Cherenkov Lab

27 September 2018

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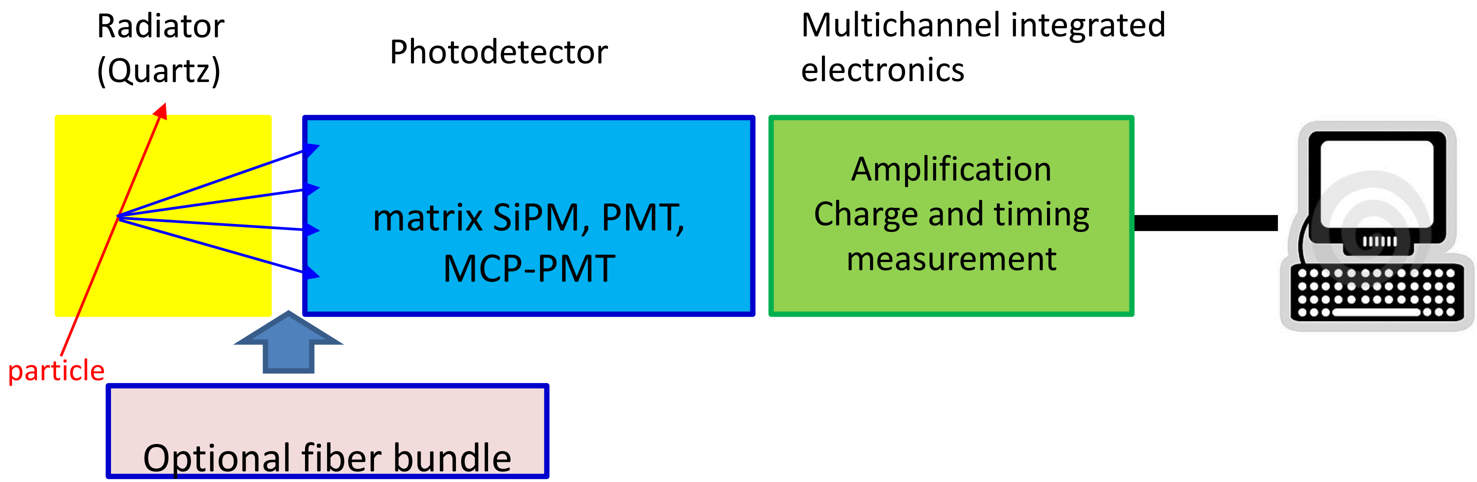
Cherenkov Lab aim

Development of a multichannel detection chain for the measurement of an absolute particles flux with an accuracy of 5 % and a timing resolution of 20 ps.



Characteristics :

- Multichannels
- Mechanical Integration: ultra vacuum compatible
- Response to single particle (proton, pion, ion)
- Charge measurement from 1 to tens of thousands of incident photo e^- on the photodetector
- Timing resolution of 20 ps (rms) for few particles

Applications

- HEP: upgrade of theTime Of Flight detector of BESS III, Tau Charm Factory in China.
- Instrumentation for accelerator: luminosity measurement, LHCb, UA9.
- Medical Imagery : TOF PET.

Technological challenges

- Optimization of the light yield : mechanical integration of the bars in a metallic flange for the uses in vacuum
- Multichannel ASIC in TSMC 0.13 µm for the measurement of the charge over a large dynamic range and with a timing resolution of 20 ps

Work packages

WP 1 : design, conception and tests of a multichannel detector

- ✓ simulation (Geant4) of different quartz bars geometries and their mechanical supports
- ✓ tests of the different quartz polishing
- ✓ optimization of the optical coupling
- ✓ tests of various photodetectors (MCP-PMT, SiPMs)

WP 2 : R&D on the mechanical integration of quartz bar in metallic flange

- ✓ metal implantation at the quartz bar surface
- ✓ Development of technics of quartz/Stainless steel brazing
- ✓ Measurement of the vacuum compatibility

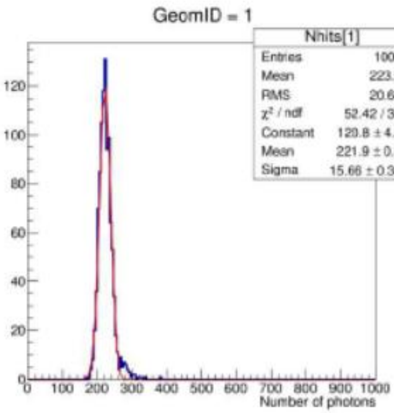
WP 3 : design, conception and tests of the ASIC

WP 4 : beam test of the complete chain

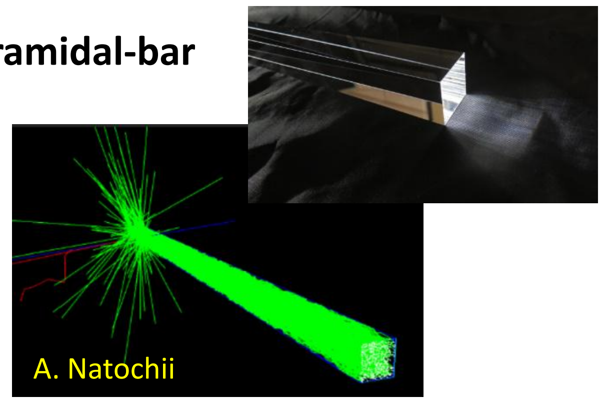
Bar geometries comparison – GEANT4 simulations

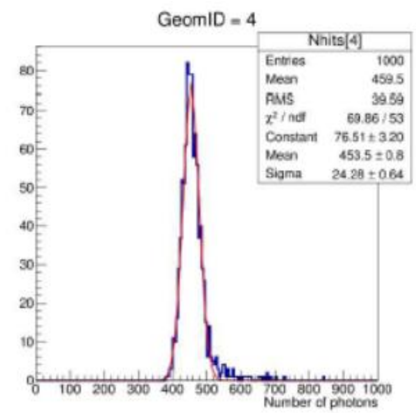
Distribution of the number of p.e per incoming proton produced at the PMT photocathode

I-bar

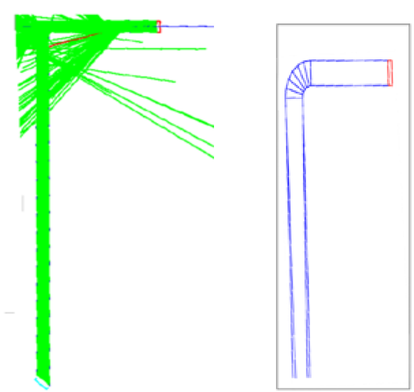


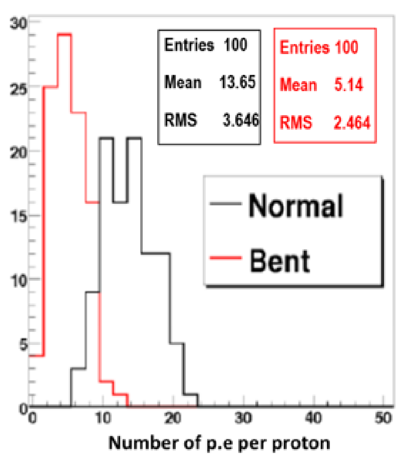
Pyramidal-bar





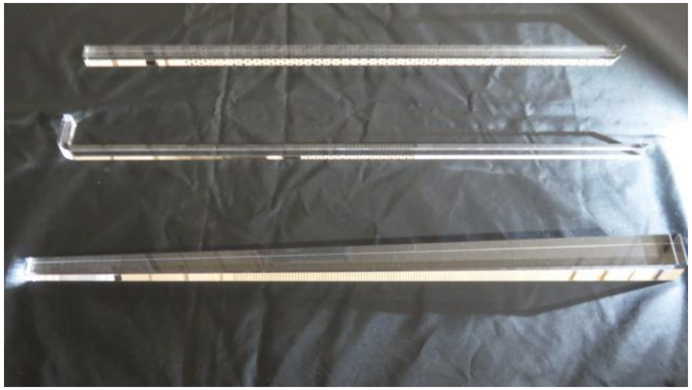
L-shape bar and **curved bar** (bar not in direct coupling with the PMT factor 10 due to the bundle)

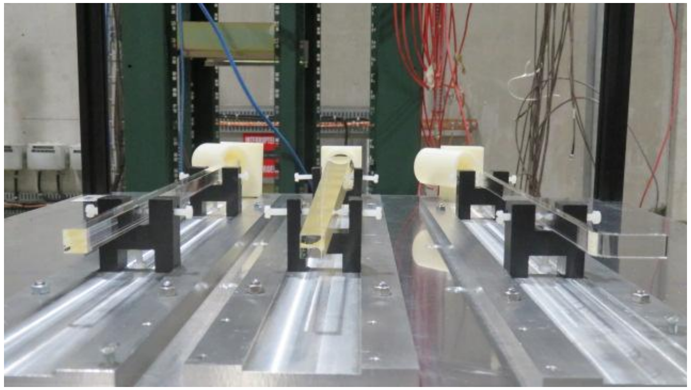


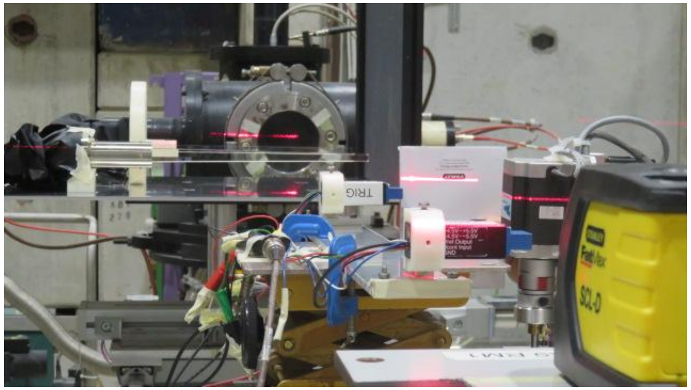


Bar geometries comparison in tests beam

Tests (@ CERN SPS & H8 facility)
with π p^+ & ions of 3 different quartz geometries: straight (I), curved and pyramidal bar

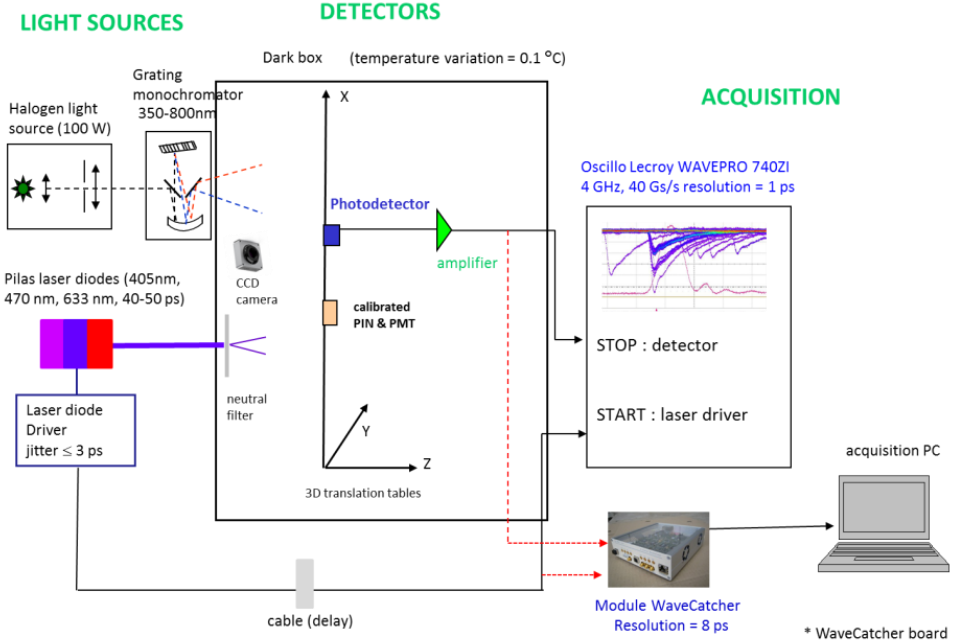


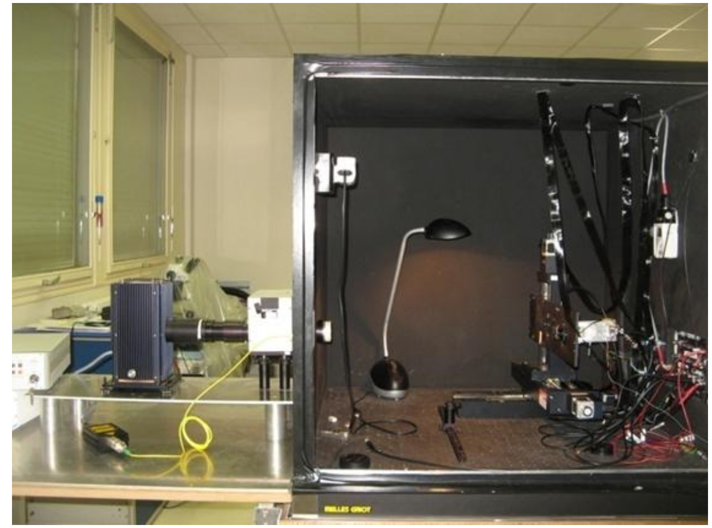


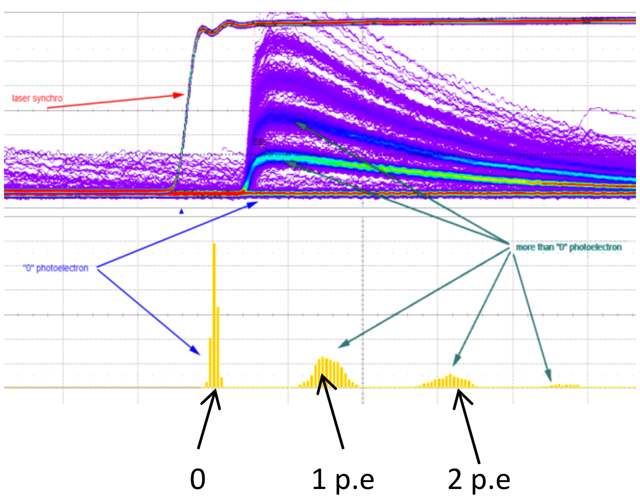


Detailed results on UA9-CpFM presentation by S.Dubos

Photodetector studies







Temperature = 15 to 30 °C (variation = ±0. 1 °C)

Light sources:

- continuous : monochromator 350 à 800 nm (± 3 nm)
- Pulsed : 405, 435, 532, 635 nm (pulse width 50 ps FWHM)

Calibration of the test bench at 6 %

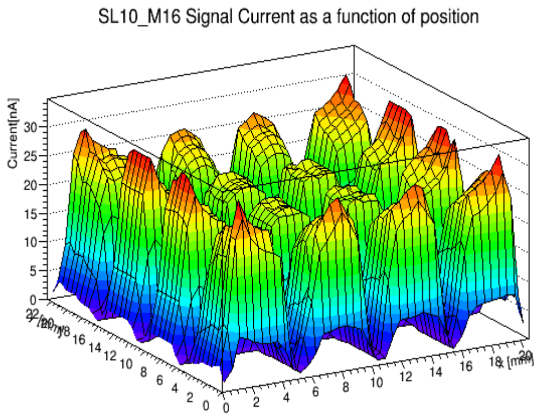
Oscilloscope 4 GHz, 40 GS/s and WaveCatcher module

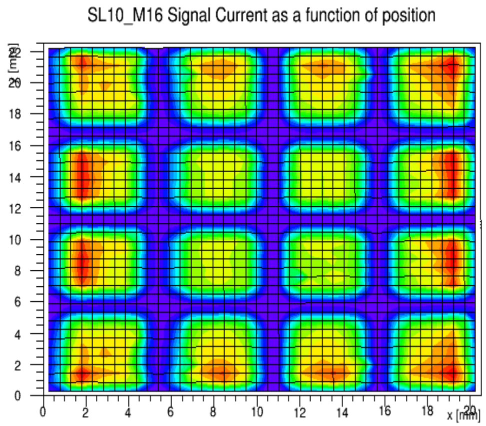
Photodetector studies

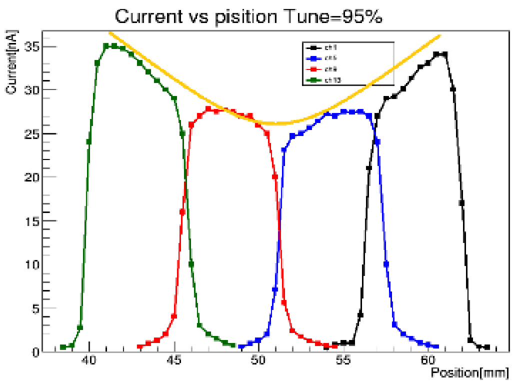
MCP-PMT HAMAMATSU SL10-M16 : MCP-PMT 16 channel, old generation

Internship work of Jiajin Zhang (University of Science and Technology of China)

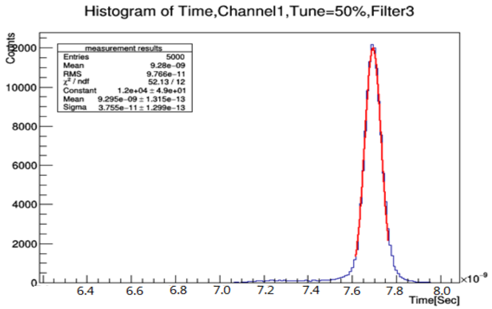
Mapping of the current response over the 16 channels







Single Photoelectron Timing Resolution (SPTR)



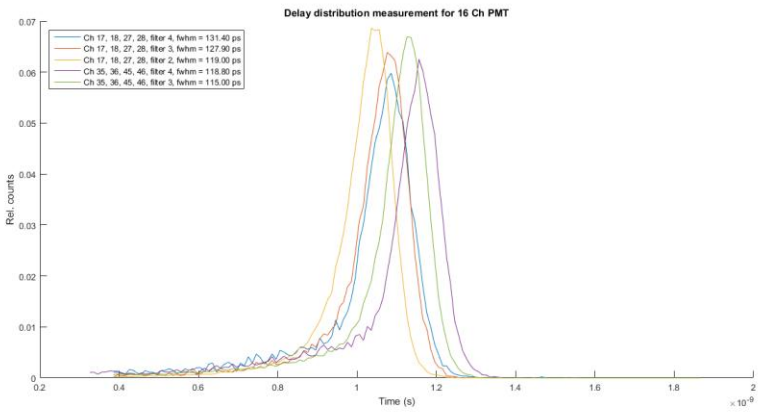
SPTR (σ) mapping

39ps	40ps	38ps	39ps
38ps	38ps	39ps	38ps
40ps	39ps	39ps	40ps
40ps	39ps	39ps	40ps

Photodetector studies

MCP-PMT BURLE XP85012: MCP-PMT 64 channels (old generation)

Time walk for some channels below 300ps p-p



$SPTR_{best}$ (σ) = 55 ps

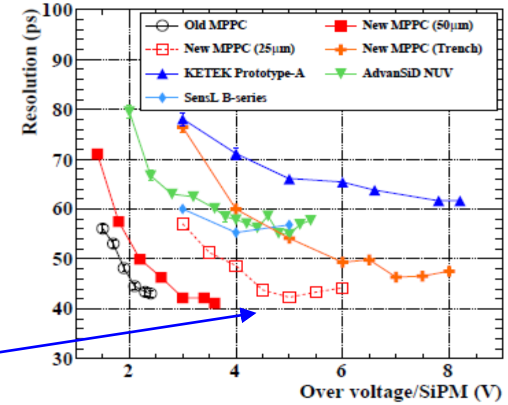
AuraTek (Photek): MAPMT228 (MCPPMT technology)

1*4 strip readout (28.16*7.04mm^2)
Gain 10^6
Sensitivity @ 450nm: Qe 14%
Expected SPTR under 40ps rms
delivery @ lab early october

Photodetector studies

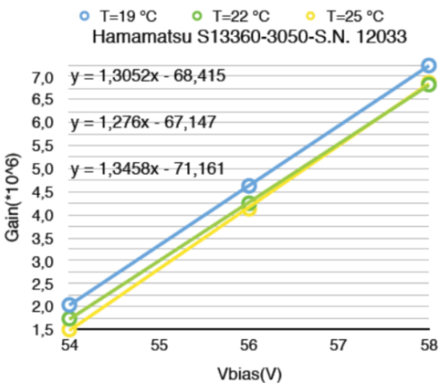
SiPMs : 4 SiPMs HAMAMATSU, 2 KETEK, 2 Sensl

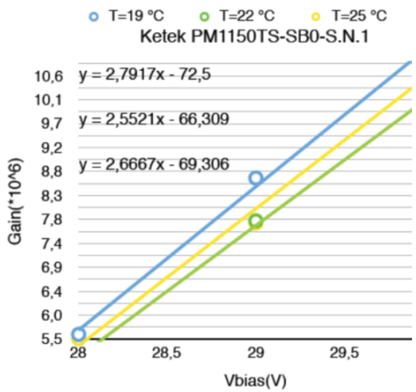
SPTR of 40 – 50 ps can be optain

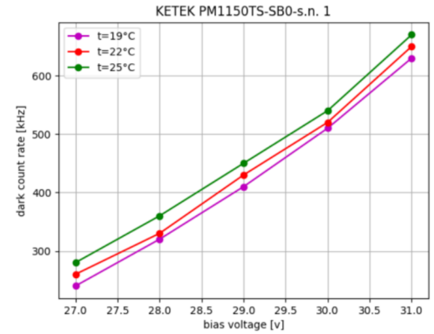


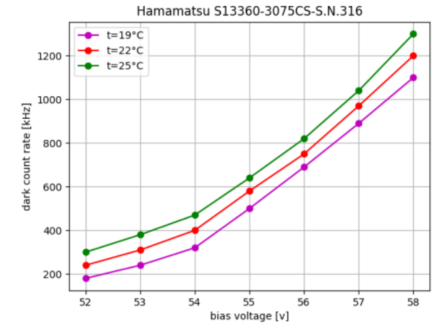
P.W Cattaneo, arXiv:1402.1404v1

Internship work of Tetiana POVAR

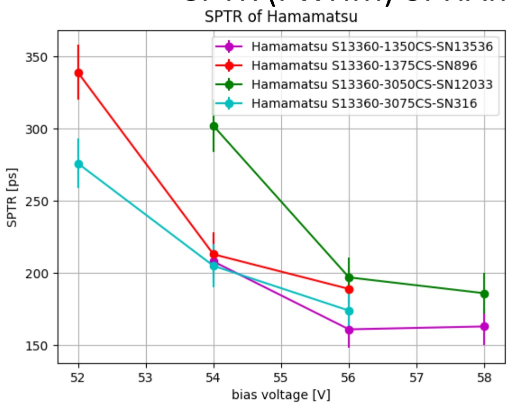


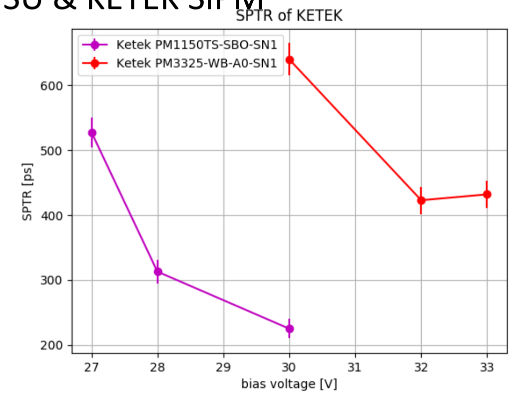






SPTR (FWHM) of HAMAMATSU & KETEK SiPM





$SPTR_{best}$ (σ) = 70 ps @ Lab for a 1mm² ASD device

Readout Electronics development

Requirements for the Cherenkov Lab ASIC

- Multichannel (8 channels)
- Dynamic from 1 to 2500p.e
- Timing resolution of 25 ps rms
- High count rate capability (from KHz to MHz)
- DACs in input for SiPM matrix polarization
- Coincidence filter to lower the dark rate

Challenge:

✓ different kinds of detectors => bipolar input
✓ wide dynamic range
✓ very high counting capability

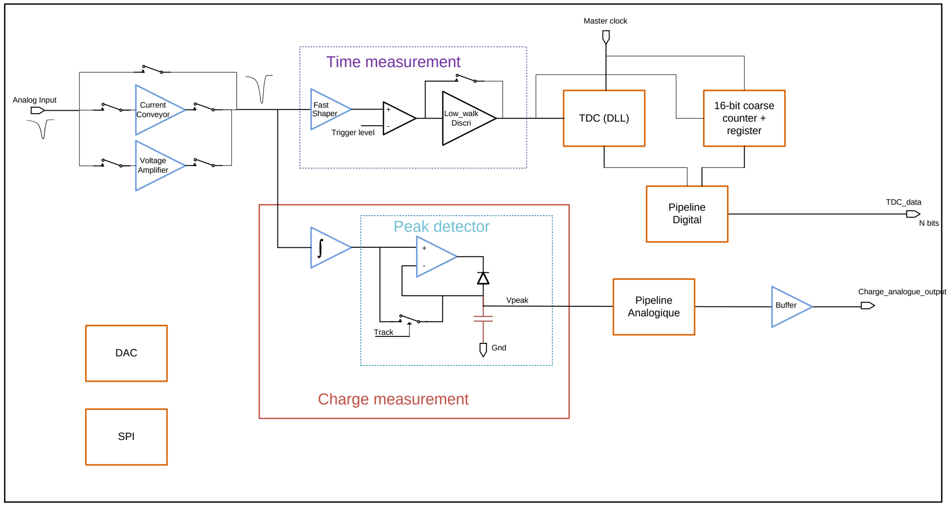
What is ready:

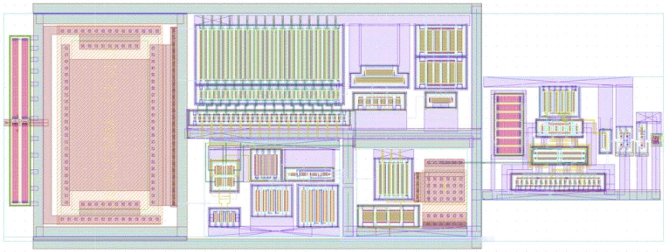
- TDC + discriminator « low-walk » end of 2017 (AMS 0.18µm): 25ps time resolution measured discriminator under tests.
- « front-end » part: Voltage pre-amp, integrator and voltage detector nearly finished in AMS 0.18µm run missed end of 2017..

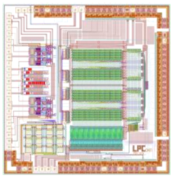
Bad news:

- Early 2018 AMS 0.18µm have to involve to TSMC 0.13µm for a new community ASIC standard (BB130, DiamAsic, Lojic130 Project).

« Front-end Chip for PM » Block Diagram







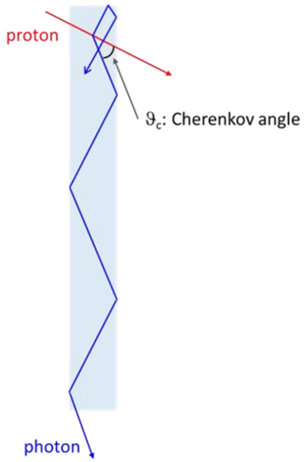
On-going:

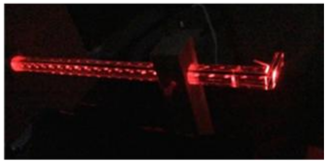
- TDC to TSMC 0.13µm tech migration early finished: submission for the 2018/11 run. (LPC_CAEN).
- LAL analog front-end part migration in progress. Will not be ready for 2018/11 run: difficulty to adapt power supply changes for input analog stages.
- Chip architecture update in progress.

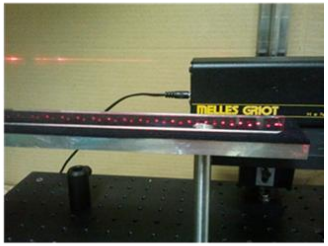
“Real” Quartz specifications

Simulation and experience from acquired from UA9 experiment had shown we need very well polished quartz bars without chamfer in order to maximize photon yield.

1. Very expensive
2. Difficult to produce
3. Difficult to grant reproducibility even in the same batch







⬇

The effect of polishing is very difficult to simulate → we need to perform tests

- Our request : roughness = 1 , 10 and 50 nm for 117 * 10 *5 mm^3
- Company Optico AG, Switzerland., answered positively to our request but the can only ensure the « best effort » for polishing but cannot provide intermediate quality…

<u>First direct measurement of polishing done by The “Laboratoire des Matériaux Avancés” (slide about mini bar)</u>

- Chamfers effects on light yield

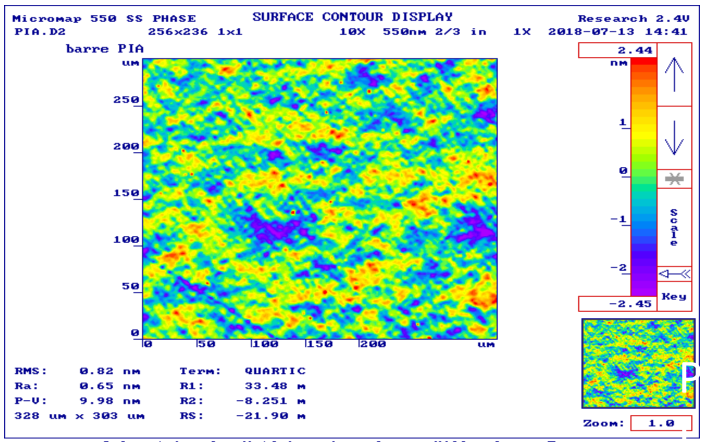
<u>Chamfer effect seems to be more difficult to solve by producer than polishing (slide about mini bar) . Could be the biggest limitation for photon yield for the radiator part of the detector.</u>

Mini-bar measured characteristics

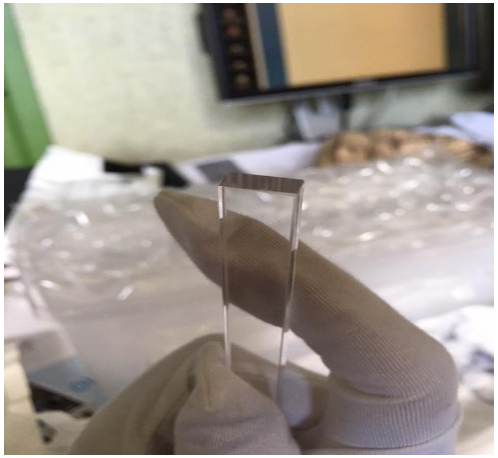
We produced 4 bars, the third was measured optically, all were test on H8 and with a strontium source

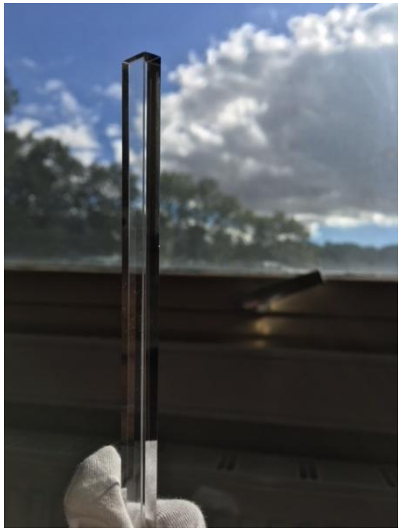
Optical:

“Laboratoire des Matériaux Avancés” measurements by Interferometry techniques

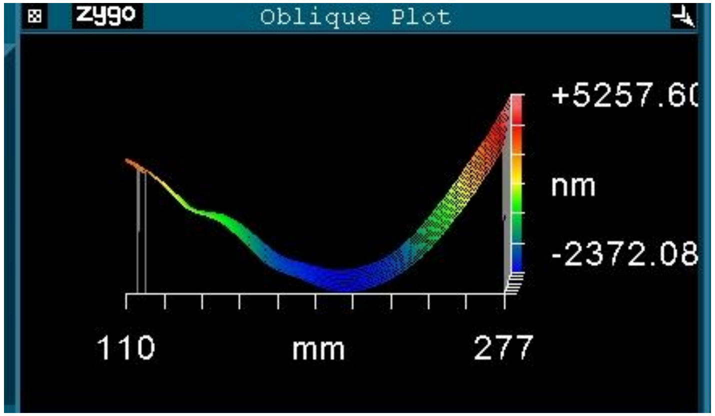


Roughness lower than 1nm on 1mm²





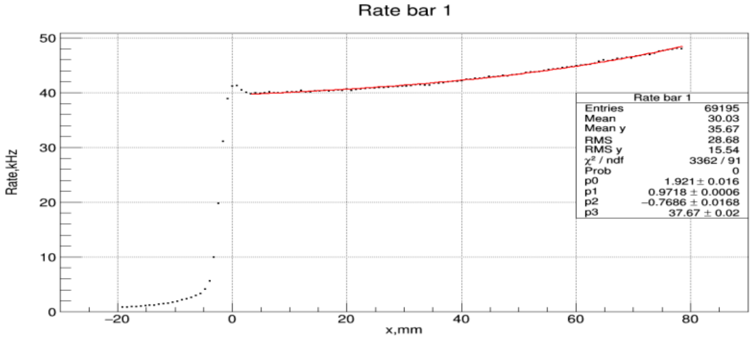
Mini bar (117 * 10 *5 mm³) by Optico AG



Planarity lower than 0.4% over 160mm

Light yield:

LAL measurements by strontium source count rate method

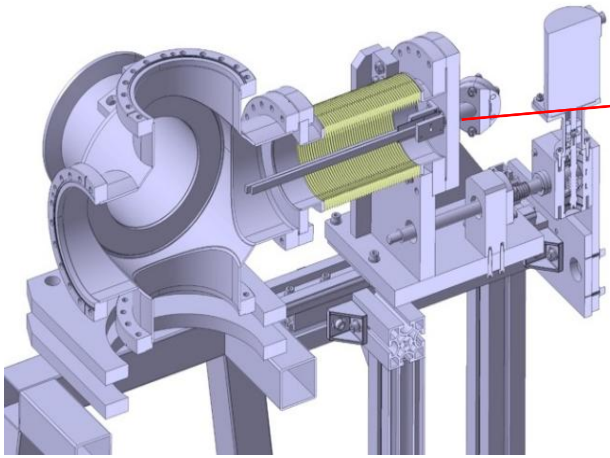


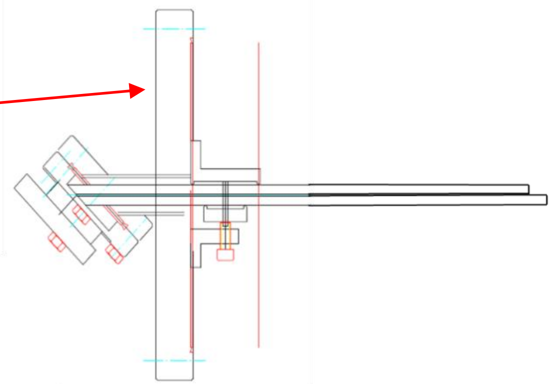
20% variation of count rate over 80mm along the bar

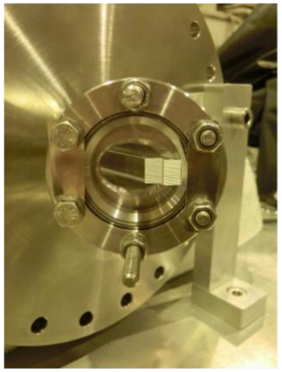
Mechanical integration of a Quartz bar in a metallic flange 1

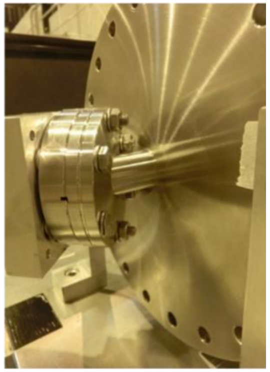
Example of quartz bar as a radiator for Cherenkov detection: the CpFM for UA9

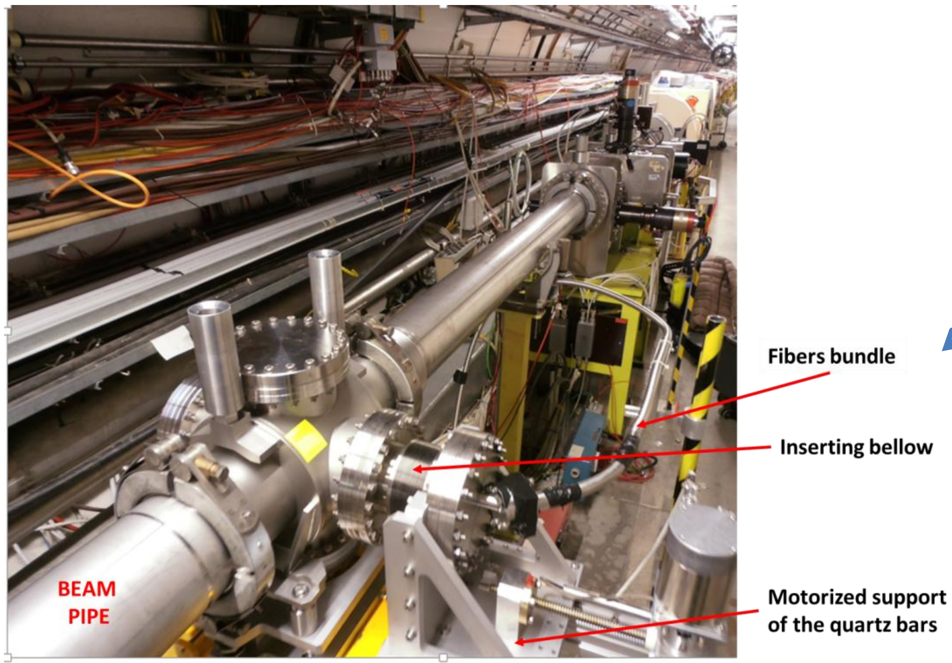
Final design : a Quartz viewport is the interface between the bars and the PMT → signal loss, factor 2







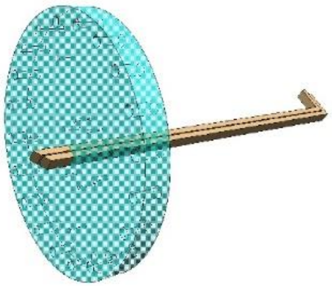




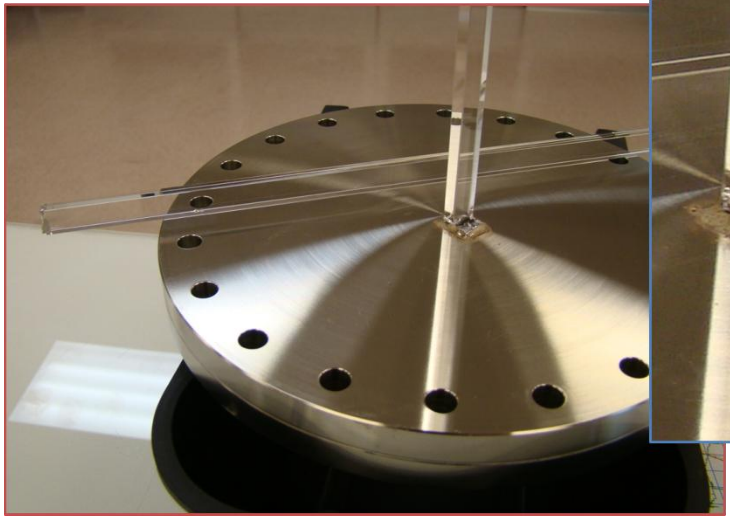
Coupling with Fibers bundle have to be Improved (On UA9 reduction by a factor 10 on light yield was shown.

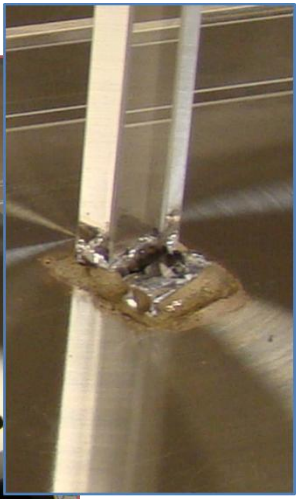
First brazing disaster!!

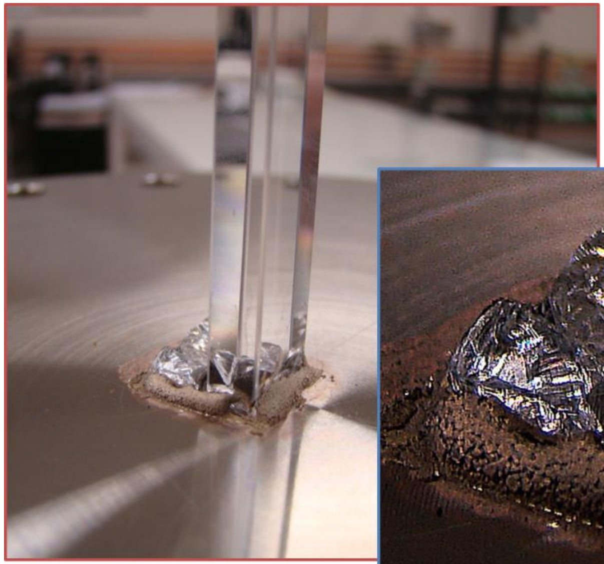
Initial design : the bars are brazed to the flange

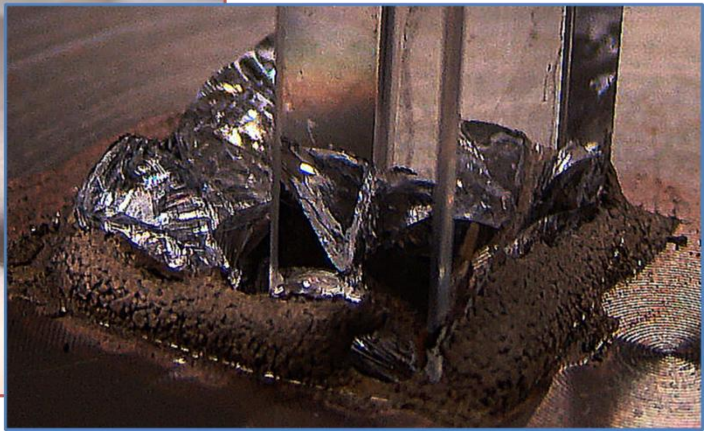


Even if company ran a very slow thermal cycle to minimize the thermal mismatch between the parts, one of the quartz bar got totally cut









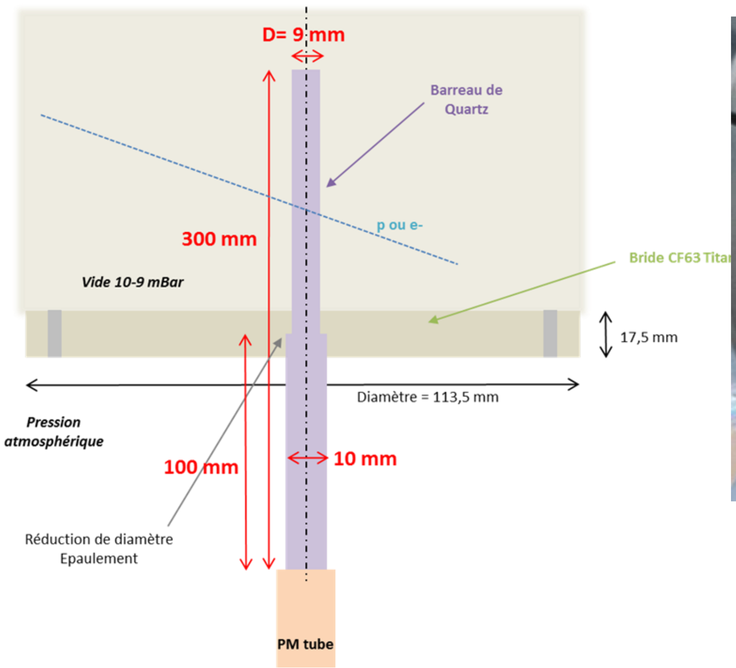
The last bar was not cut and hold on the flange but it is cracked

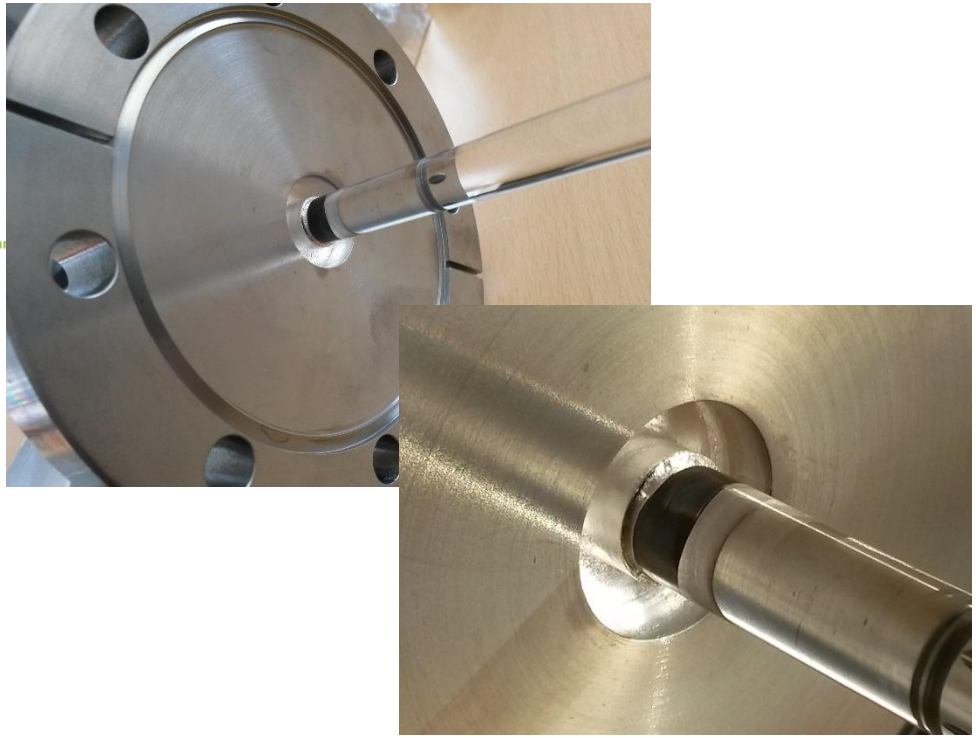
The issue seems to be the CTE gap (coefficient of thermal expansion) between the metal and the fused silica

Mechanical integration of a Quartz bar in a metallic flange 3

Design of the First specific prototype for brazing test :

- Round quartz bar with shoulder (brazing easier with a circular symmetry)
- Stainless steel flange





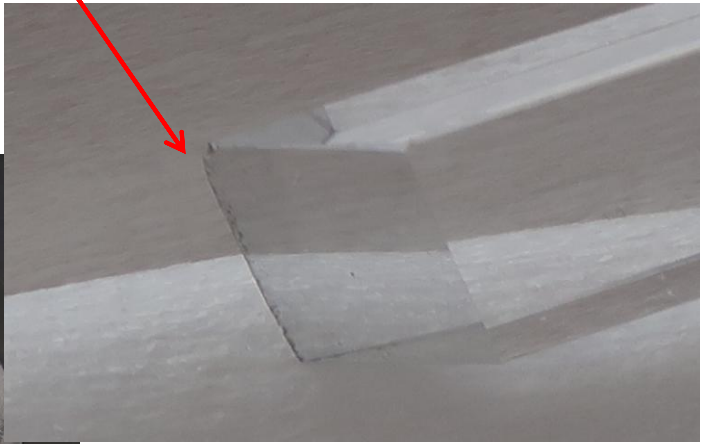
Good surprise : no breaking of the bar

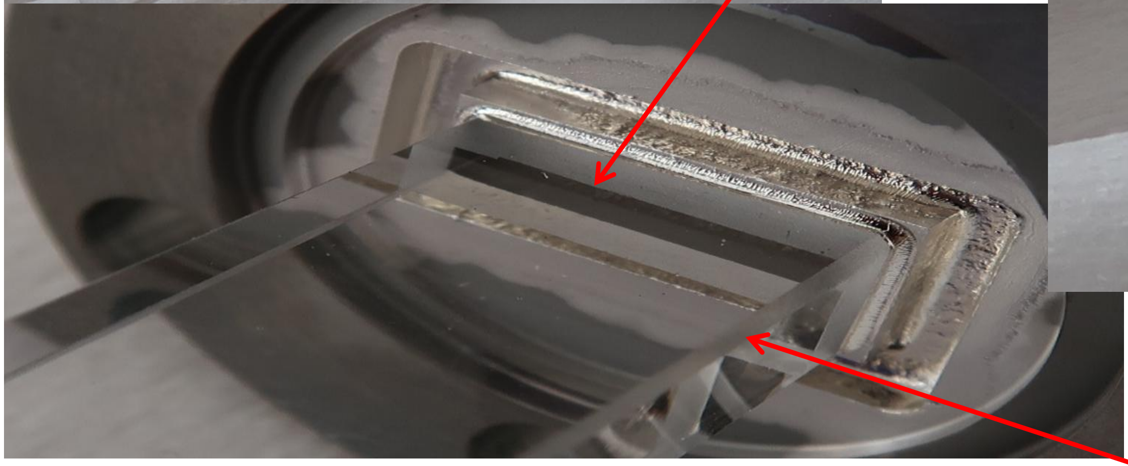
Mechanical integration of a Quartz bar in a metallic flange-3

Mini-bar

Brazing through a Ti flange by the PNL compagny.
Depth of brazing: 2mm
Helium vacuum test achieved

Problems that appear with brazing process
-Depolished surface
-Damaged end





Undesired chamfer

Needs of brazing process improvement

Indium brazing give a 100°C eating limitation before flowing : can be a problem for vacuum baking on LHC (250°C)

Mechanical integration of a Quartz bar in a metallic flange-4

Characterization of mini-bars for brazing through a flange

Rates counters – measure with a 90Sr source (electrons)		
Quartz bar	Rates at the nose	Difference with bar #4
Bar #1	37.67 kHz	- 7.96 %
Bar #2	23.76 kHz	- 41.95 %
Bar #3	34.98 kHz	- 14.54 %
Bar #4	40.93 kHz	0 %

Amplitudes / single part. – measure at H8 beam-line (pions)		
Quartz bar	Amplitude / part.	Difference with bar #4
Bar #1	120 mV	- 8.40 %
Bar #2	95 mV	- 27.48 %
Bar #3	-	-
Bar #4	131 mV	0 %

Brazing through a flange – Amplitudes / single part. – measure at H8 beam-line (pions)			
Quartz bar	Amplitude / part. before brazing	Amplitude / part. after brazing	Difference (before / after)
Bar #3	112 mV (estimated)	38 mV	- 66 %

Conclusion

R&D project for the development of a Cherenkov detection Chain

- R&D mechanical integration: first brazing test with rectangle bar done: lost of 66% of photon yield (worst than coupling through viewport). Optimization of the brazing process (limitation of depolished and contact surface)
- Possible issue with the use of indium for the brazing (100°C baking limitation)

- R&D electronics: A bit delayed due to the technology gap. (TDC part on the way November run, Analog front-end next year)

- Quartz shape & polishing quality study: very difficult to find a company that can provide us with quartz samples with specific polishing quality, but capability to measure the roughness after manufacturing. (Still have work on polishing techniques to avoid chamfers)

- Photodetector study on-going: we need detectors at their limits (still have a MCPPMT to test to be at the state of the art)