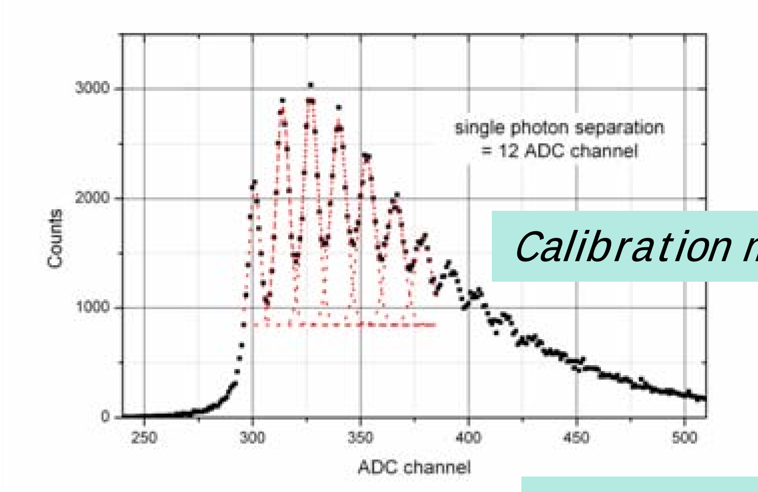


See talk by G.Martin-Chassard

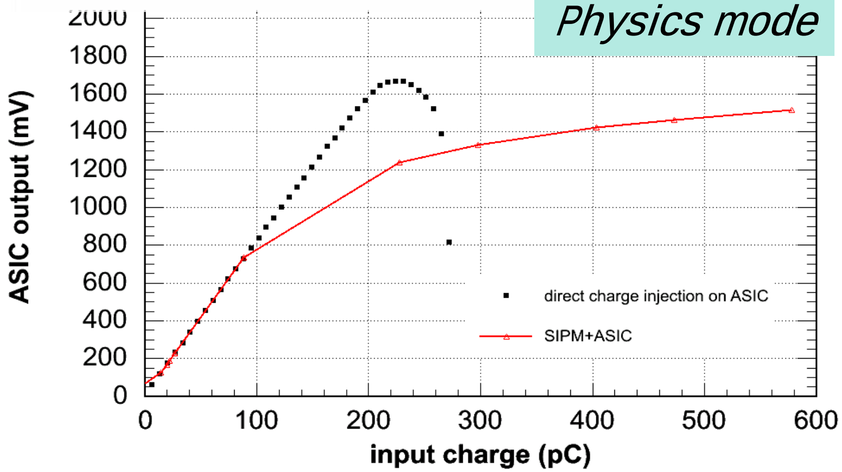
From L.Raux (LAL)



ASIC commissioning with SiPM



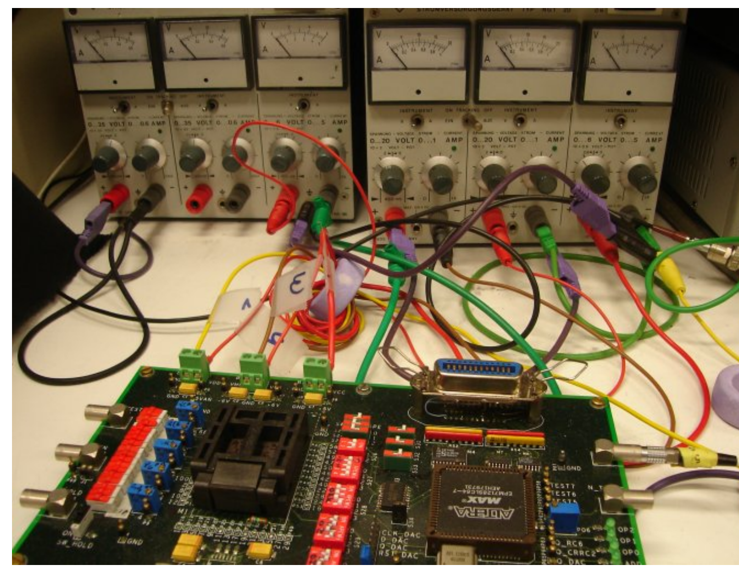
Calibration mode



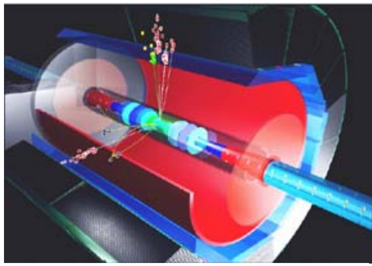
Physics mode

Input light (MIP units) → *~200*

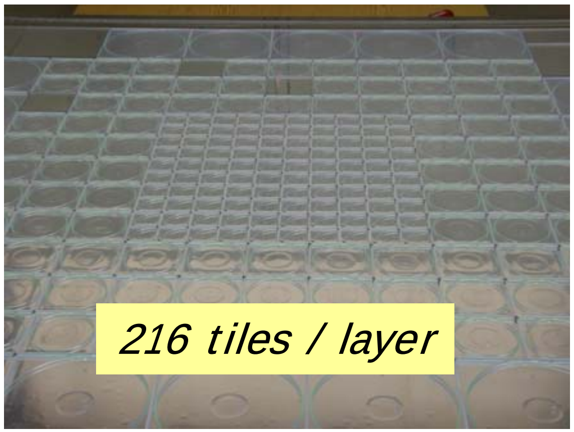
- Optimize readout chain
- Thanks to LAL: proliferation of test boards (and know-how)



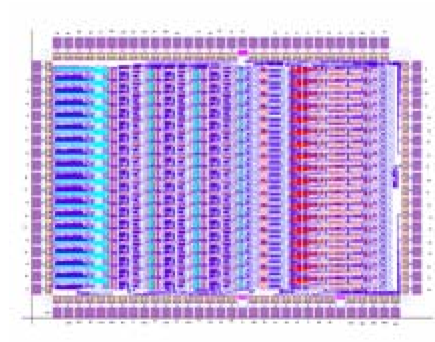
M.Groll (Hamburg), A.Karakash (MEPHI)

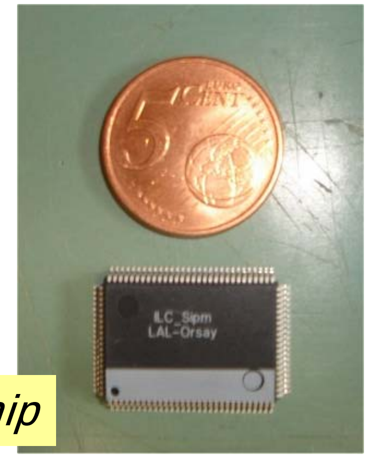


HCAL readout architecture



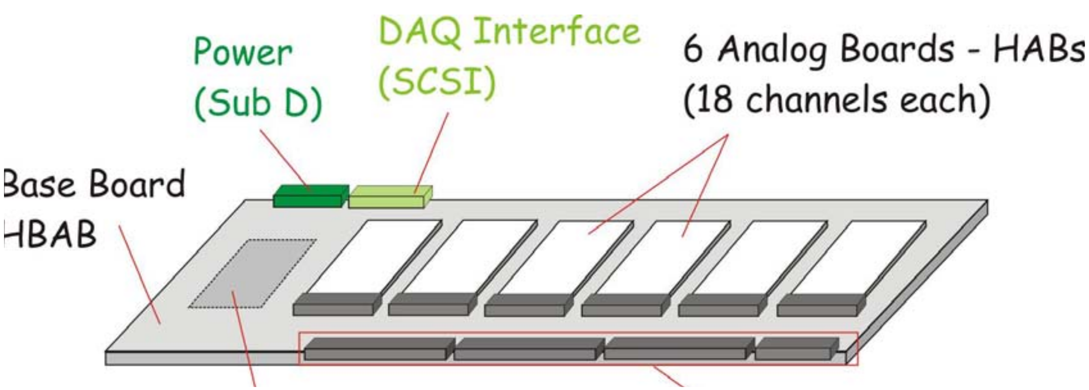
216 tiles / layer





18 analog channels / chip

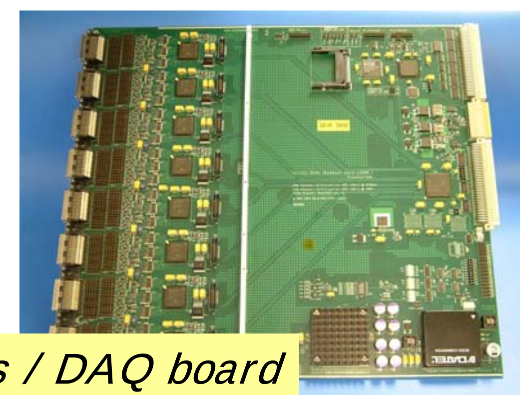
ILC_SiPM chip



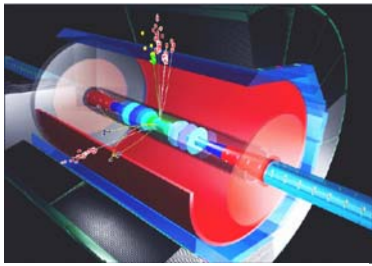
2 base boards (12 piggy backs) / layer

CRC

CALICE Readout Card



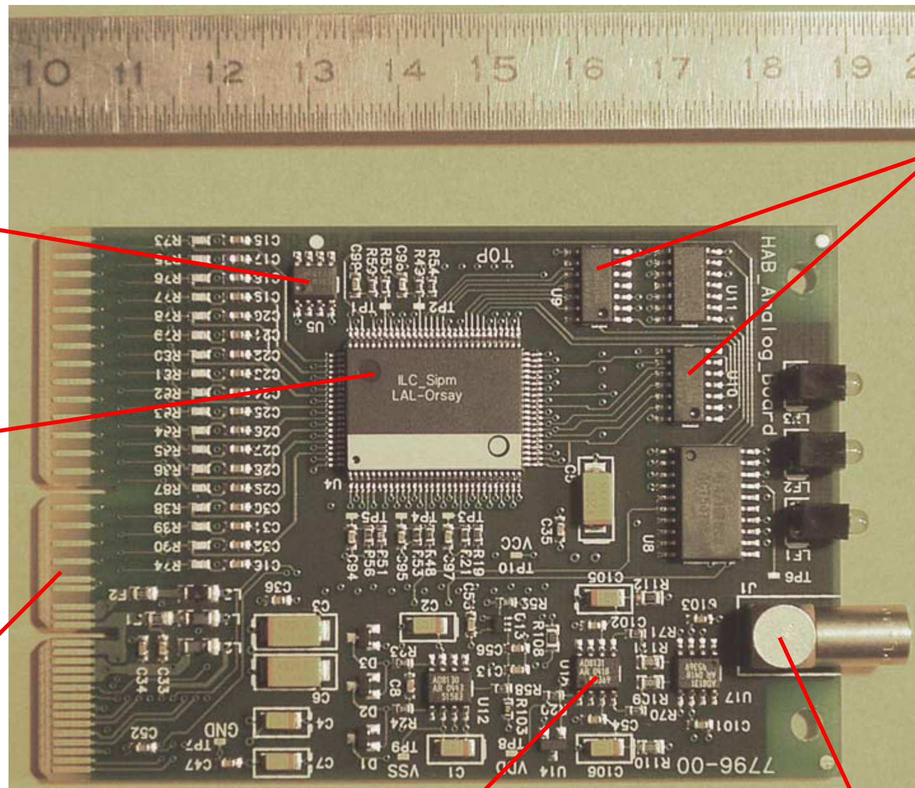
8 layers / DAQ board



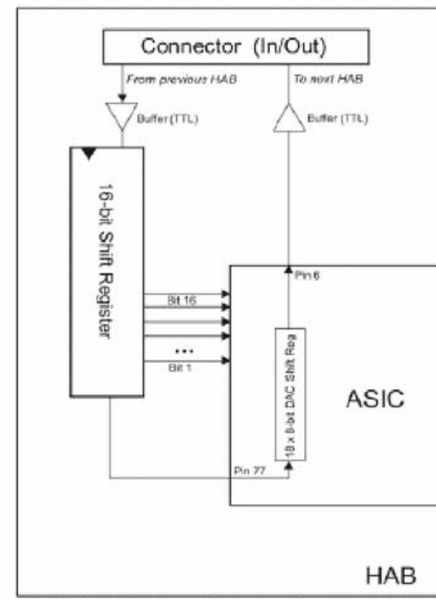
HAB (“piggy back”)

Temperature Monitor

ASIC



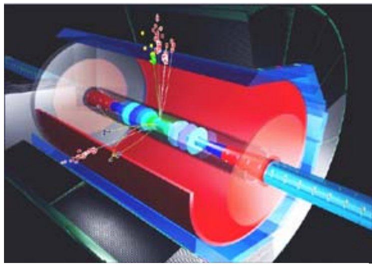
Parameter Shift-Reg



Analog Line Driver

Analog Test Output

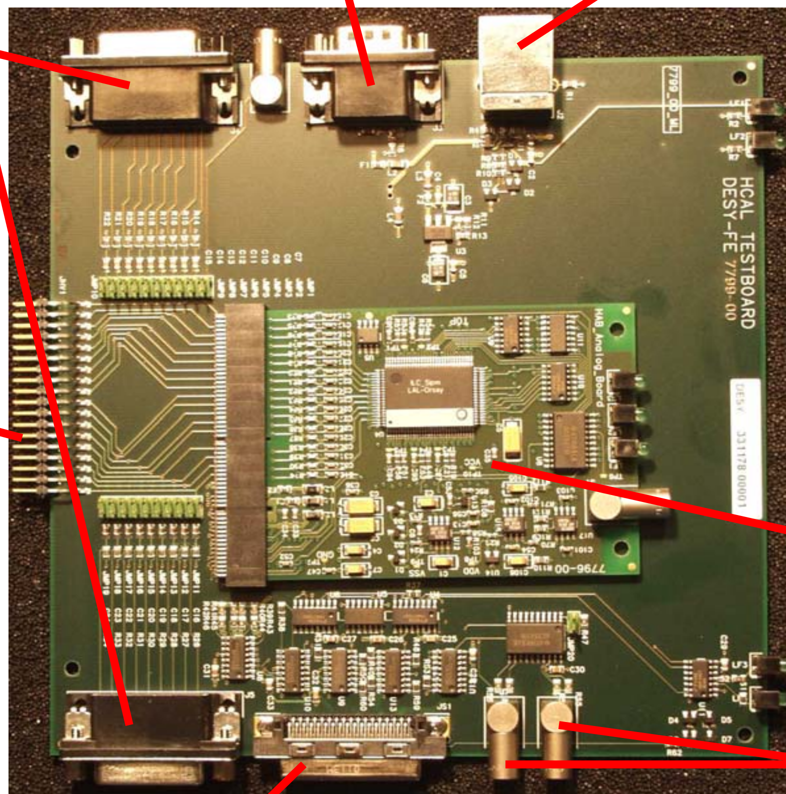
M.Reinecke (DESY)



Front end test board

Charge Injection

SiPM Interface, 18 chns.



Dimensions:

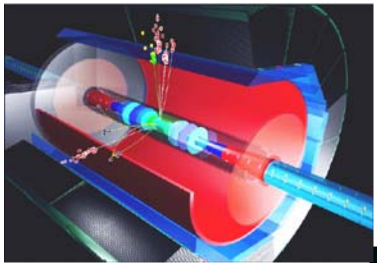
16 x 16 cm²

HAB

Test Outputs (SRIN, TCALIB)

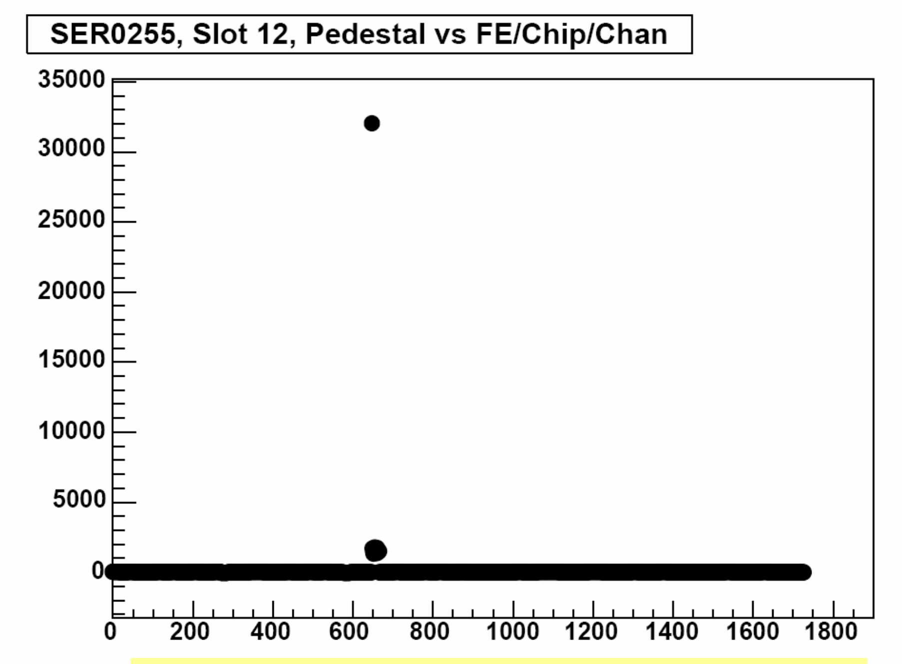
DAQ Interface

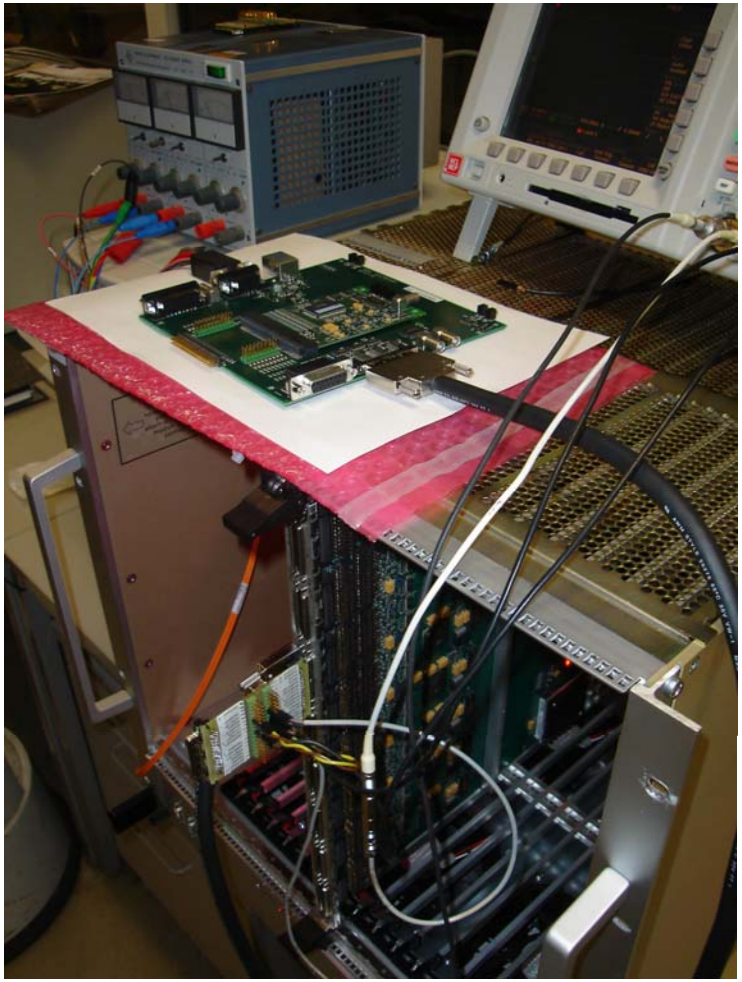
M.Reinecke (DESY)



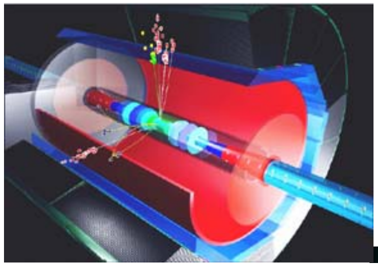
ASIC commissioning with DAQ

- Connected to CRC
- Load shift registers
- Test using charge injection



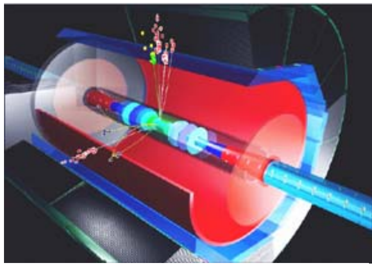


Now developing software tools



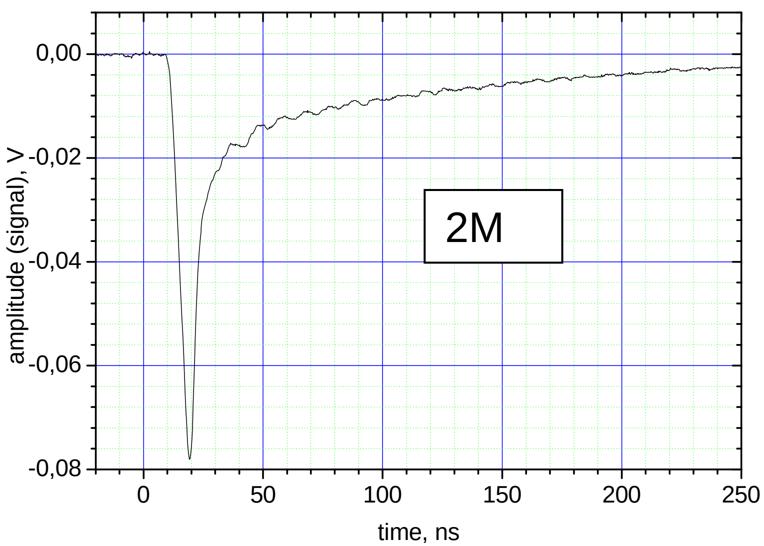
Readout electronics

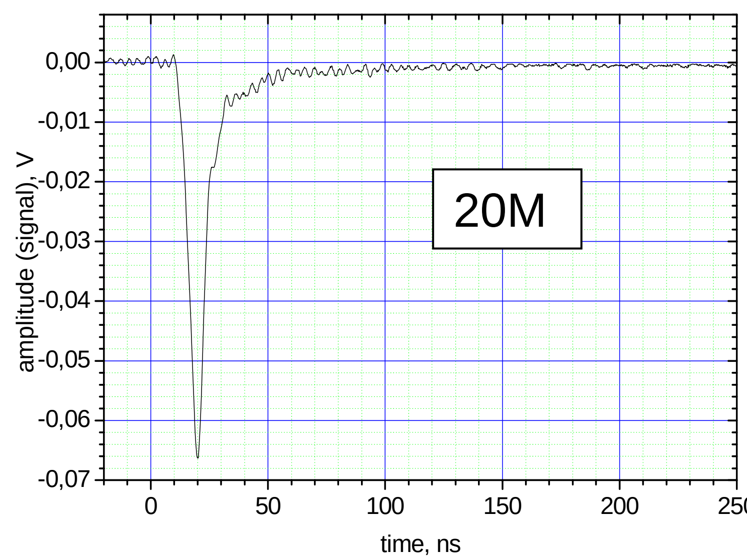
- Unified ECAL and HCAL readout concept developed
- Sample and hold type solution for SiPMs found
- 18 ch ASIC developed and mass-produced in less than 1 year
- Commissioning of readout boards ongoing, in parallel with detector construction. (Base boards not yet tested.)
- Same system to be used for tail catcher / muon tracker



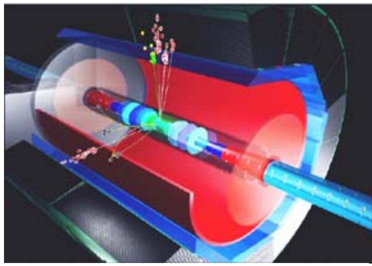
SiPM optimization

- Quenching resistor larger than in minical SiPMs
- Advantages:
  - Better pixel uniformity, gain stability
  - Reduced sensitivity to shape of calibration light pulse
  - Safer production process





E.Popova, MEPHI



SiPM ageing studies

- Tested 20 SiPMs for 1500 hours
- 5 SiPMs up to 90ºC
- No parameter changes observed
- More studies with higher statistics needed – and underway
- Be the first to know…

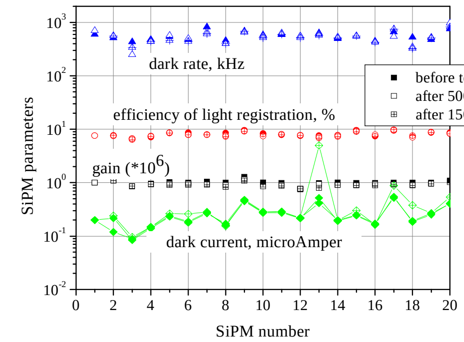


Fig14

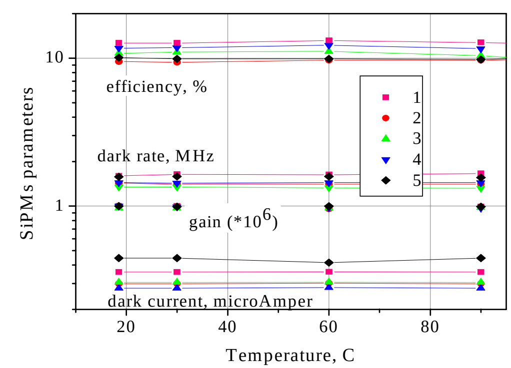
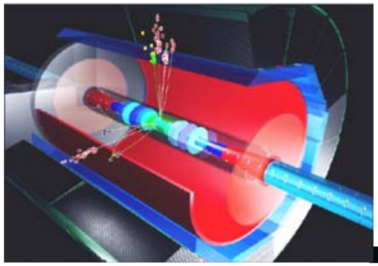


Fig15

E.Popova, MEPHI

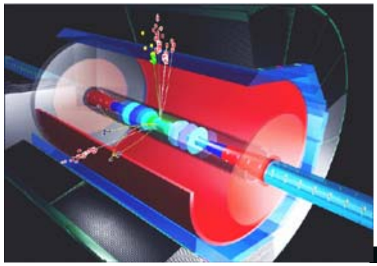


SiPM production

- Still a pioneer endeavor (MEPhI, PULSAR)

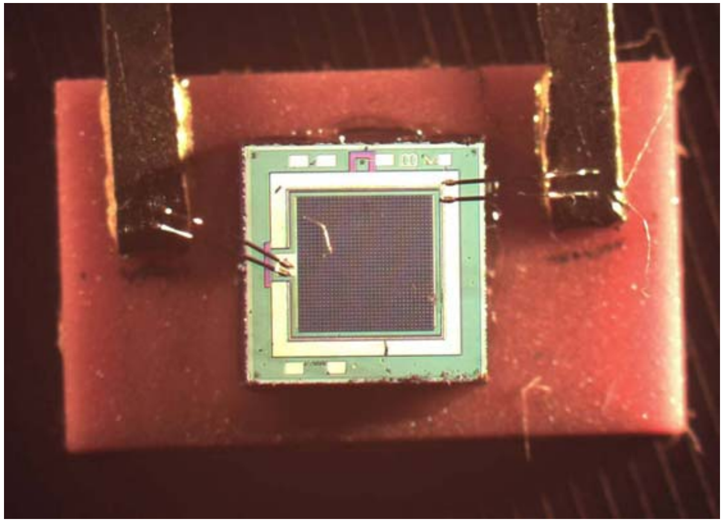
	Date	SiPMs on wafer total amout	Delivered to ITEP
1) Test batch with different resistivity of a quenching SiPM pixels resistors (from 2M to 20M)	May 2004	3000	840
2)Main batch	Yuly 2004	15000	No delivering - bad wafer quality
3) Repeated main batch resistivity	February 2005	10000	Under semiautomatic probe selection

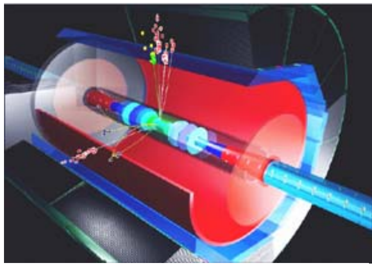
Latest news from Moscow: seems OK



SiPM tests, mounting

- Two-stage test procedure:
  - On wafer, probe station at MEPHI, fast
  - On mounting plate; test bench at ITEP
- First half ready in May
- Some difficulties with support plate, under improvement
- Biggest unknown: yield of main batch; may need another cycle

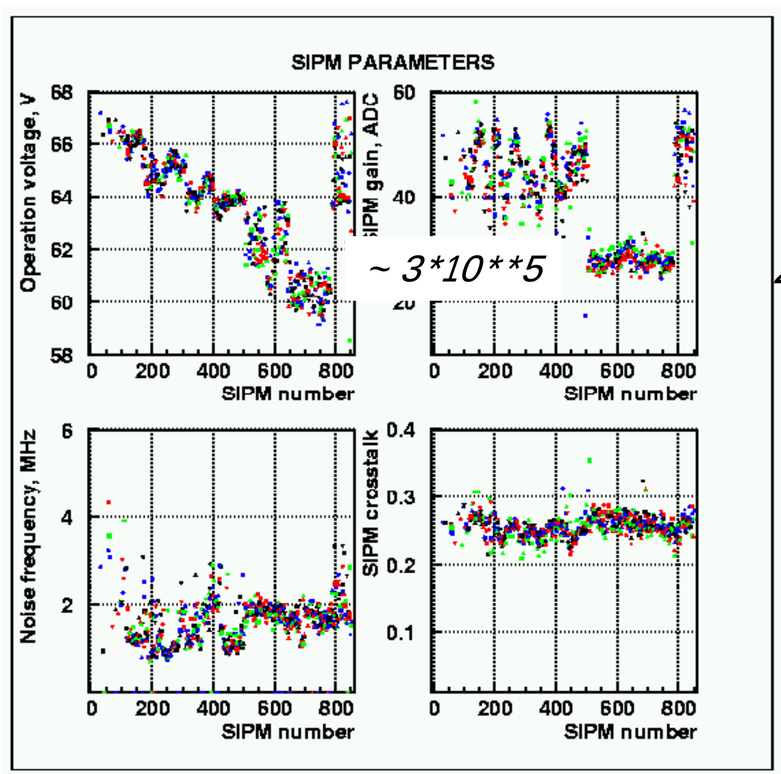




SiPM tests – stage 2

- Semi-automatic test bench: equalize light yield
- Measure "all" parameters and select

Pilot batch

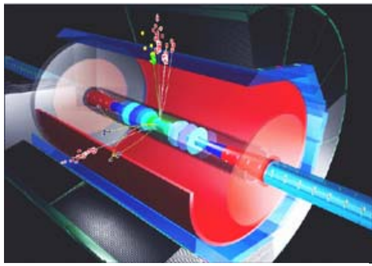


2M

20M

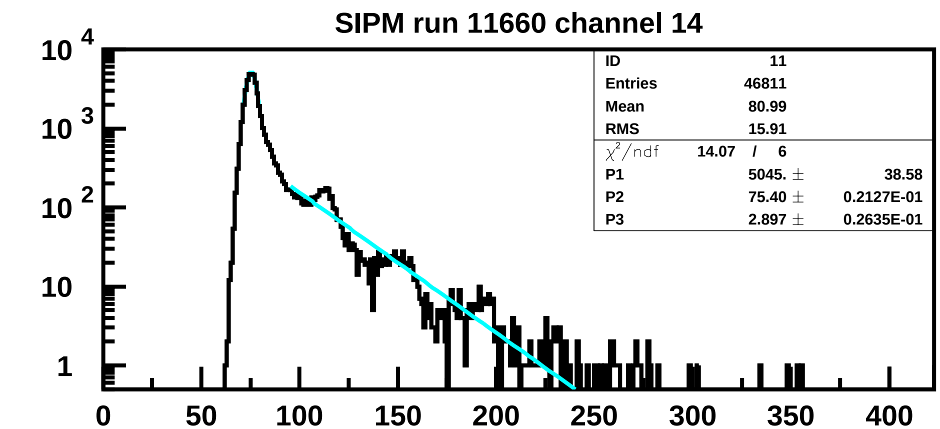
E.Tarkovsky, ITEP

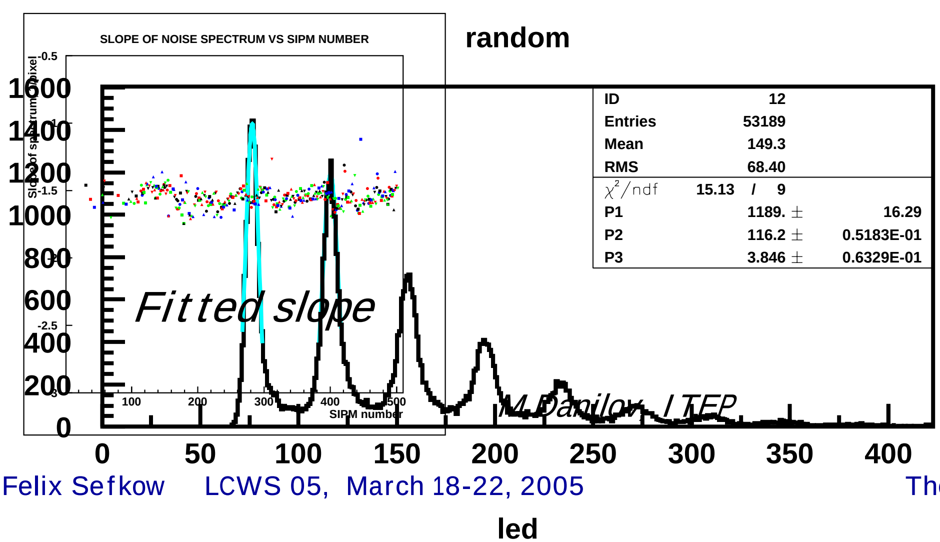
obtained	**840**
tested	**830**
good	**712** *85%*
bad	**118**
a) high noise	90
b) low gain (no signal)	7
c) single p.e. peak width	21
broken	**10**

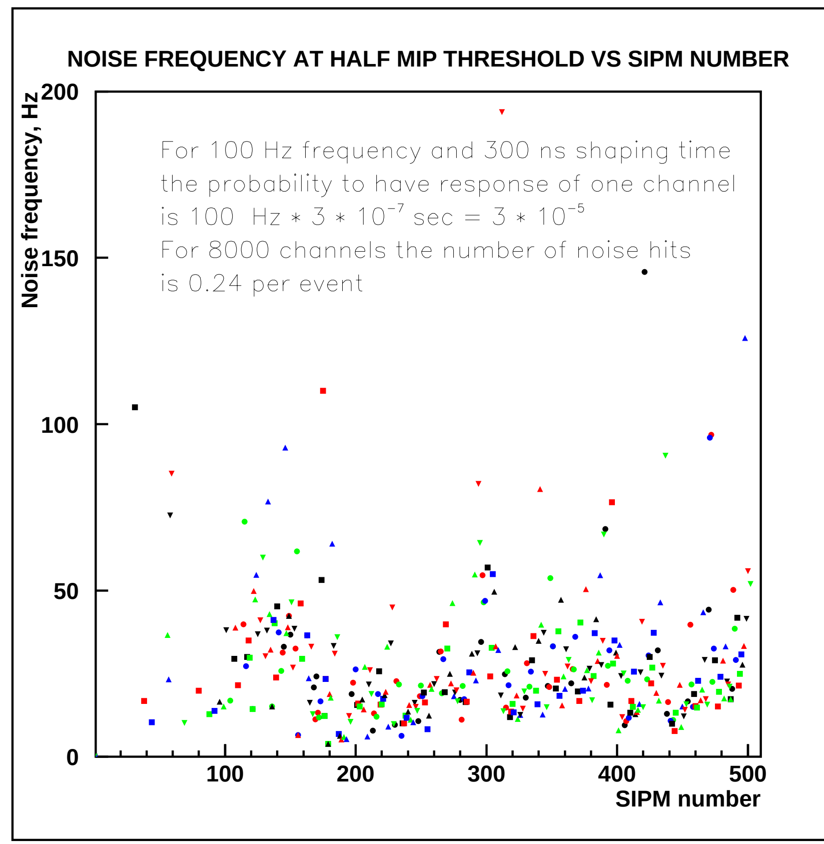


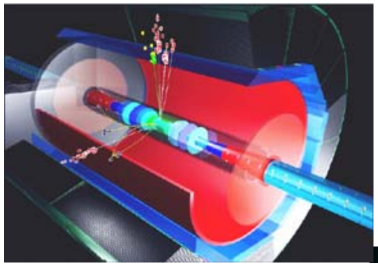
SiPM noise

- Noise drops like exp $(-1.5*N_{px})$



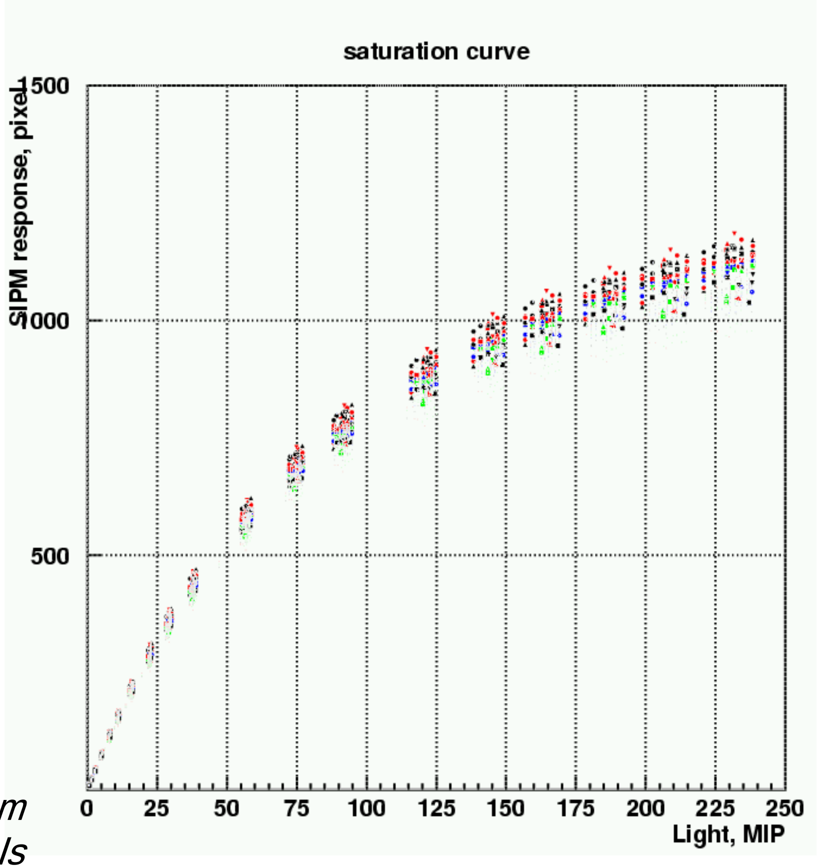






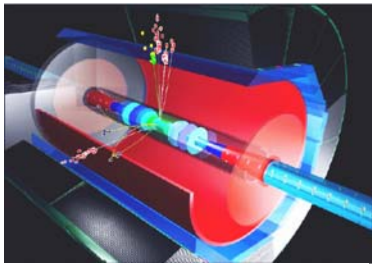
SiPM parameters

- Adjust bias voltage to 15 px/MIP
- SiPM parameters:
  - gain
  - noise frequency at zero pixel and at ½ MIP levels
  - cross talk
  - Efficiency
  - width of single p.e. peak
  - dark current
  - saturation curve
  - SiPM temperature during test
- To data base



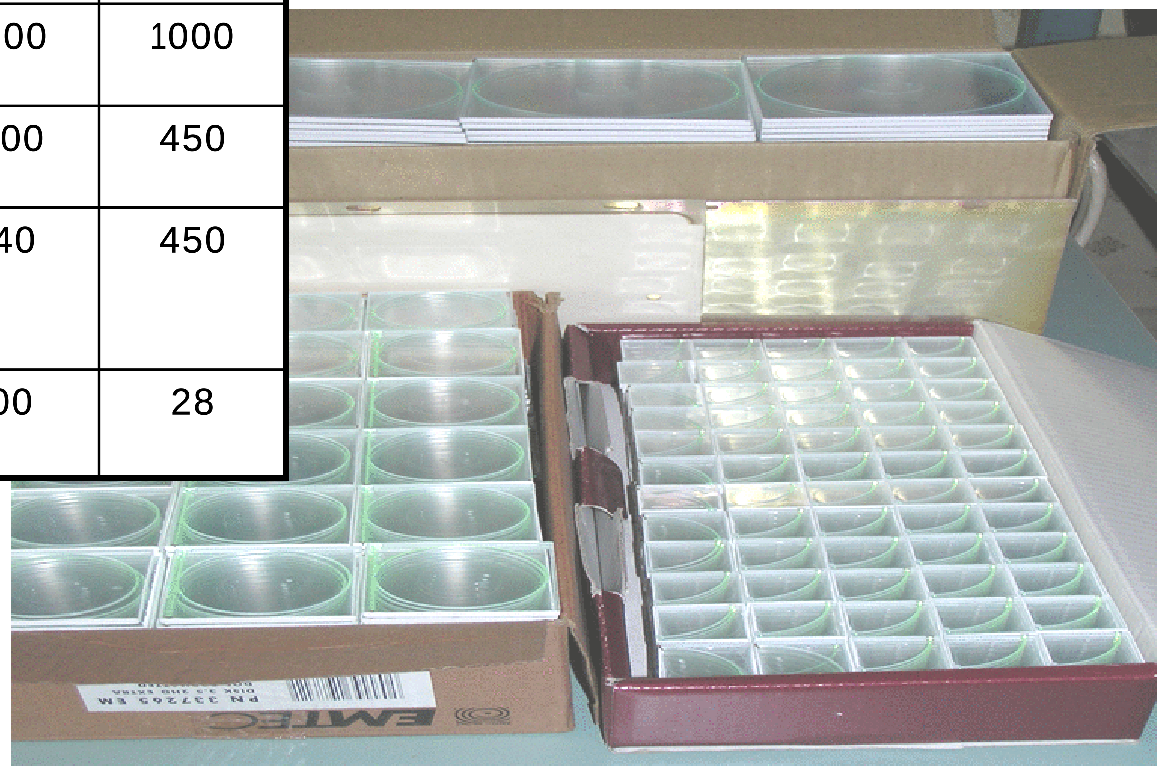
Differences mostly from different test bench channels (colors/markers)

E.Tarkovsky, ITEP

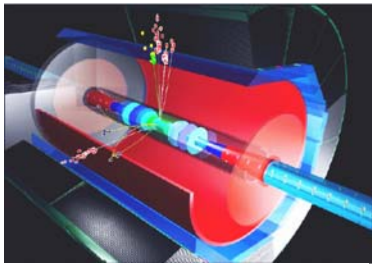


Scintillator tile production

	3x3 cm^2	6x6 cm^2	12x12 cm^2
to be produced	3500	3500	1000
mold	3500	3500	1000
edge mated	1500	1500	450
groove milled and fiber installed	850	840	450
shipped to DESY	100	100	28

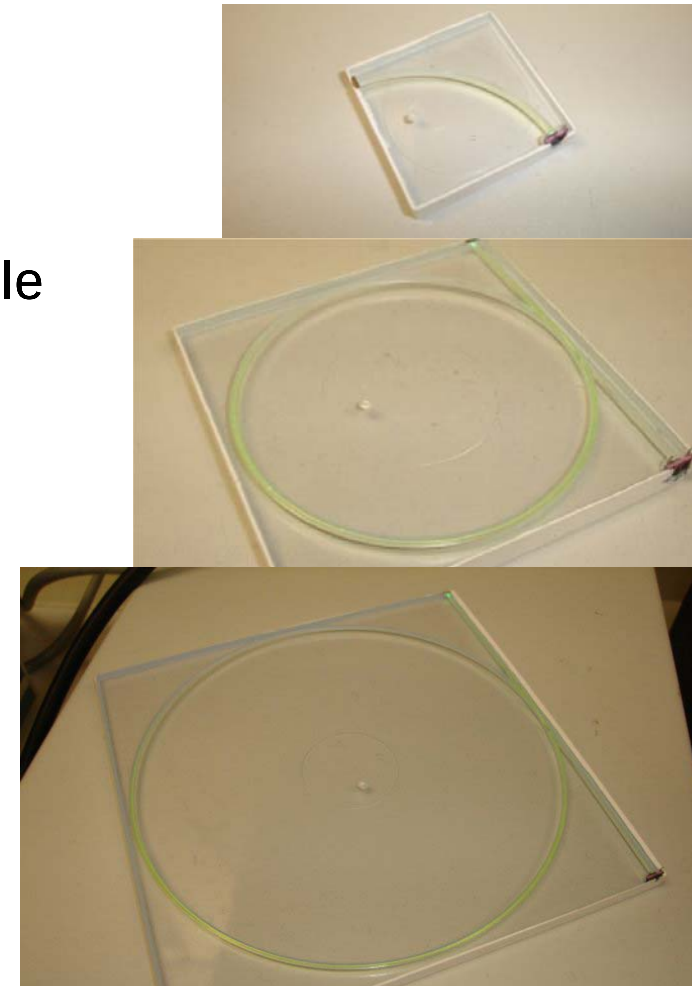


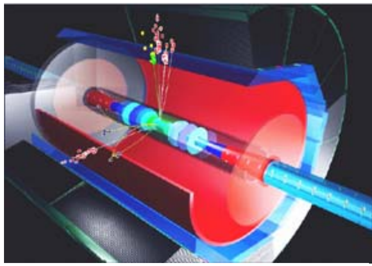
Bending loops for 60mm tiles is most time consuming step



Instrumented tiles

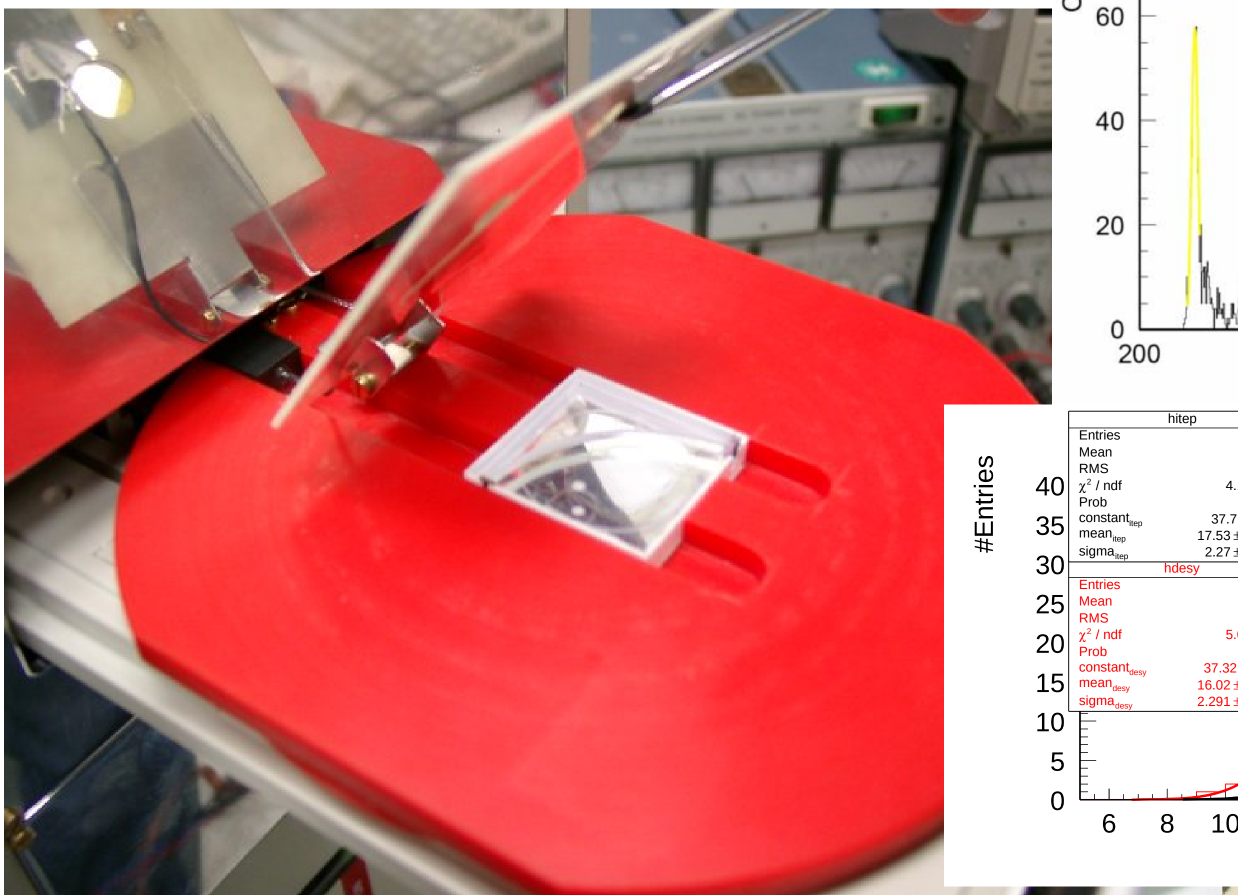
- Scintillator production well advanced
- Semi-automatic test bench for SiPM tile system almost ready
  - Measure light yield in px/MIP
- Ready for mass production of SiPM tile systems with data sheet
- Tiles for cassette no. 2 shipped this week

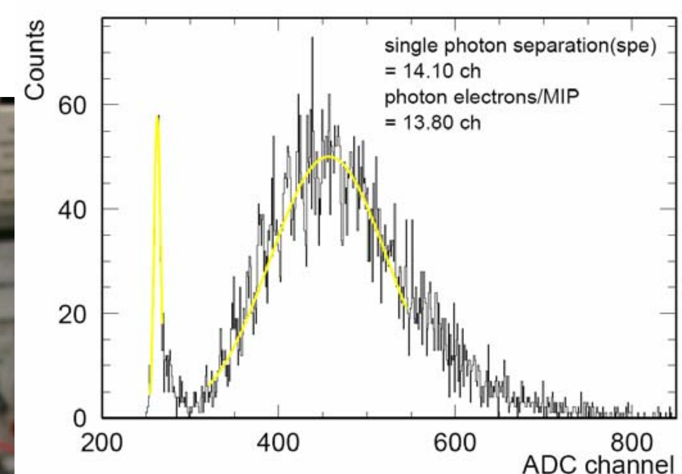


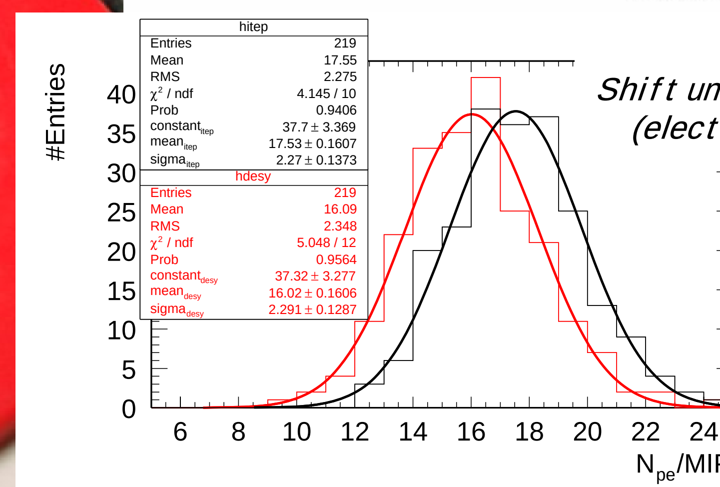


Tile tests at DESY

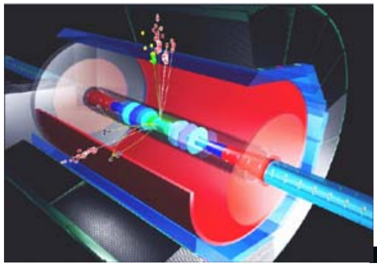
- Check after transport



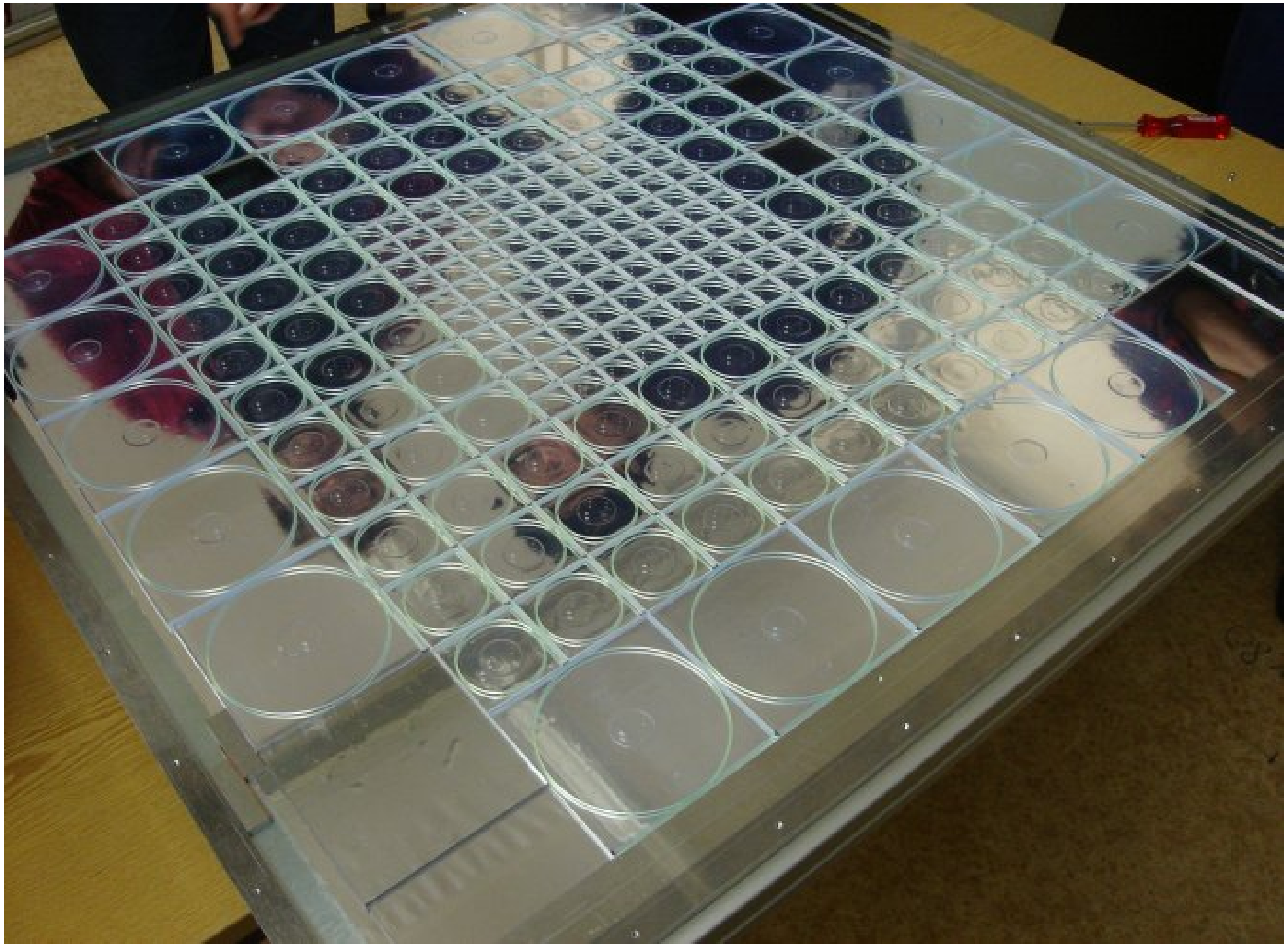


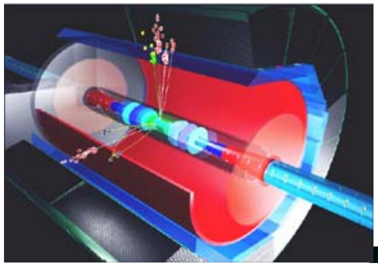


Shift understood (electronics)



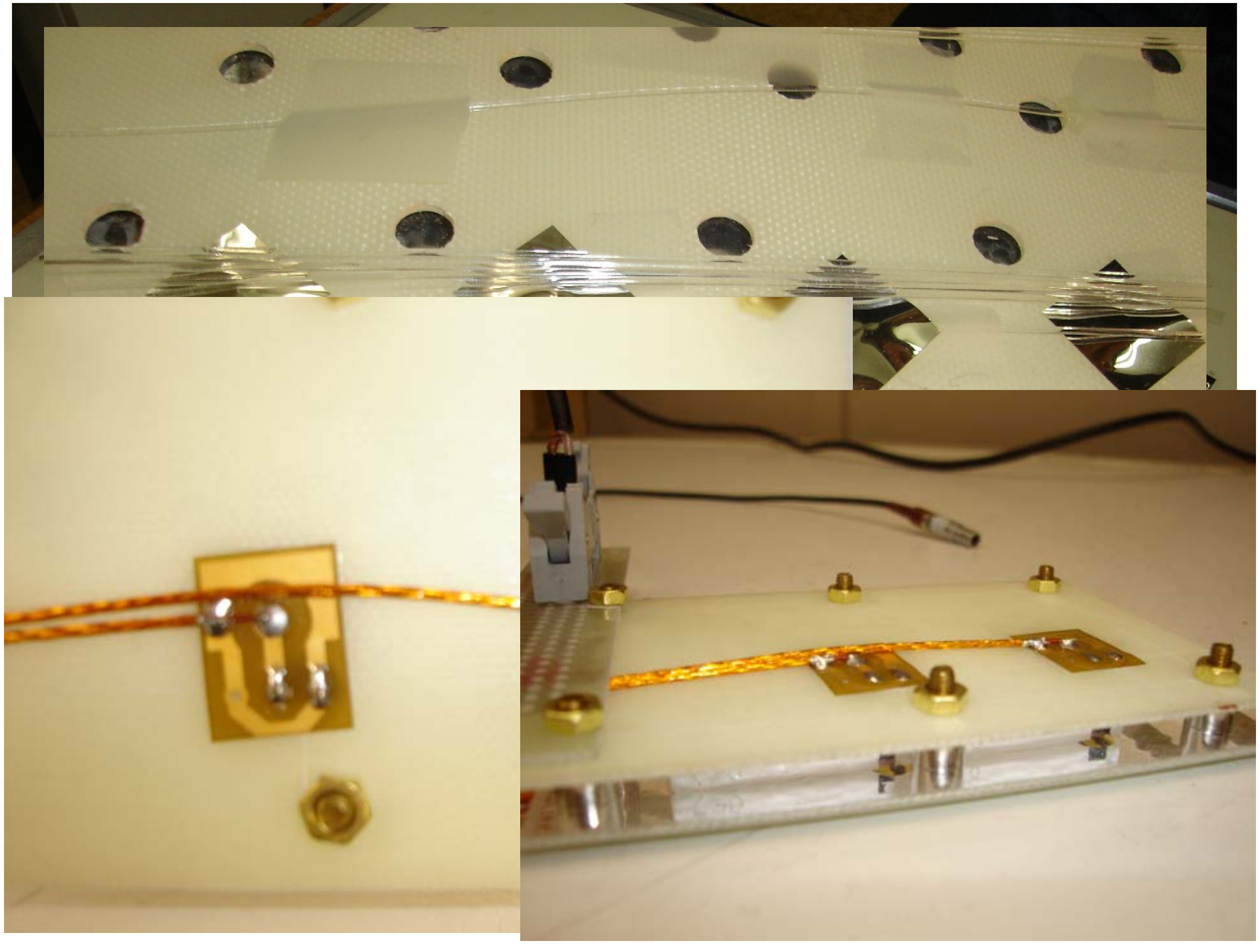
Cassette assembly

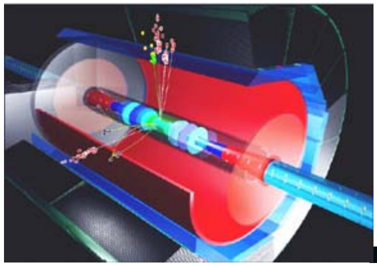




Next steps: fibers and wires

- Measure SiPM positions
- Drill FR4 board, check
- Fiber routing, test
- Done
- Glue flex prints
- Solder cables
- Test
- Number One ready in April

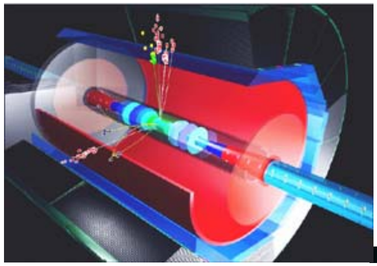




Outlook

Still considerable risks and unknowns. – Yet, if all goes well:

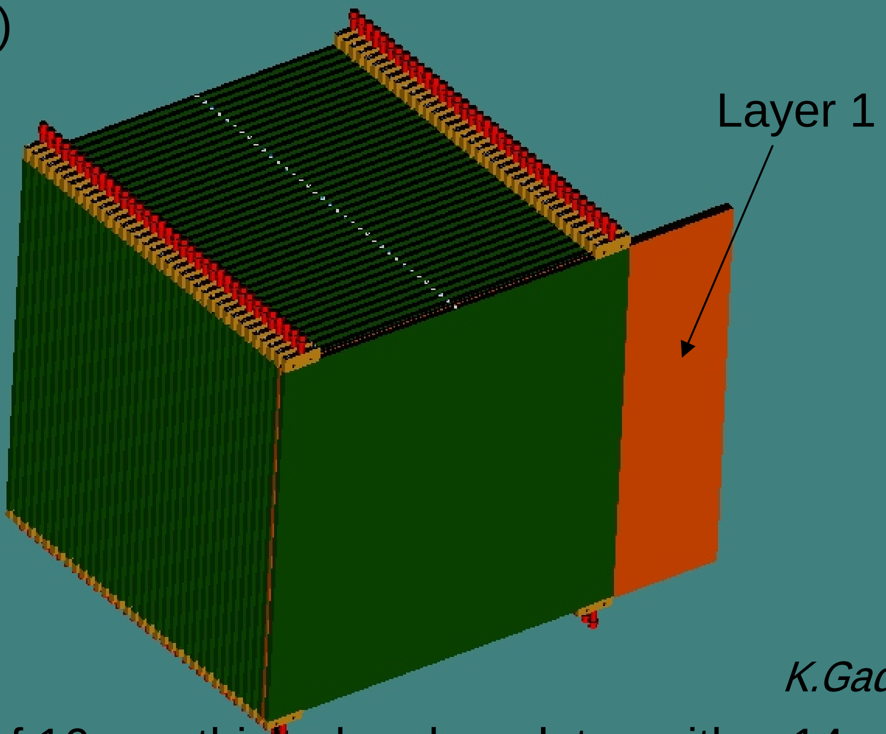
- Establish electronics chain — Spring
- Beam test cassette Number One — Summer
  - With ECAL at DESY
- Several (few...many) cassettes with final electronics and monitoring system — Fall
- Movable stage built & fully cabled up — Winter
- Hadron beam — Spring



HCAL stack

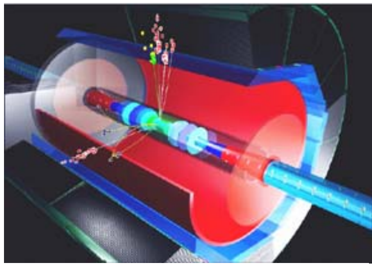
(*CMB not shown*)

Adjustable gaps
Should also hold
gasous DHCAIL

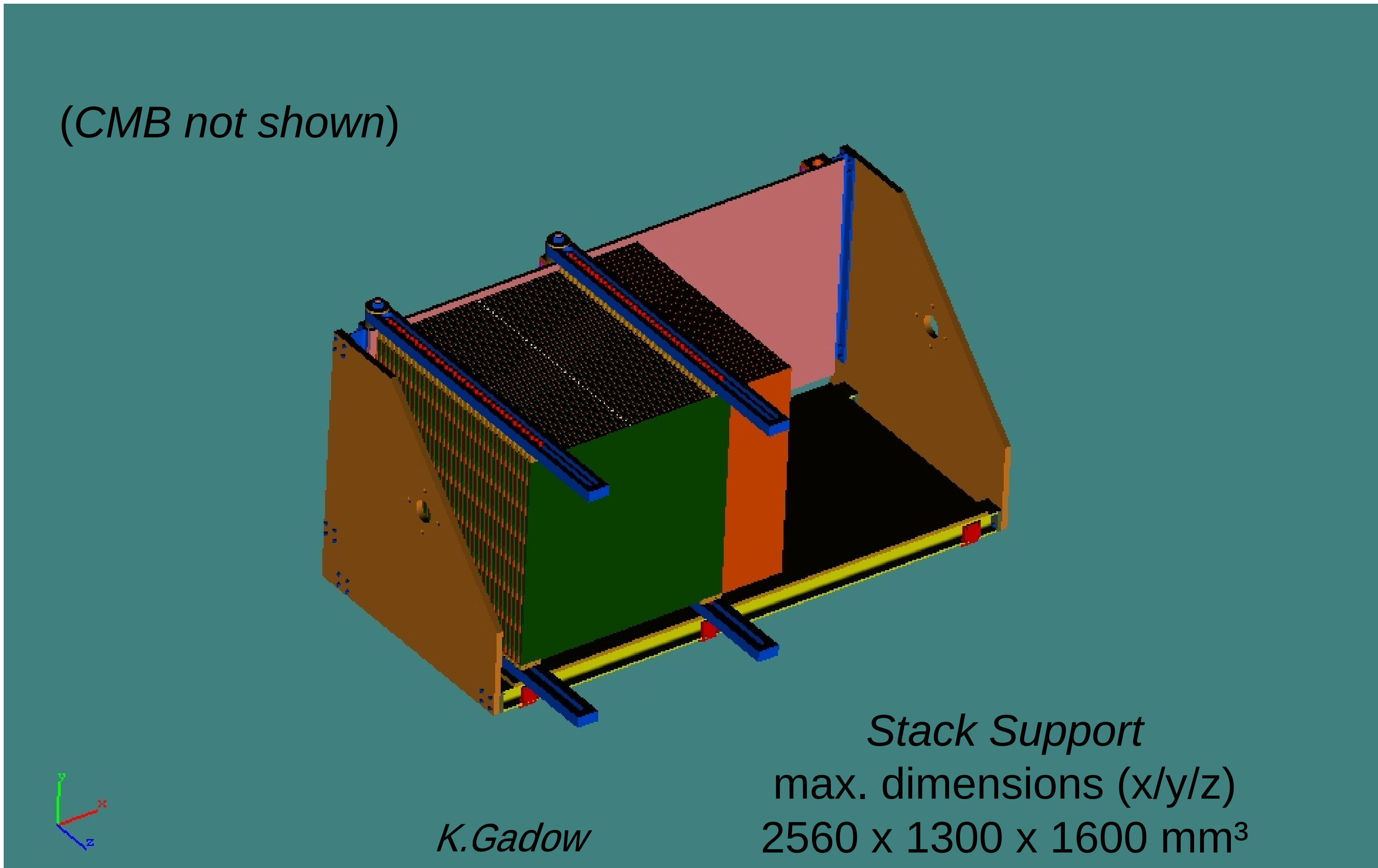


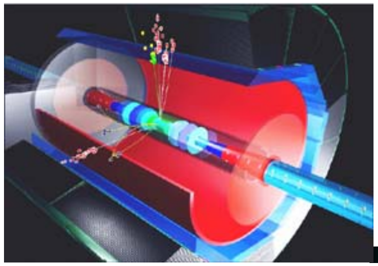
K.Gadow, DESY

38 pieces of 16 mm thick absorber plates with a 14 mm gap between the plates forms the *Absorber Stack*

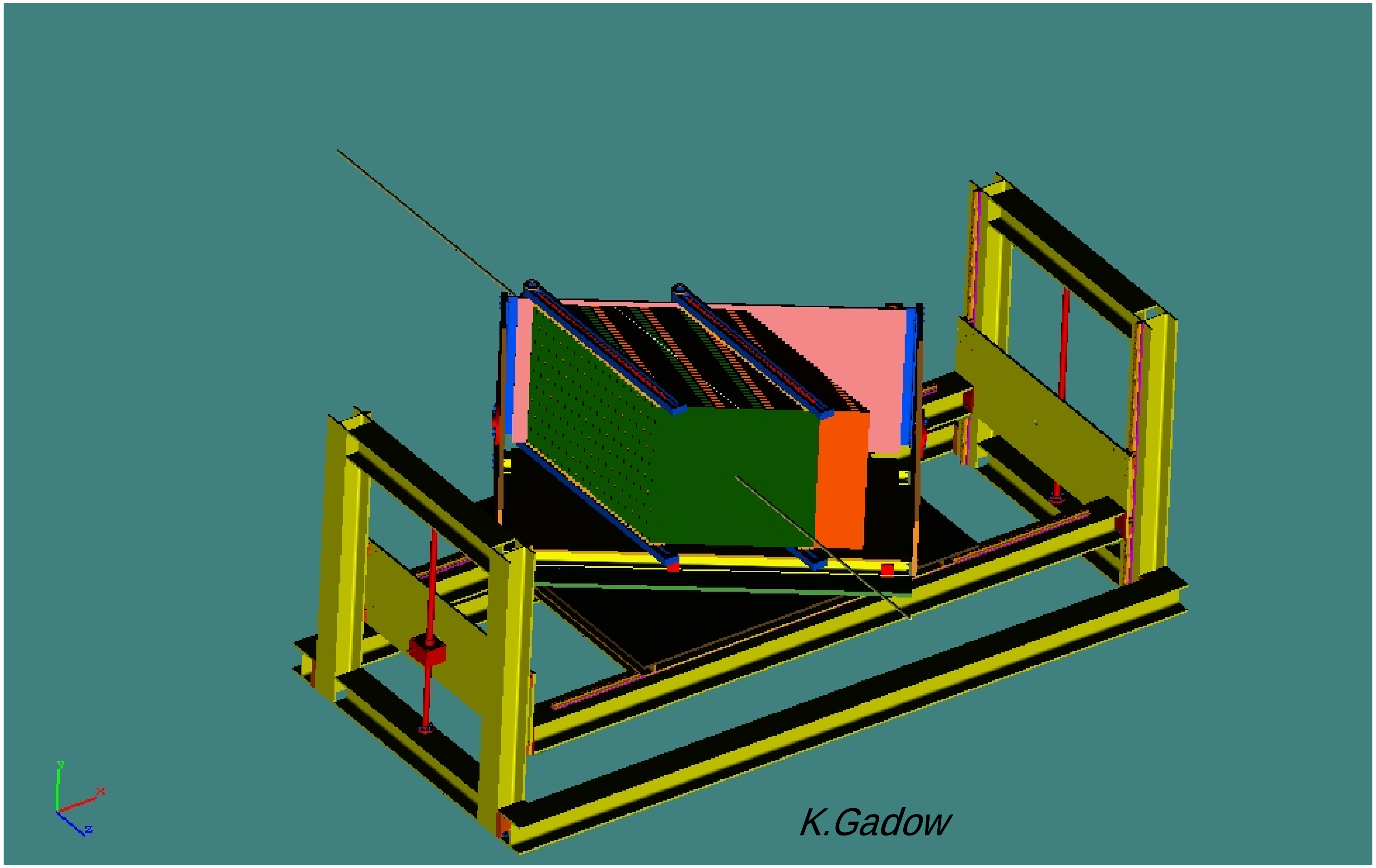


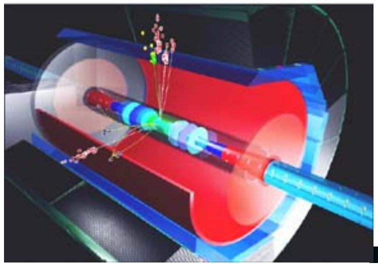
Stack support



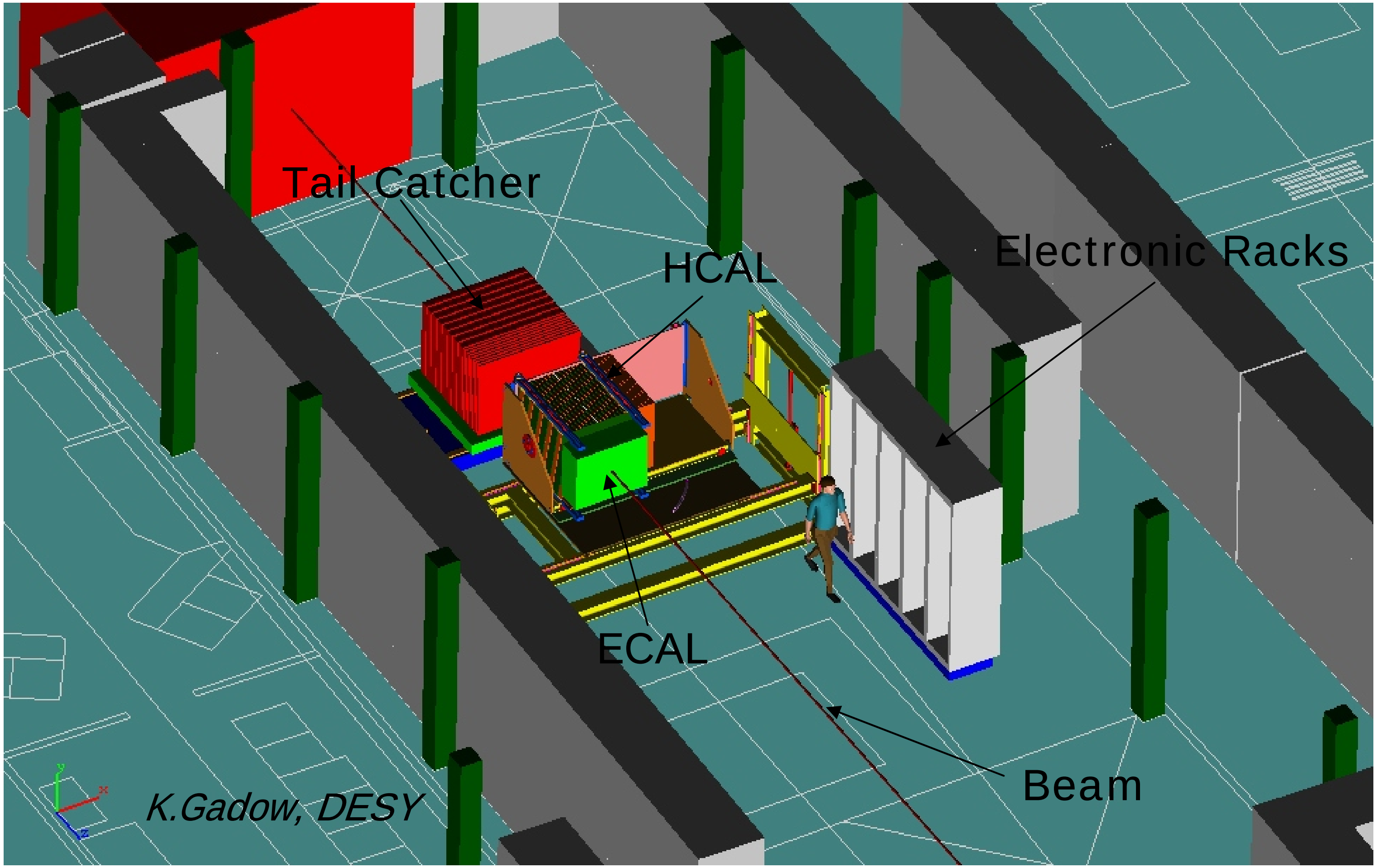


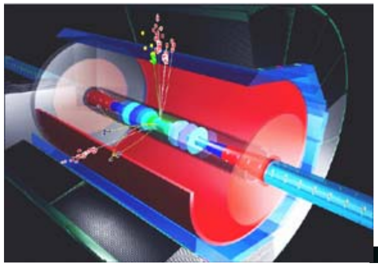
Movable table





Testbeam set-up





No conclusion

... as we are in full swing

We are serious about testbeam.