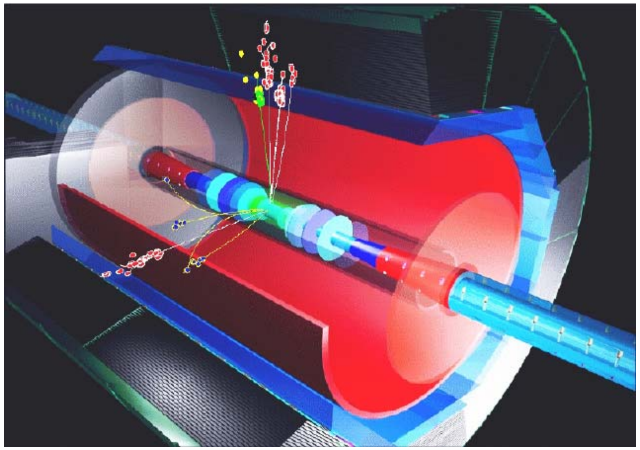
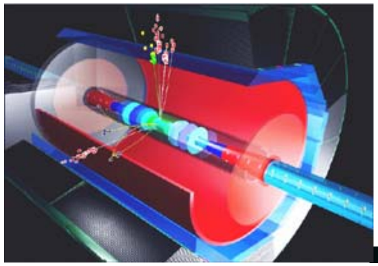


SiPM readout – experience and prospects

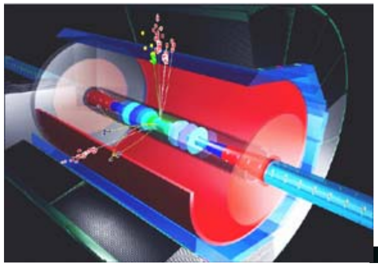
Felix Sefkow
DESY
CALICE collaboration

ALCPG workshop at Snowmass
August 23, 2005



This talk

- SiPM mass production and tests
- Experience with multi-channel readout
- Future directions

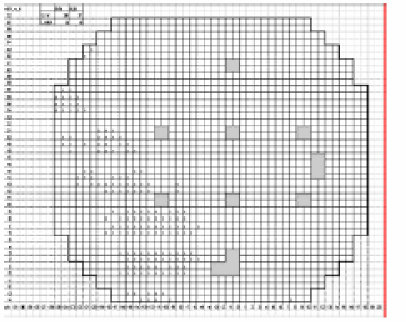


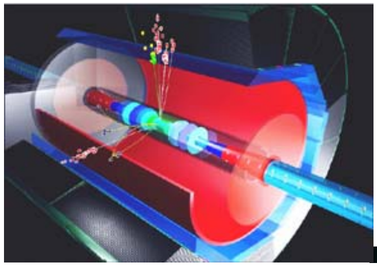
SiPM 1st selection stage

- At the producer (PULSAR, Moscow)
- Uncut wafer on probe station
- Test response to light (given signal amplitude) with not too high noise
- Up to 1000 / day

START
file 481_4_14.def
time is: 15:57; data: 26.4.2005;
type: B
DATA

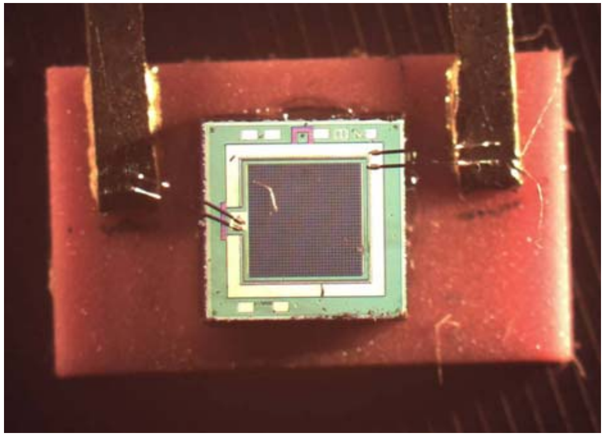
x	y	U(V)	I(mkA)	comment
-17	-4	23.4071	44.1610	bad
-16	-4	23.4213	44.1637	bad
-15	-4	39.3215	1.2410	work
-14	-4	40.4247	1.2902	work
-13	-4	35.7515	32.8656	bad
-12	-4	40.7056	1.3321	work
-11	-4	41.0897	1.4401	work
-10	-4	40.8400	1.7106	work
-9	-4	41.3195	1.1611	work
-8	-4	41.2988	1.1396	work
-7	-4	41.6149	1.2387	work
-6	-4	41.7435	1.0789	work
-5	-4	41.3084	1.1884	work
-4	-4	41.9314	1.2043	work
-3	-4	41.7322	1.1388	work
-2	-4	37.8563	20.2680	discharges
-1	-4	42.2476	1.0396	work
0	-4	42.2311	2.6090	work

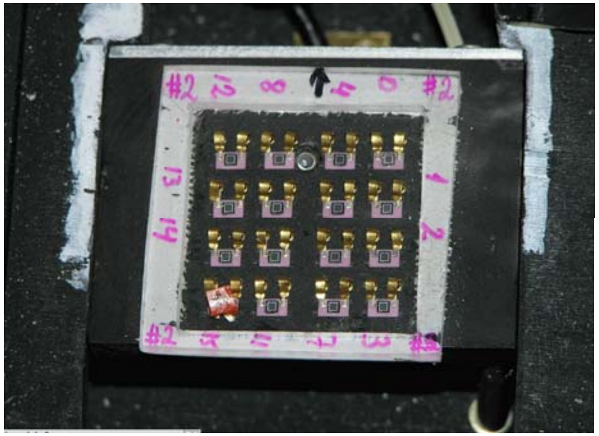


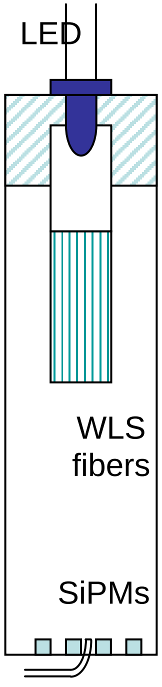


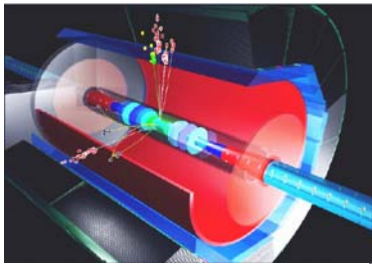
2nd stage: test bench

- After assembly on precision mounting plate
- Semi-automatic set-up at ITEP
- 15 SiPMs under monitored light source (calibrated with reference tile: "MIP")
- Adjust working point (HV) to 15 px / "MIP"
  - Compromise between MIP efficiency and dynamic range
- Up to 500 / week



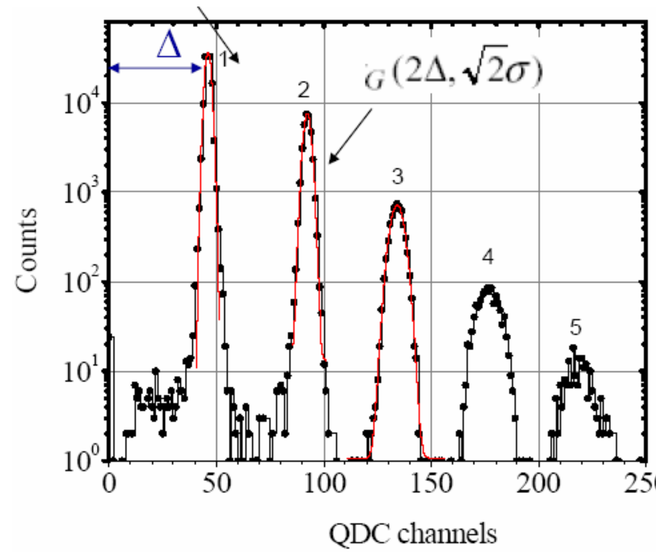






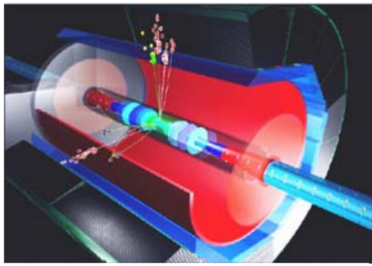
SiPM selection

- Automatic fitting procedure
- Selection criteria at W.P.
  - Ped RMS < 50 ADC channels
  - Gain > 4*105 or 1 pixel > 26 ADC ch., corresponds to 1 pC/MIP
  - Cross talk < 0.35
  - At HV adjusted |Npix/MIP – 15| < 0.75
  - Noise frequency at zero threshold < 2.5 MHz
  - Noise frequency at ½ MIP threshold < 500 Hz
  - Single photoelectron peak width to gain ratio < 0.20
  - Mean value of SiPM current < 2 μA
  - RMS of SiPM current during test < 20 nA
  - Number of pixels at maximal light (~200 MIP) > 900



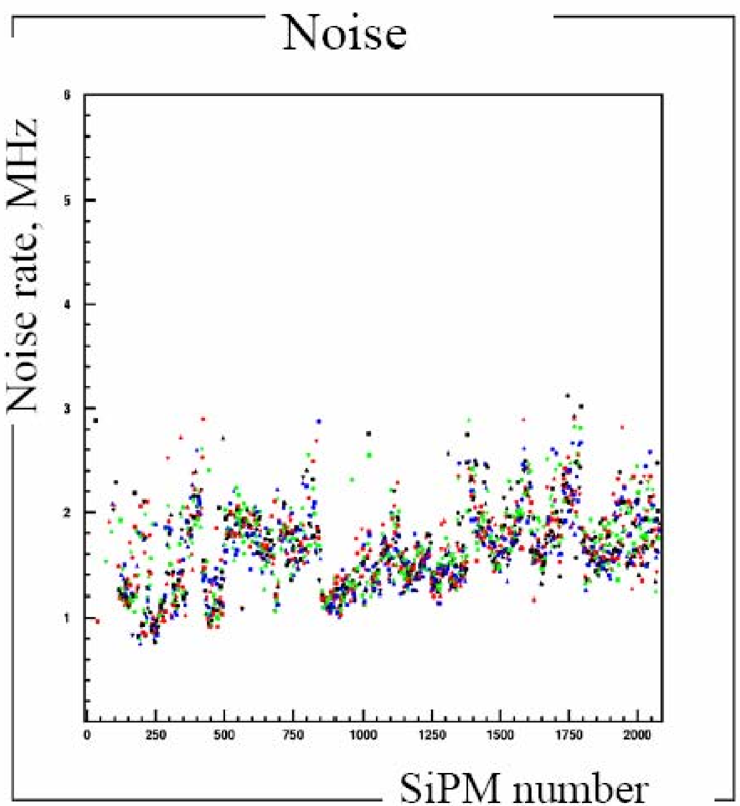
E.Tarkovsky

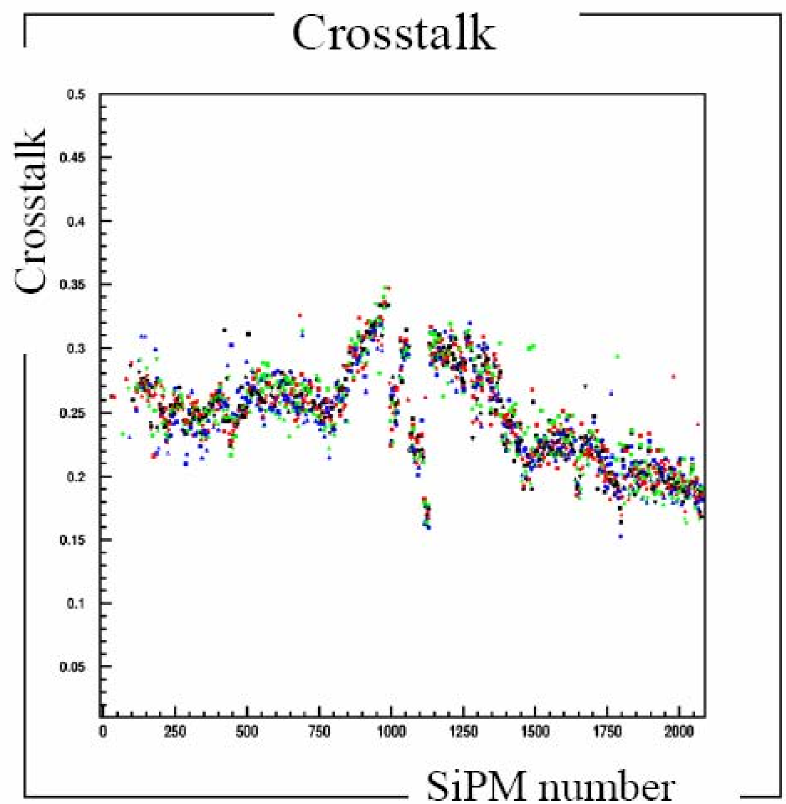
Yield: 80%



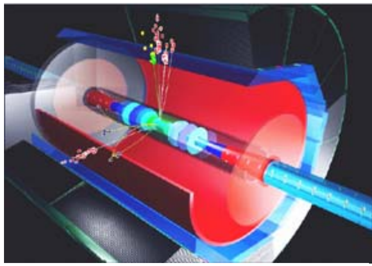
SiPM data sheets

- Many more SiPM parameters measured and stored in a data base
  - Temperatures, HV depnedences, saturation behaviour,…



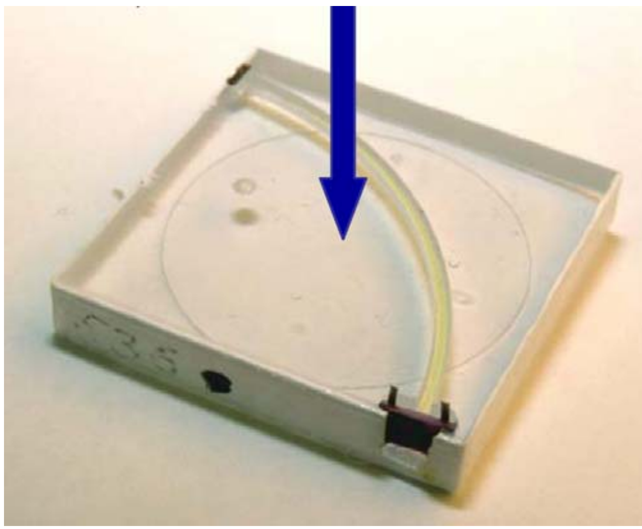


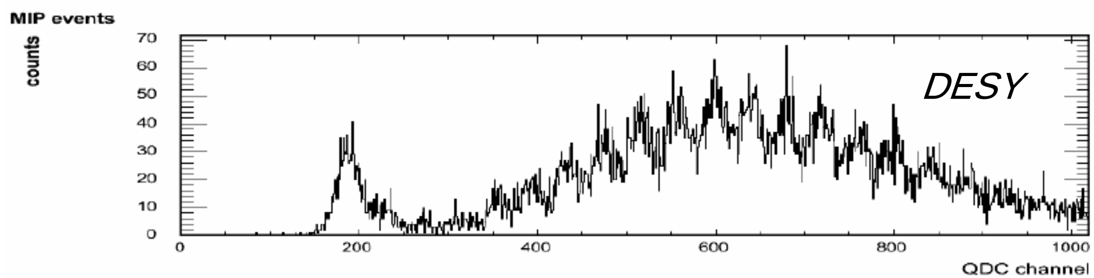
ITEP

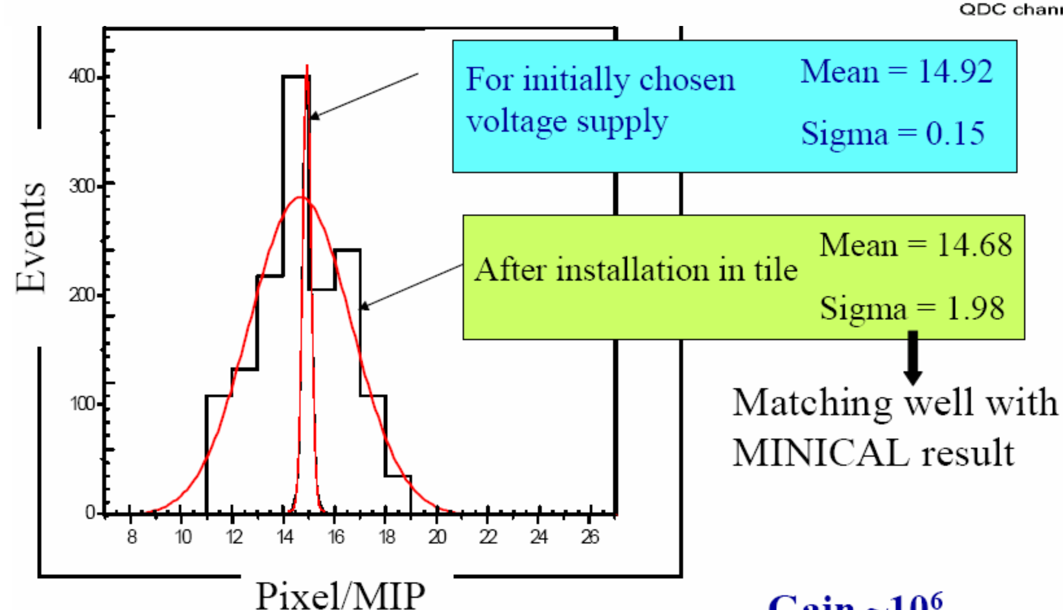


3rd stage: light yield

After installation on tile





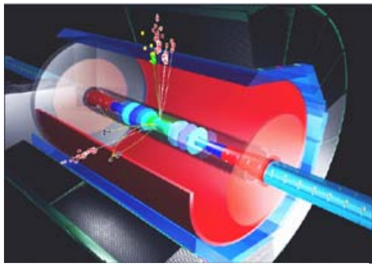


For SIPM working point

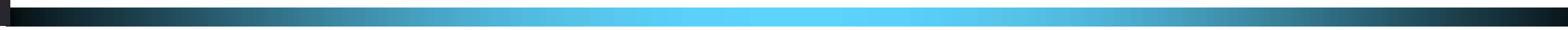
Beaune 2005 E.Popova MEPhI

Gain ~10^6

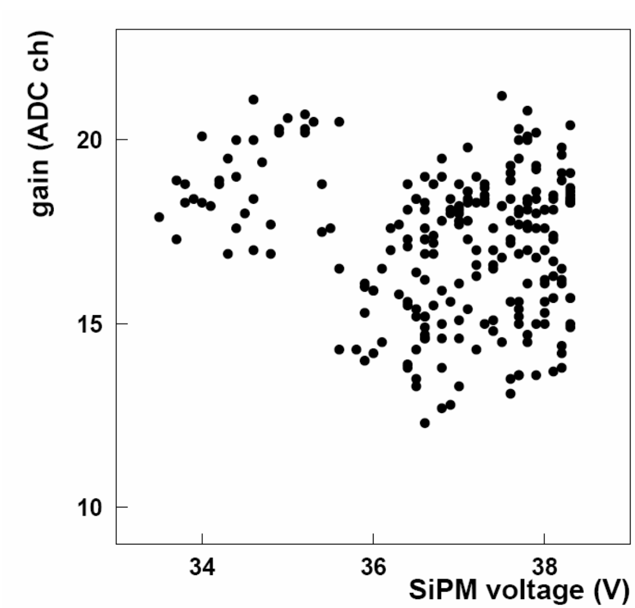
Efficiency of light registration ~10%

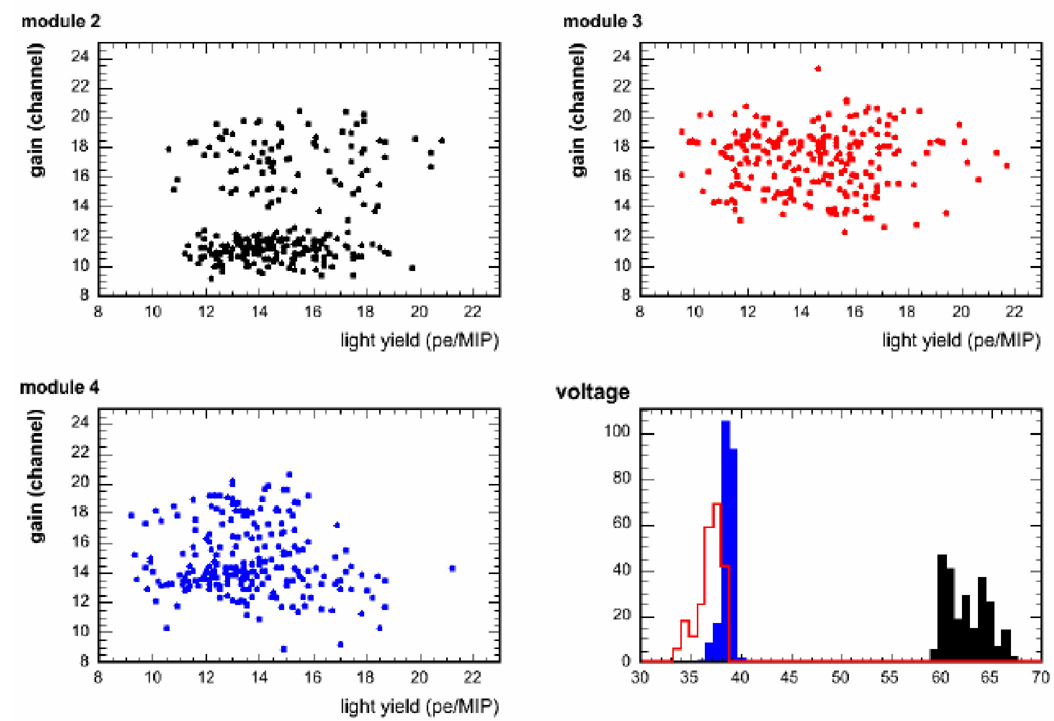


Samples for cassettes

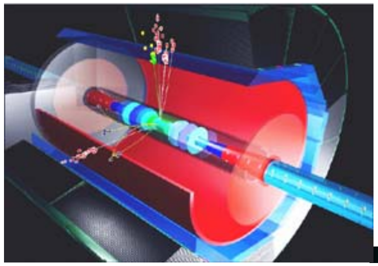


- Tiles are grouped according to bias voltage
  - 108 / half module
  - +- 2V adjustment range



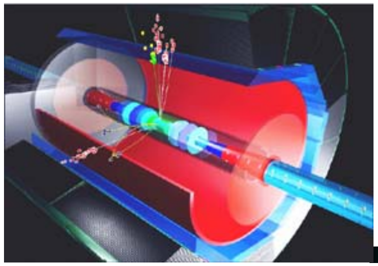


Limited room for optimization
- Gain 3% / 0.1V, LY 7% / 0.1V
- Gain equalization would increase LY spread



SiPM summary

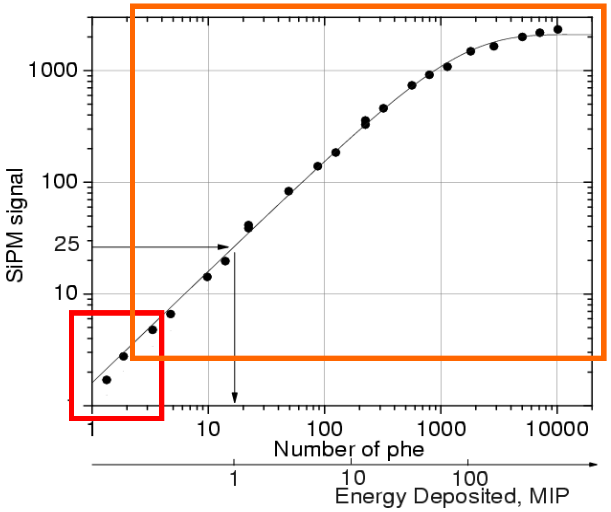
- Mass production and quality control chain established
- Samples of few 1000 SiPMs under study now
- Long term stability tests become possible



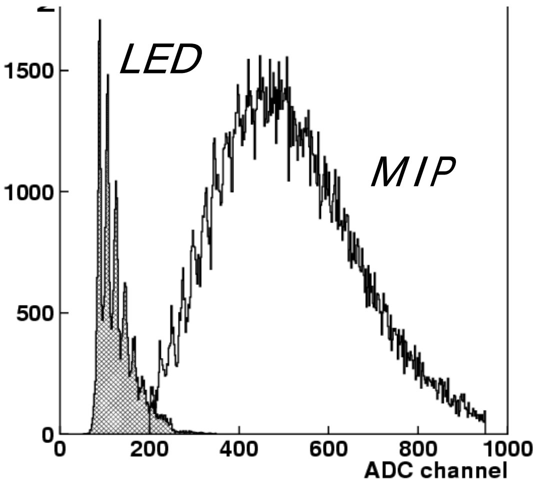
Calibrating & monitoring SiPMs

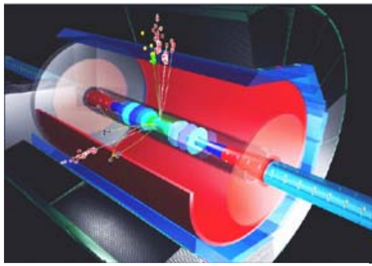
Two scales:

- Energy scale is set by MIP response
- SiPM response and saturation is measured in pixels



- Non-linearity correction requires LY in pixels / MIP for each channel together with universal response function
  - Need fast shaping to avoid noise pile-up
  - By-product: directly observe SiPM gain: **auto-calibration**

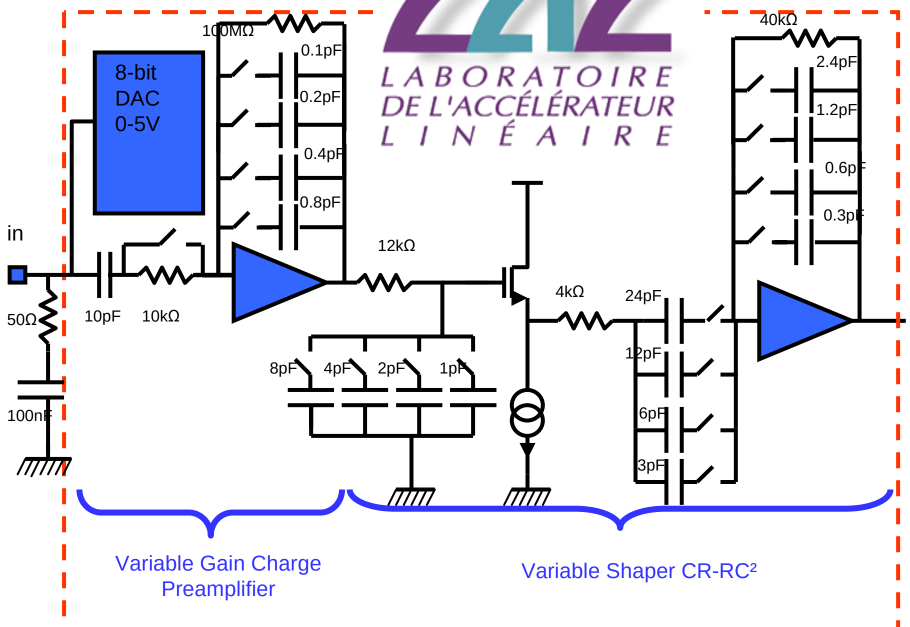


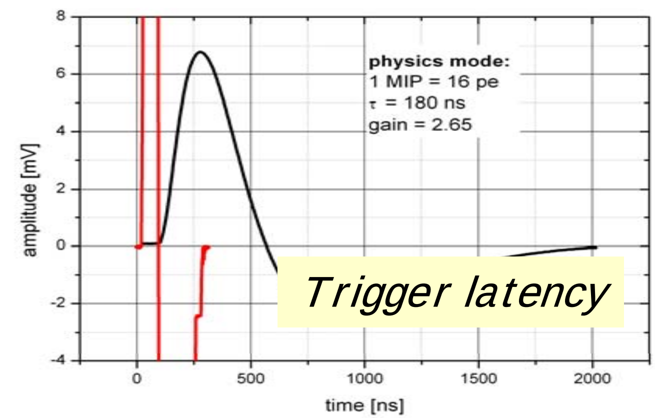


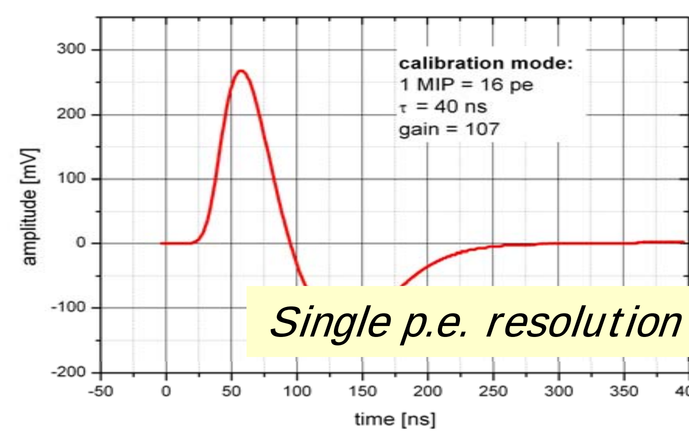
Front-end electronics

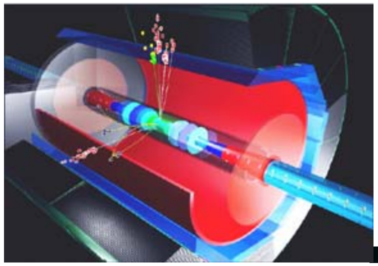
- ILC-SiPM chip: 18ch Pre-amplifier, shaper, track and hold, mux
  - based on CALICE SiW ECAL chip

SiPM bias adjustment

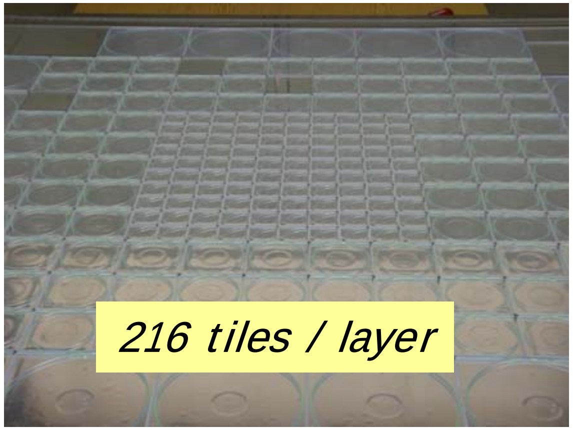


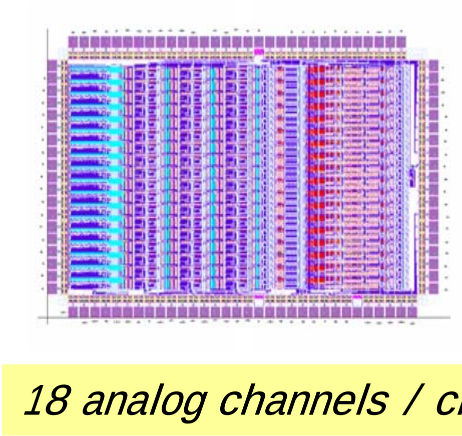


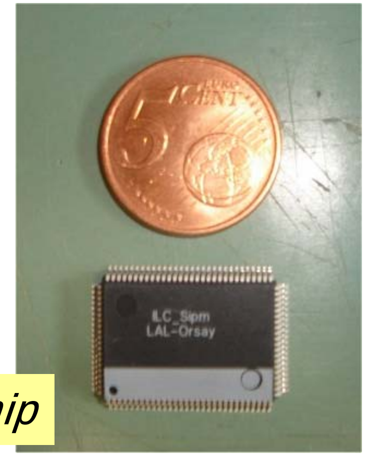




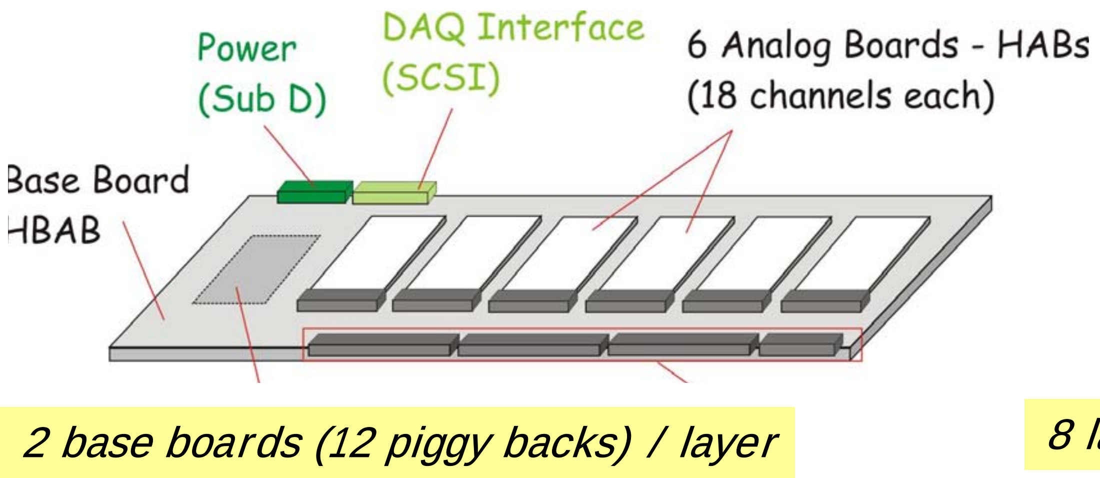
HCAL readout architecture



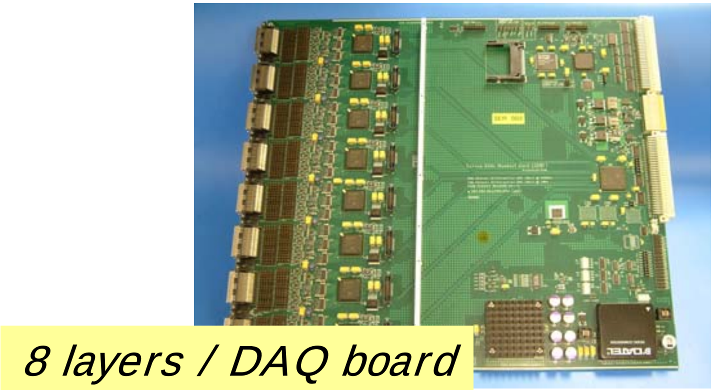




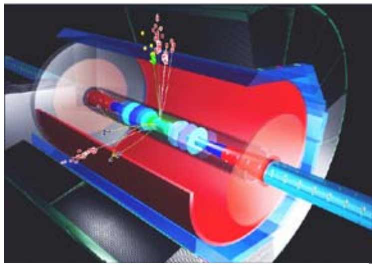
ILC_SiPM chip



CRC
CALICE Readout Card

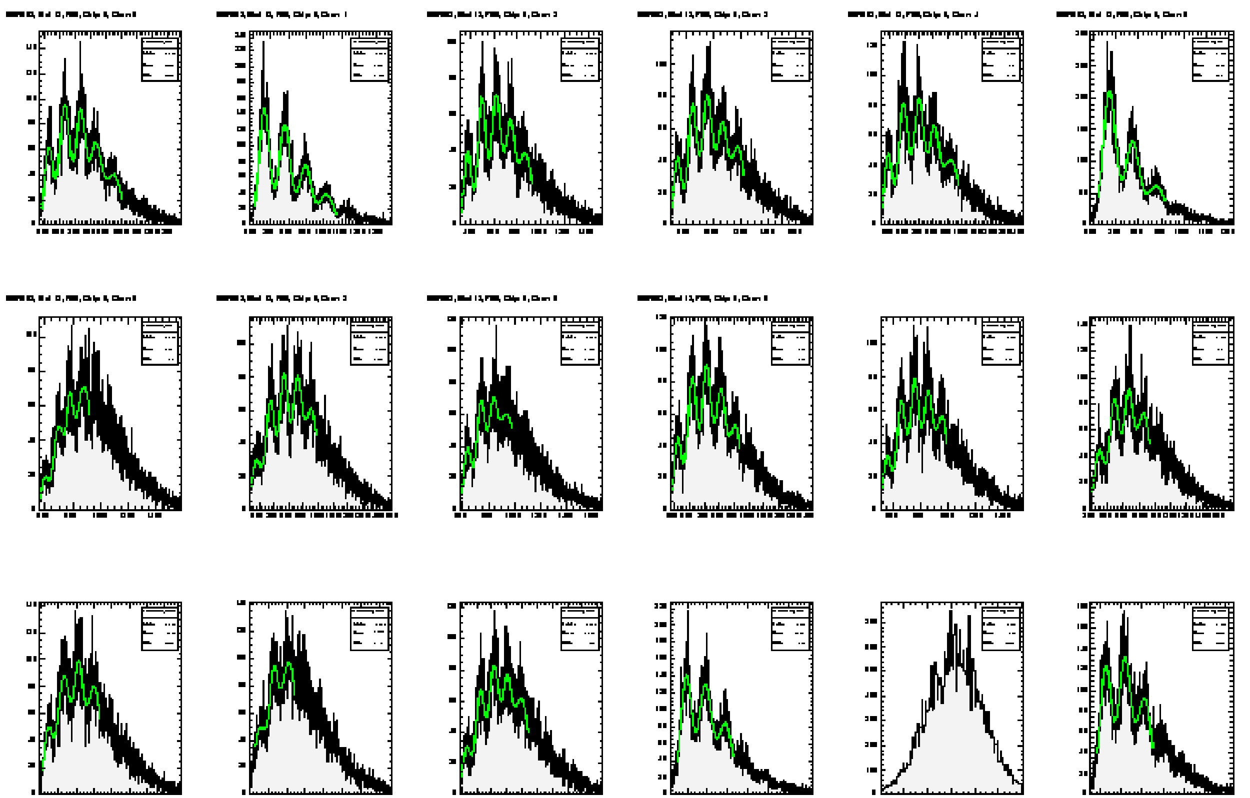


First modules

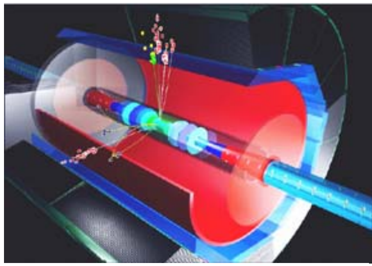


Multi-channel tests

- Simultanous gain measurement (with one LED)
- Will be 216 “stamps” with calibration board (12 LEDs)

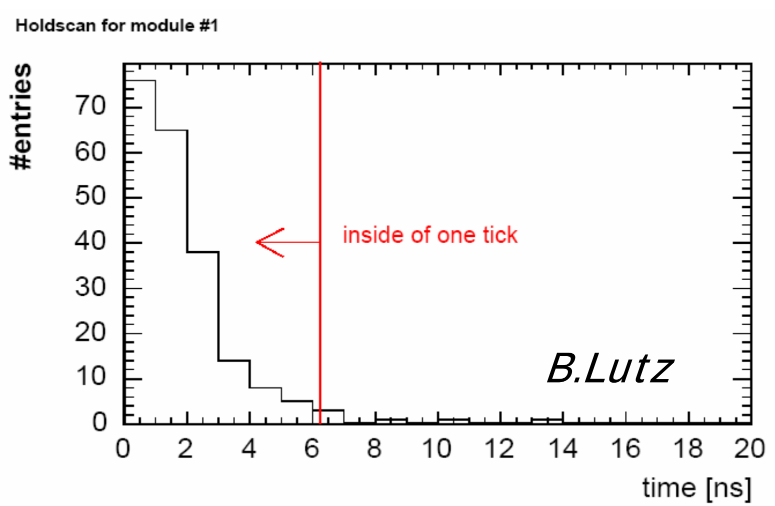


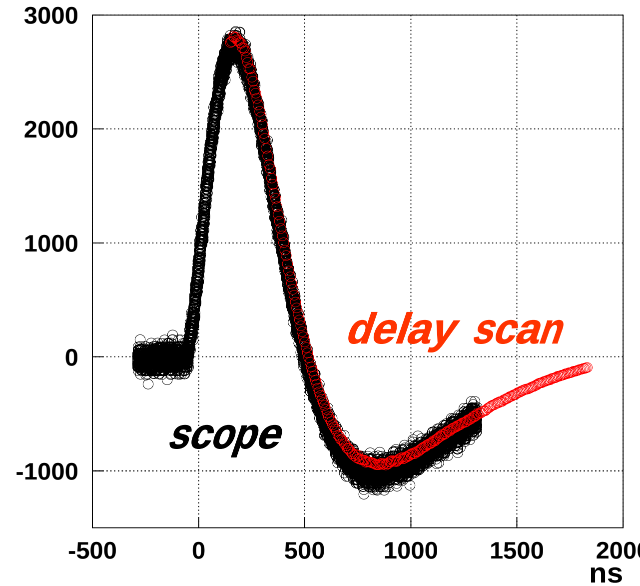
Optimization of light amplitude spread ongoing



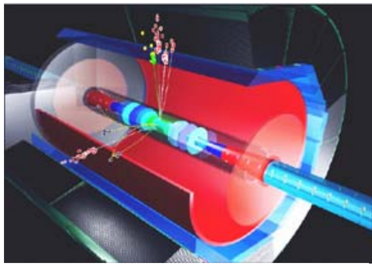
Timing

- Only one adjustable delay for HOLD per cassette
- Timing uniformity OK



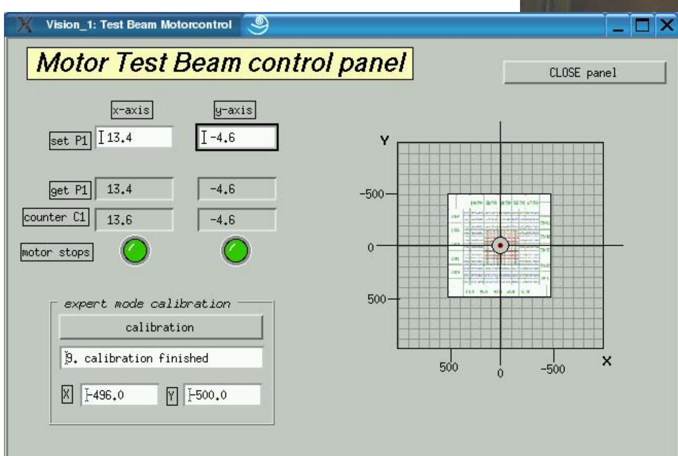


- Delay scan: latency sufficient for fast trigger
- and not too long readout cables

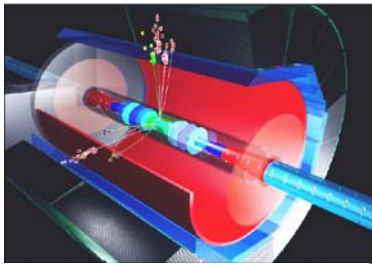


DESY testbeam

Module ONE in the "air stack"



CALICE ECAL DAQ



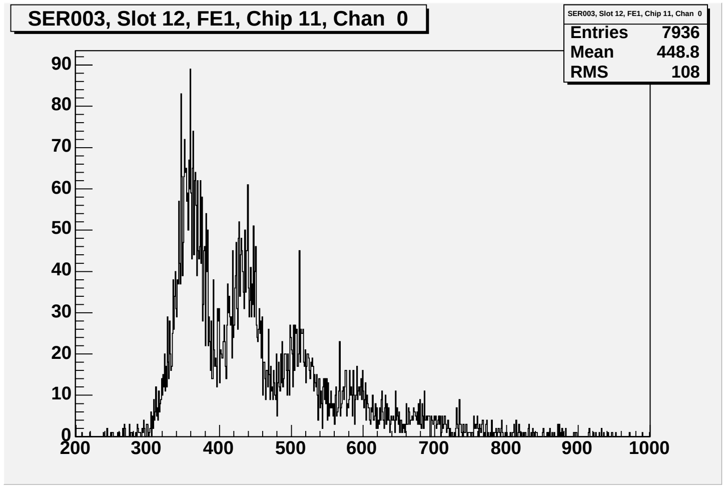
In-situ light yield

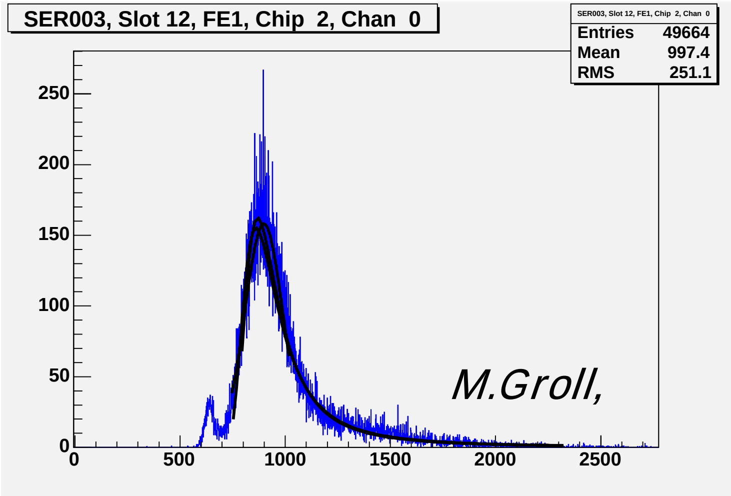
- With test beam electrons
- Single pixels signals (LED, calibration mode)

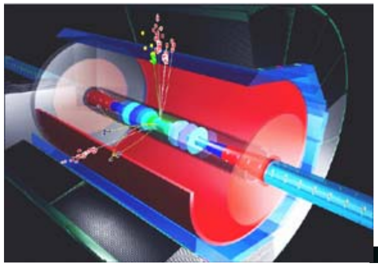
- MIP signal (physics mode)

- Cross-calibration: LED (5-10 MIP)
- Systematics (few %) mostly due to fitting procedure

$$LY = \frac{A_{MIP}}{gain} * \frac{A_{LED}^{calib}}{A_{LED}^{physic}} = 15\ px / MIP$$

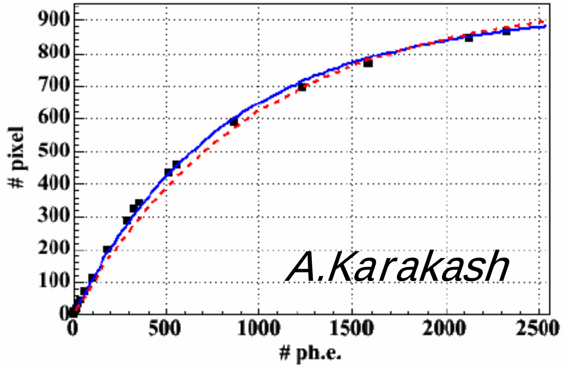




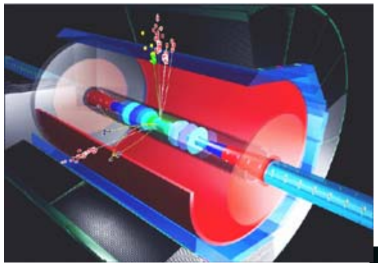


Commissioning

- The electronics chain successfully established in multi-channel mode
- Much more to do:
  - Reproducibility
  - Uniformity
  - Non-linearity
  - Integration of calibration electronics
  - Monitoring, stability
  - Multi-layer tests
  - ECAL integration
  - Testbeam integration



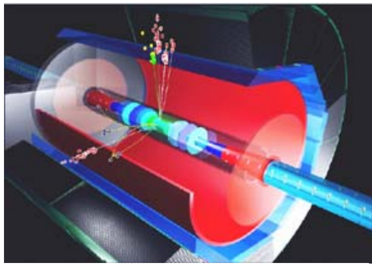
Ongoing studies, single channel (not easy)



Beyond testbeam

- The “physics prototype” name is misleading – it is a testbeam calorimeter and not a technical prototype

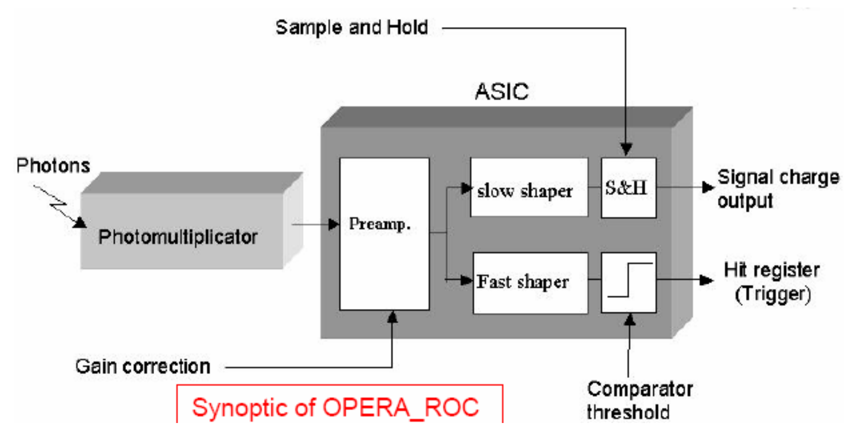
- Technical solutions scalable to a full detector need to be developed
  - Front end electronics and DAQ
  - Readout boards
  - Calibration system
- SiPMs are under rapid development



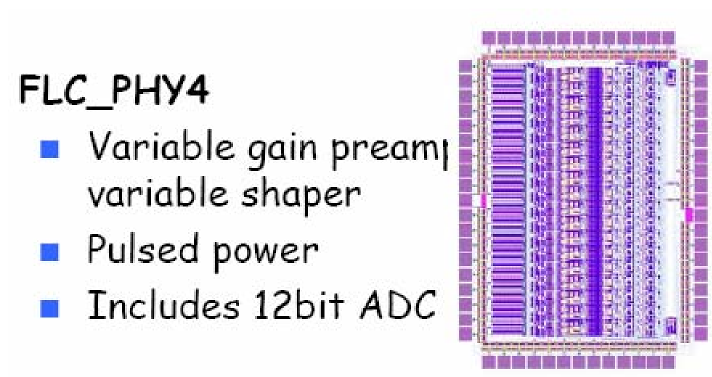
Front end directions

- The fast SiPM signal can be exploited for auto-triggering; see OPERA ROC

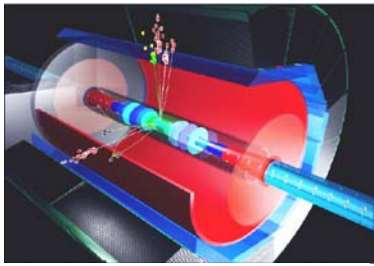
  [NIM A521 (2004), IEEE NSS 03]
  - Would decouple shaping and latency
  - Would allow calibration with r/a sources - or even noise
- Following the ECAL trail: incorporate the ADC in the front end
  - G.D.A.S.A.P.
  - simpler or higher integrated DAQ



Synoptic of OPERA_ROC

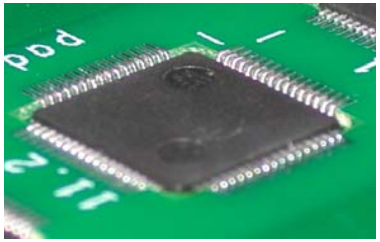


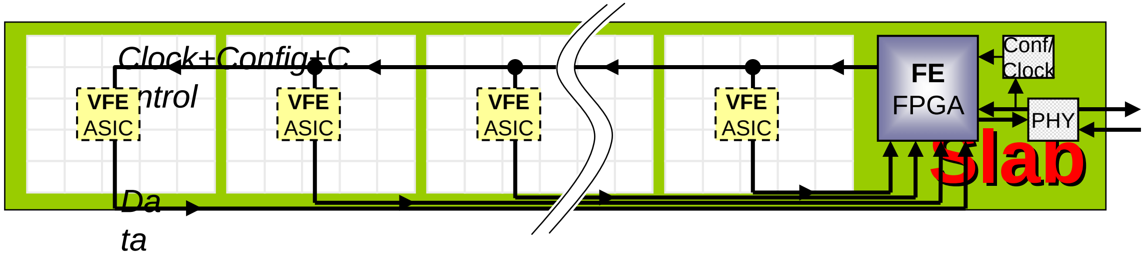
C. De La Taille



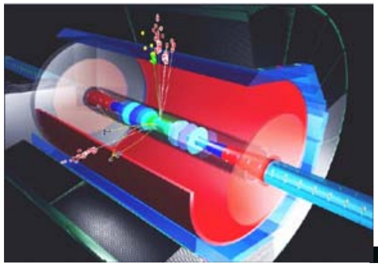
Readout boards

- The micro-coax cable was a conservative extrapolation of the minical experience
- 1st step: replace cables by PCB
- 2nd step: integrate the ASICs in the PCB
  - See – again – the ECAL example
- 3rd step: develop full electro-mechanical concept including
  - Signal readout
  - Coupling to SiPMs (and tiles)
  - Calibration system
  - Cooling





JC Brient

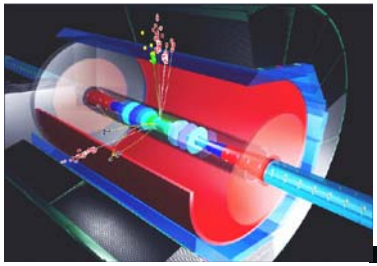


Calibration system

- The present system has belts **and** suspenders
  - Classical LED reference signal (with PIN diode monitoring)
  - Gain calibration with low light intensity
  - Saturation monitoring with large light amplitude
  - Temperature sensors

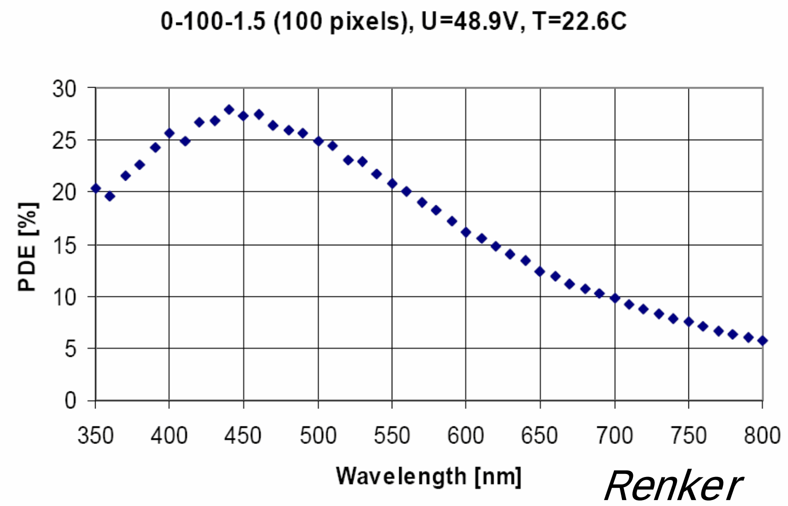
- Testbeam experience will tell how to simplify:
  - Saturation stable? Less light, fewer fibres!
  - Gain monitoring sufficient? Drop the PIN diodes!
  - Auto-trigger? Use alpha source instead of LED! (A. Karakash)

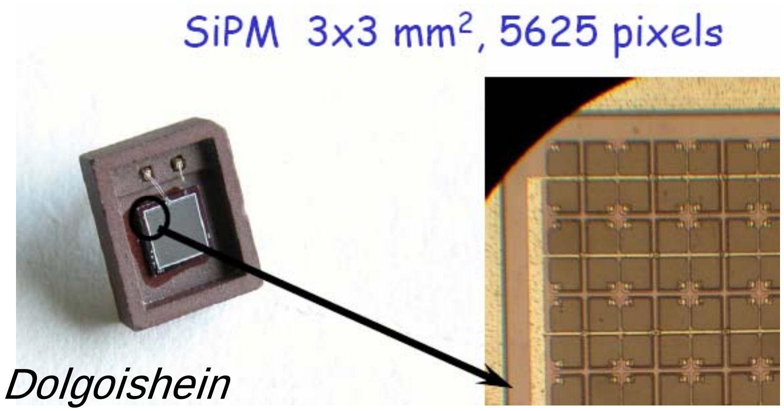
- I like the LEDs – I can’t imagine commissioning without…
  - Use both?

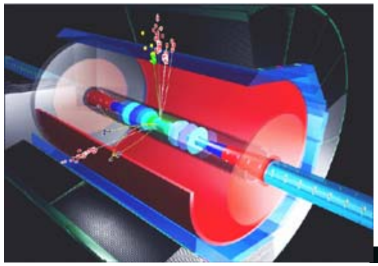


SiPMs

- Development driven by bigger markets (PET)
- First tests with Hamamatsu devices reported at LCWS, more details at Beaune conference
  - Performance similar to MEPHI/PULSAR devices, but better sensitivity to blue light
- MEPHI has tested larger area SiPMs
  - Still somewhat noisy
- Large area + blue sensitivity: get rid of the WLS fibre and couple the SiPM directly to the tile edge
  - Big simplification!

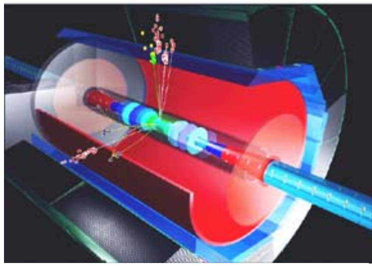






Conclusion

- SiPMs have just opened a new chapter in scintillator based calorimetry
- The proof-of-principle prototype is well underway
- The technical realization has just begun to emerge – there is much room for new ideas.



SiPM noise

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