Cherenkov Lab

5th French-Ukrainian Workshop
Instrumentation developments for HEP

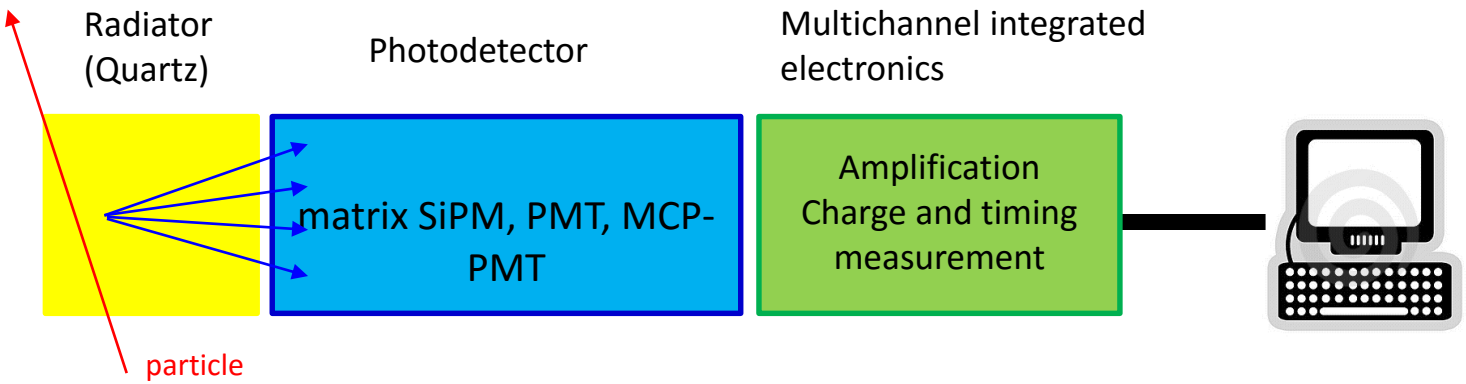
6 Novembre 2017

Véronique Puill

C. Bachelet, C-O. Bacri, S. Barsuk, J. Bettane, D. Breton, L. Burmistrov, V. Chaumat, S. Drouet, S. Dubos, P. Halin, O. Lemaire, L. Leterrier, P. Loaiza, J. Maalmi, A. Natochii, T. Povar, S. Renouf, P. Rusquart, P. Vallerand, S. Wallon, V. Yeroshenko

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 photons 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
- Médical 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 AMS CMOS 0.18 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

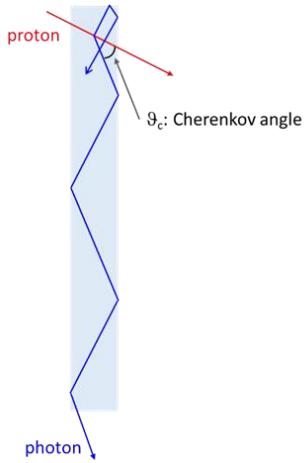
WP 4 : beam test of the complete chain

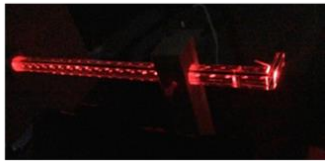
Tests of different quartz polishing qualities

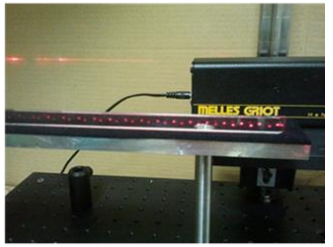
We use ultra polished Quartz in order to maximize the total internal reflections but they are :

1. Very expensive
2. Difficult to produce

→ Would it be possible to work with bars with a lower quality of polishing ?







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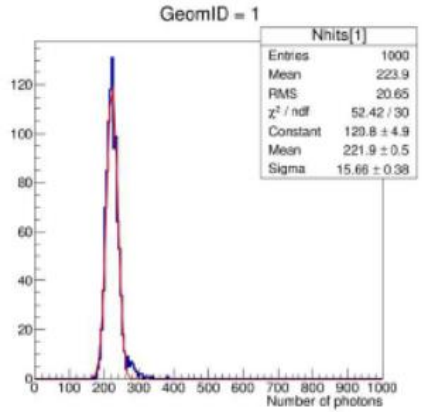
The effect of polishing is very difficult to simulate → we need to perform tests

- Our request : roughness = 1 , 10 and 50 nm
- Search for companies which produce/polish quartz bars (Fused Silica) : USA, China, Ukraine, Switzerland, Germany, Czech Republic, Japan, Russia → only 2 companies answered positively to our request but the can only ensure the « best effort » but cannot provide intermediate quality of polishing …
- We are looking for a way to measure this polishing quality

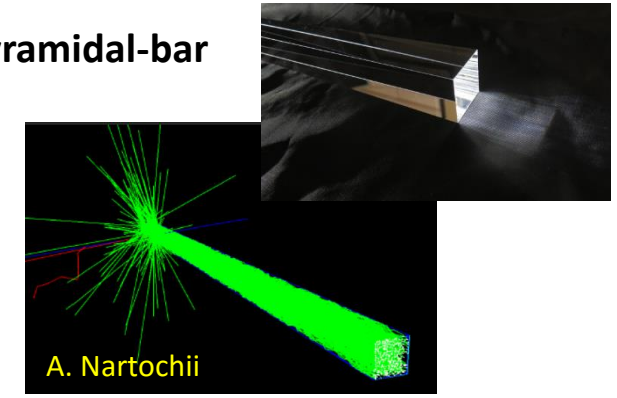
Bar geometries comparison – GEANT4 simulations

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

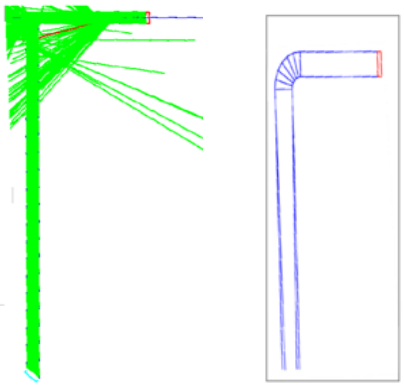
I-bar

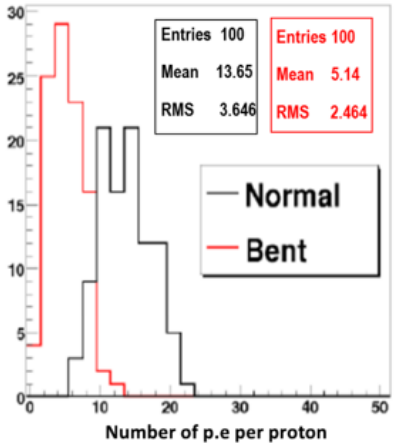


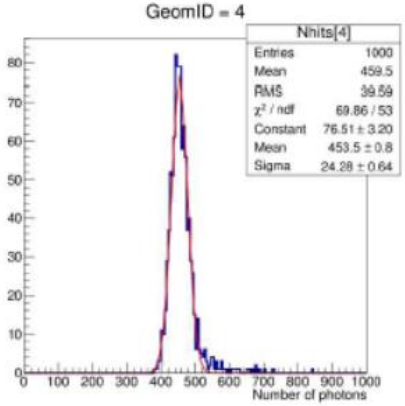
Pyramidal-bar



L-shape bar and **curved bar** (bar not in direct coupling with the PMT)

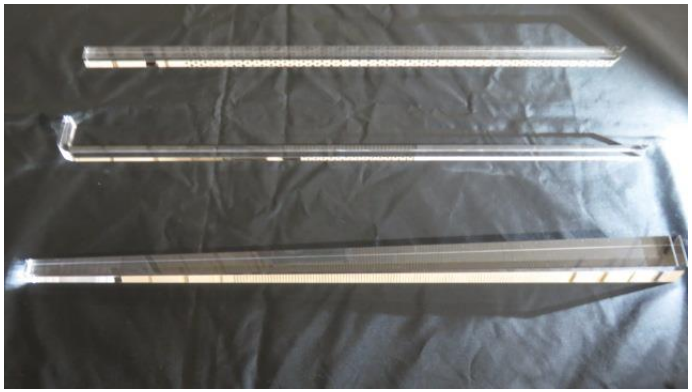


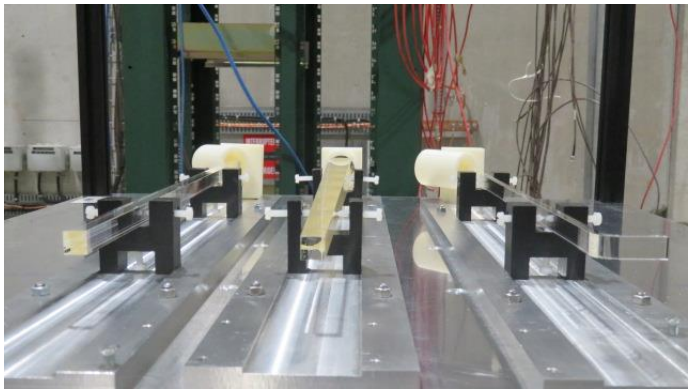


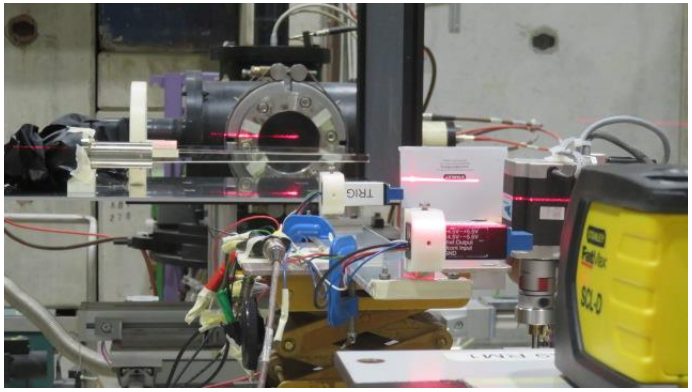


Bar geometries comparison in tests beam

Test (CERN - end of October) with π of 3 different quartz geometries: straight (I), curved and pyramidal bar

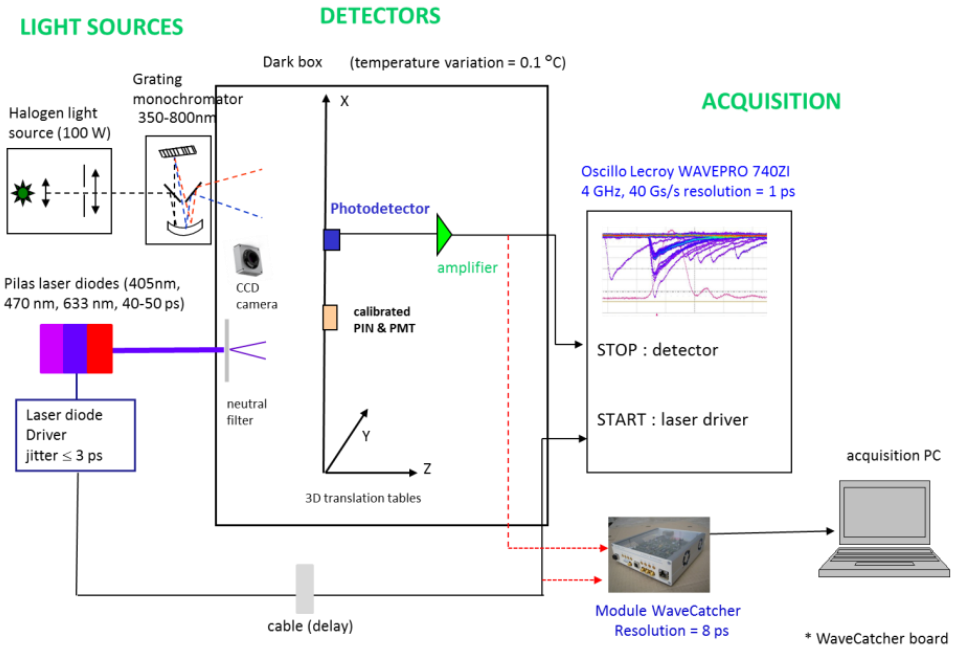


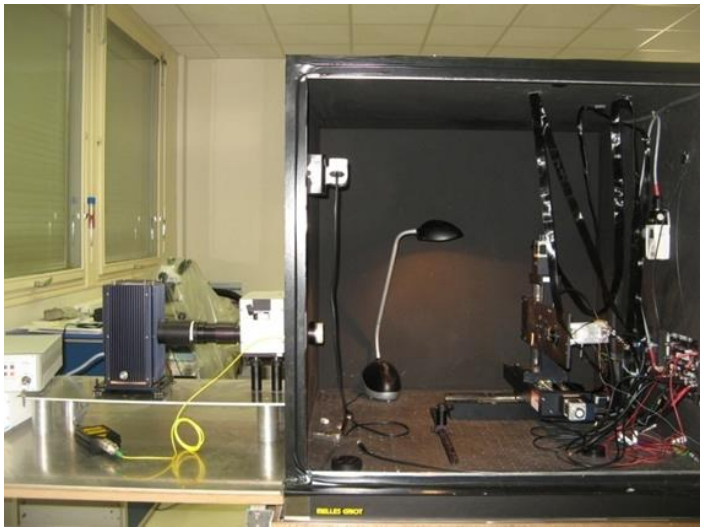


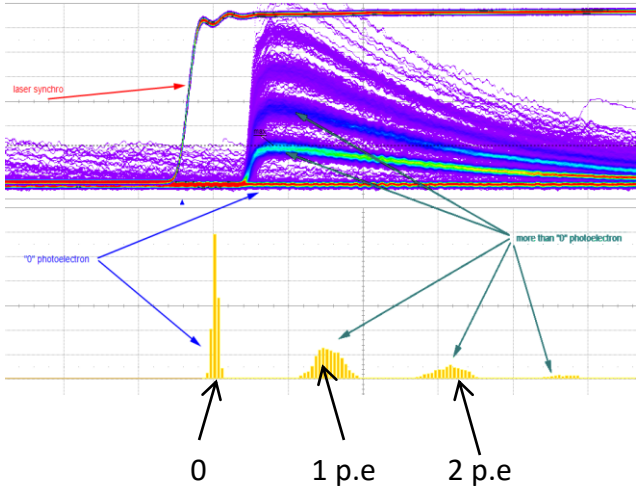


Analysis on-going but the in agreement with the simulation: pyramid is the best one

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 %

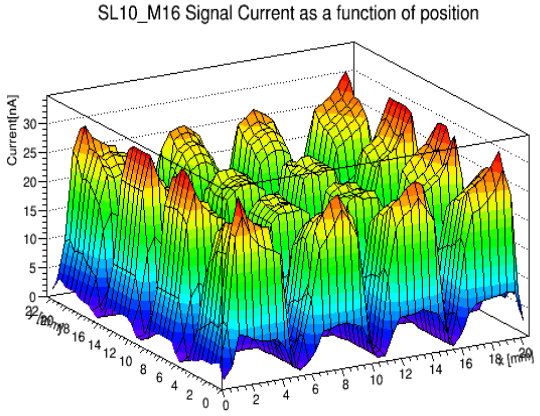
Oscilloscope 4 GHz, 40 GS/s and WaveCatcher module

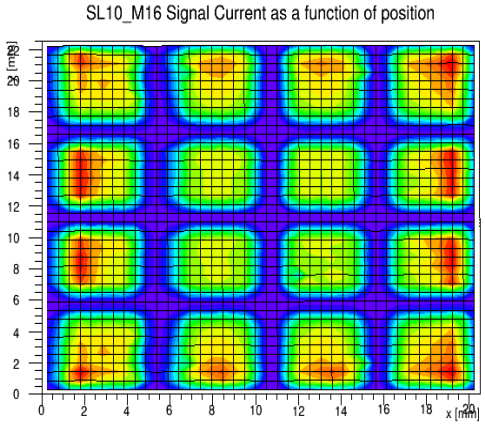
Photodetector studies

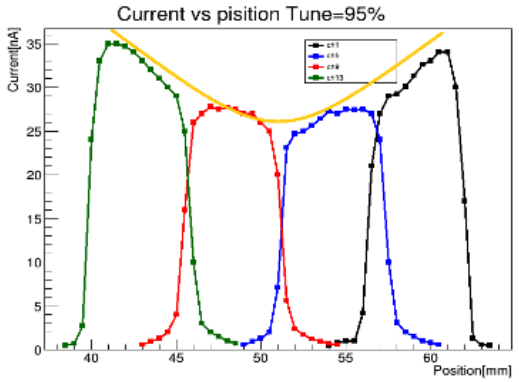
MCP-PMT HAMAMATSU SL10-M16 : MCP-PMT 16 channel, old generation

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

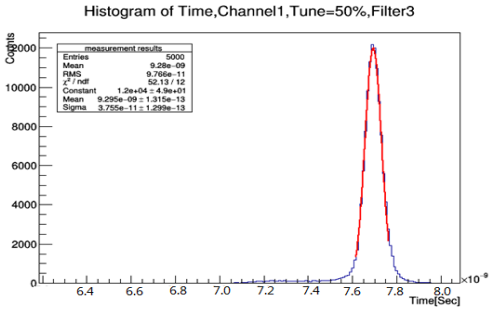
Mapping of the current response over the 16 channels







Single Photoelectron Timing Resolution (SPTR)

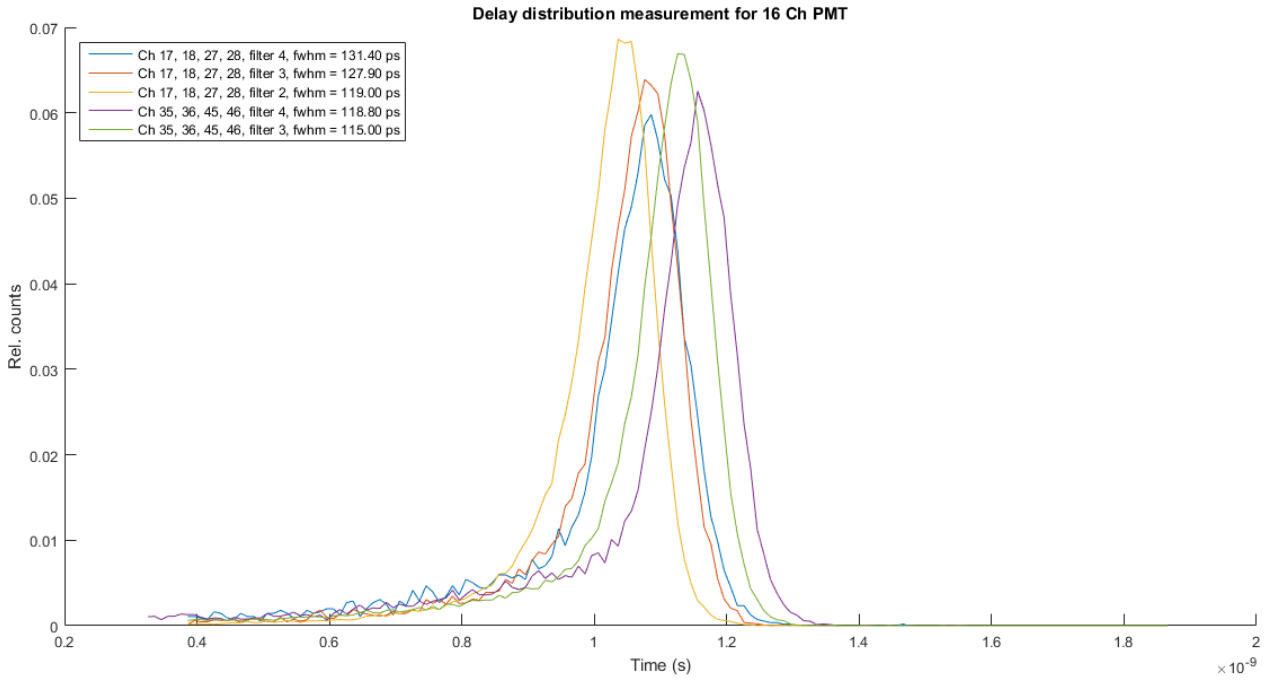


SPTR (σ) mapping

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

Photodetector studies

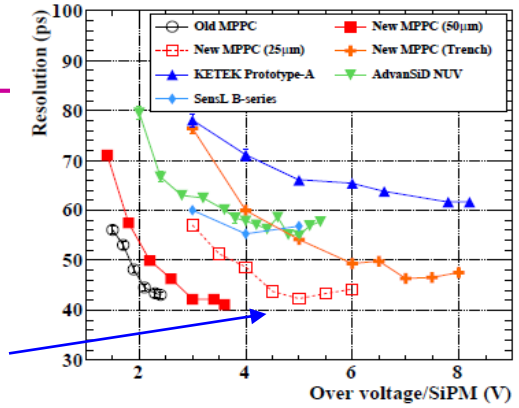
MCP-PMT BURLE XP85012: **MCP-PMT 64 channels (old generation)**



$SPTR_{best}$ (σ) = 55 ps

Photodetector studies

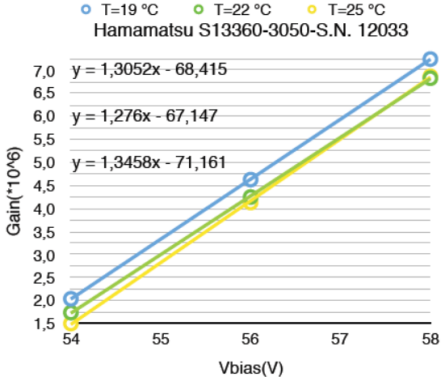
SiPMs : 4 SiPMs HAMAMATSU, 2 KETEK, 2 Sensl

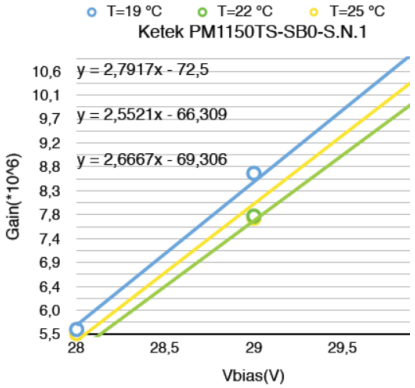


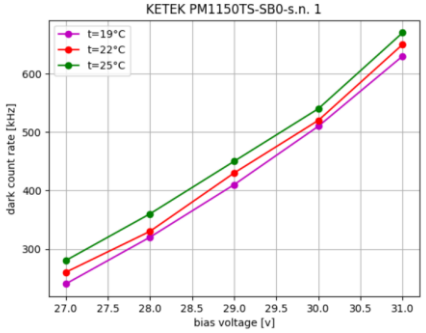
SPTR of 40 – 50 ps can be optained

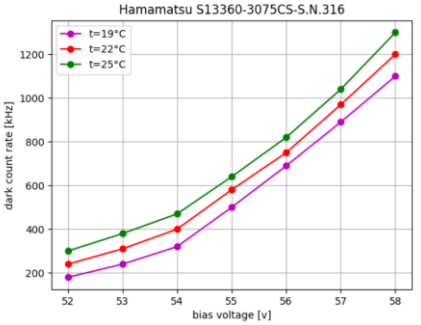
P.W Cattaneo, arXiv:1402.1404v1

Internship work of Tetiana POVAR

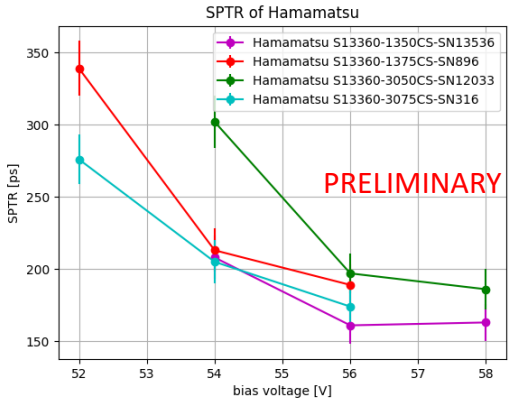


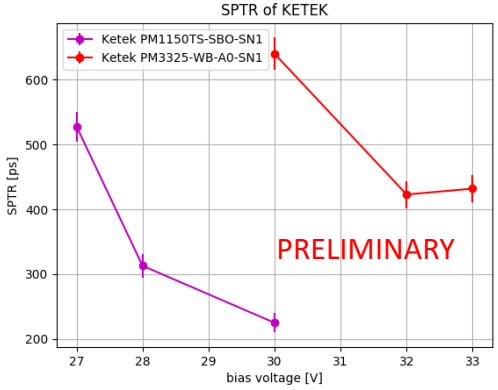






SPTR (FWHM) of HAMAMATSU & KETEK SiPM



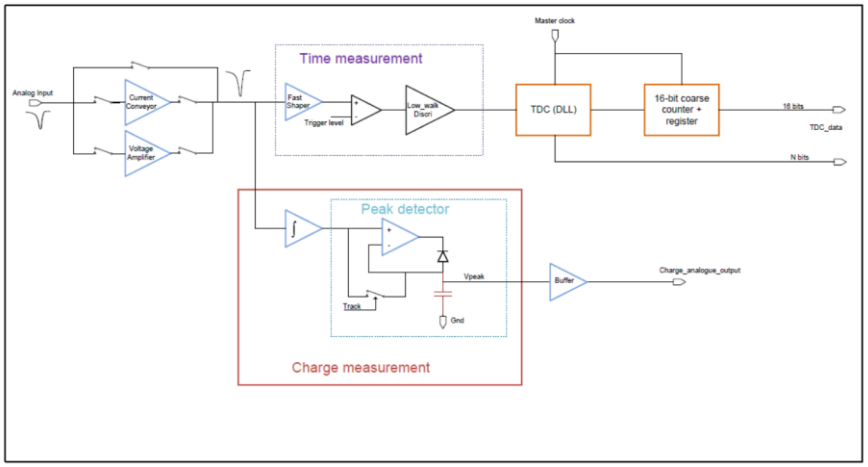


$SPTR_{best}$ (σ) = 70 ps

Readout Electronics development

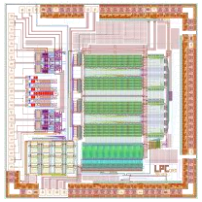
Requirements for the Cherenkov Lab ASIC

- Multichannel
- Single photon response
- Dynamic range of tens of kp.e
- Timing resolution of 20 ps rms
- High counting capability (2 MHz in average, 40 MHz for a few tens of events)



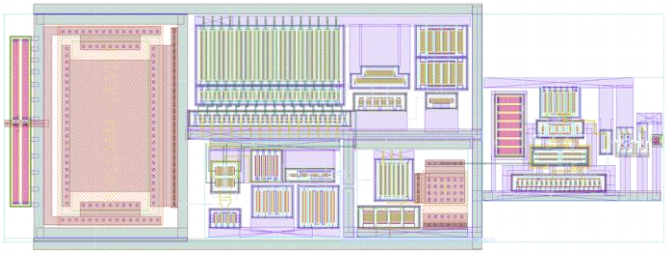
Challenge:

- ✓ the circuit has to work with different kinds of detectors
- ✓ wide dynamic range
- ✓ very high counting capability



What is ready:

- ✓ timing measurement
- ✓ threshold detection
- ✓ frontend stage
- ✓ charge measurement



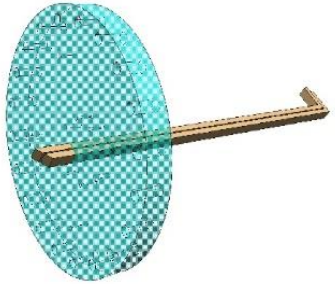
On-going:

Tests of the first proto (timing, partial charge measurement, slow control)

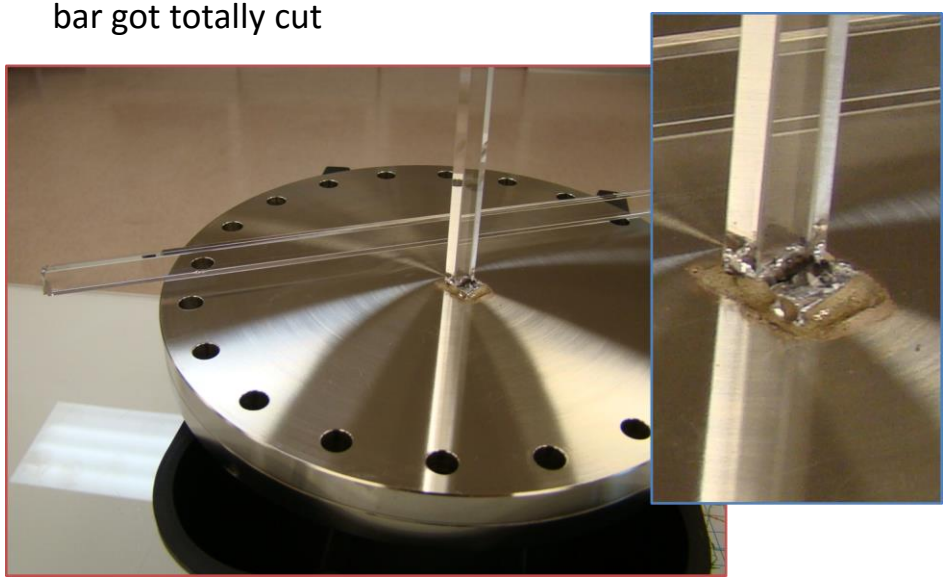
Mechanical integration of a Quartz bar in a metallic flange

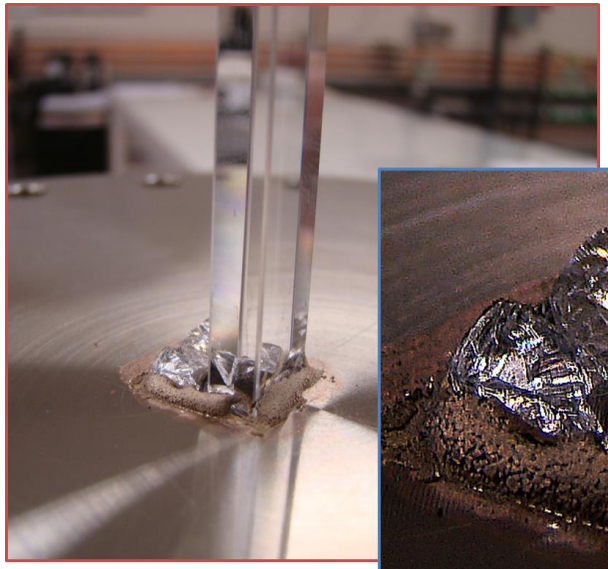
Example of quartz bar as a radiator for Cherenkov detection: the CpFM for UA9

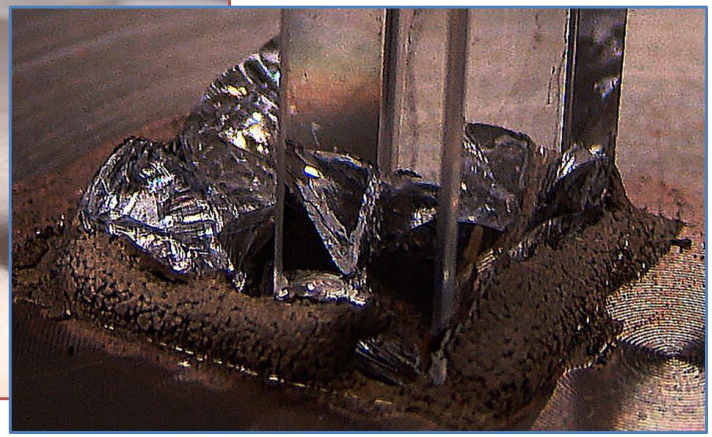
Initial design : the bars are brazed to the flange



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







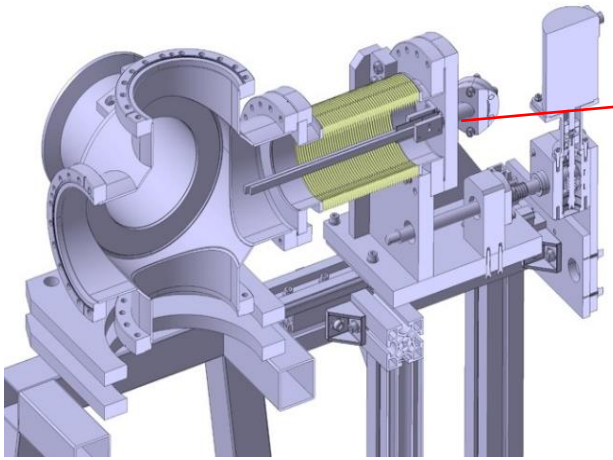
The last bar was not cut and hold on the flange but it is cracked

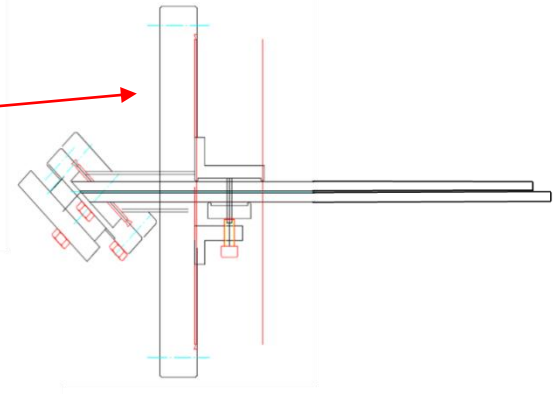
The issue seems to be the CTE gap (coefficient of thermal expansion) between the metal and the fused silica

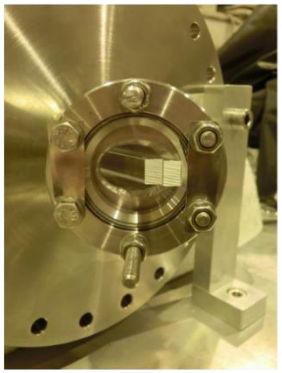
Mechanical integration of a Quartz bar in a metallic flange

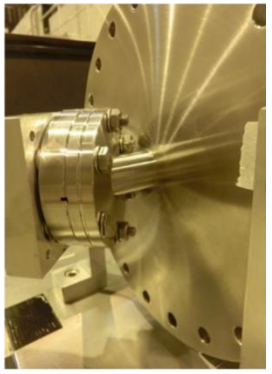
Example of quartz bar as a radiator for Cherenkov detection: the CpFM for UA9

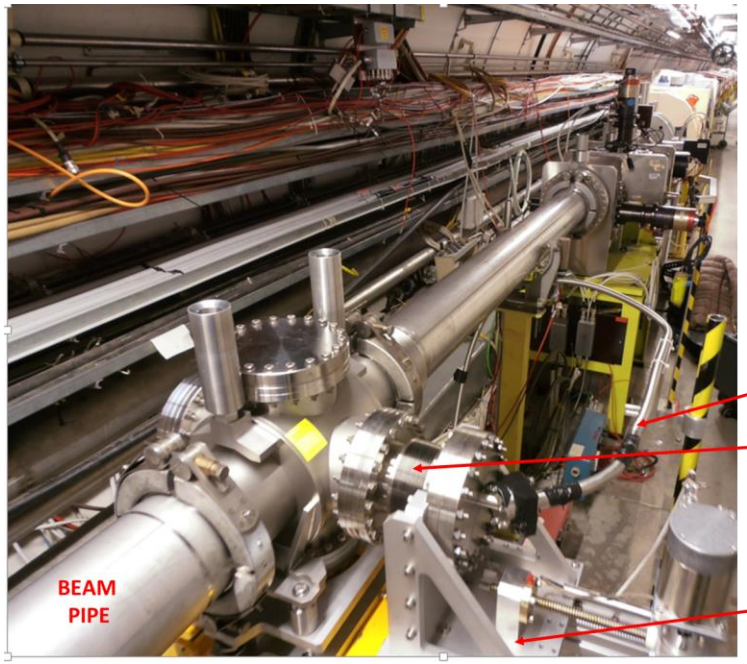
Final design : a Quartz viewport is the interface between the bars and the PMT → signal loss, low S/N







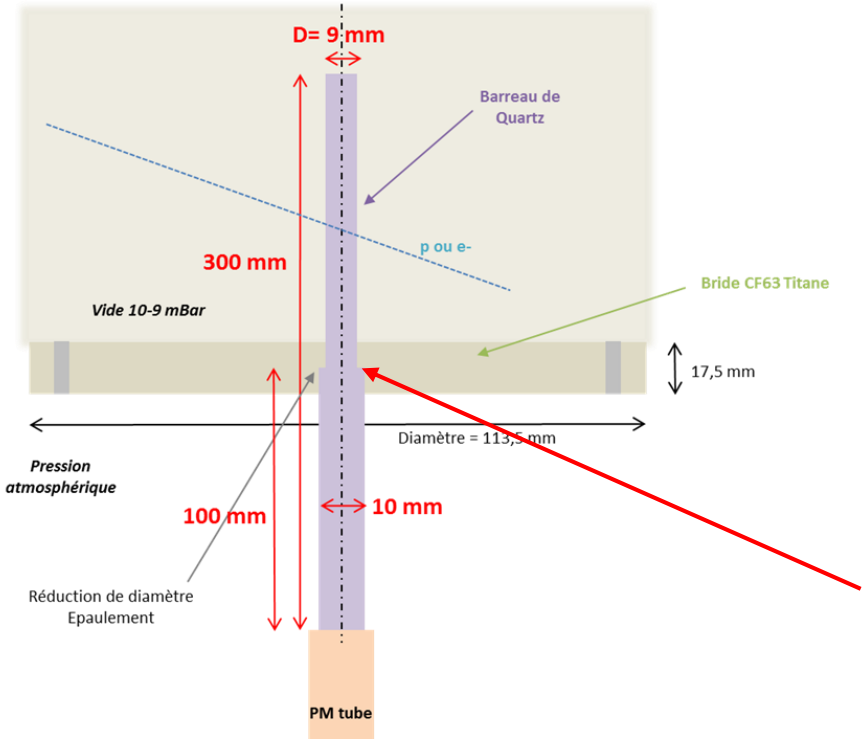




Mechanical integration of a Quartz bar in a metallic flange

Design of the First prototype for Cherenkov Lab :

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

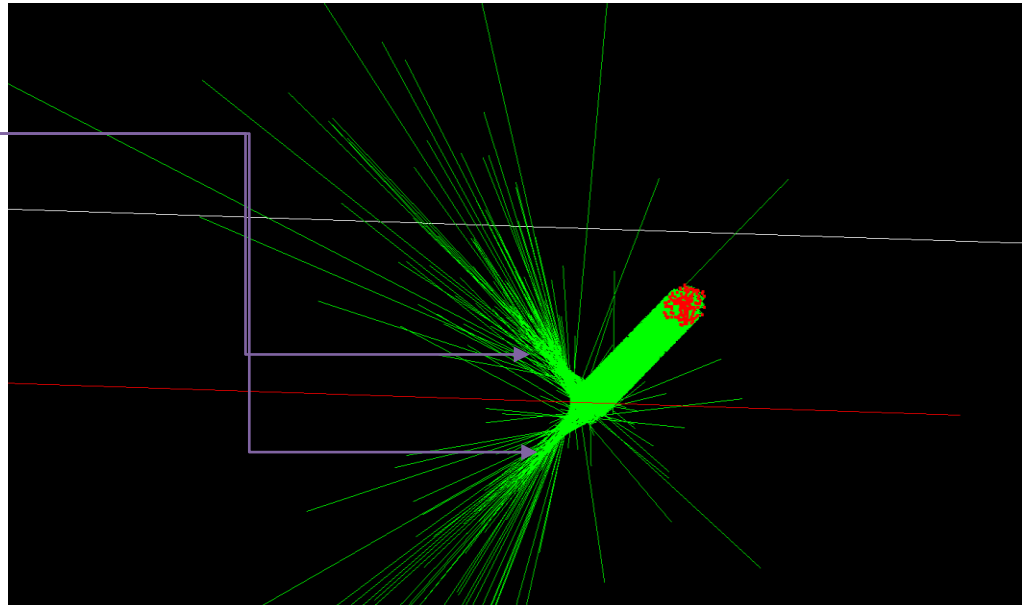


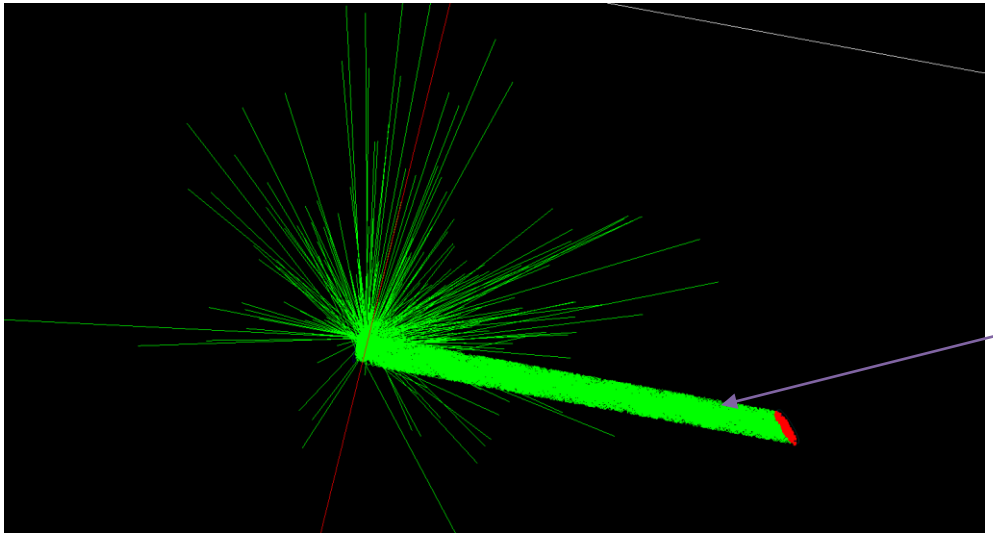
Asked by the company : shoulder where the flange and the bar will be brazed together

→ What consequences on the output signal ?

Simulation of a round Quartz bar (1/5)

diameter = 1 cm

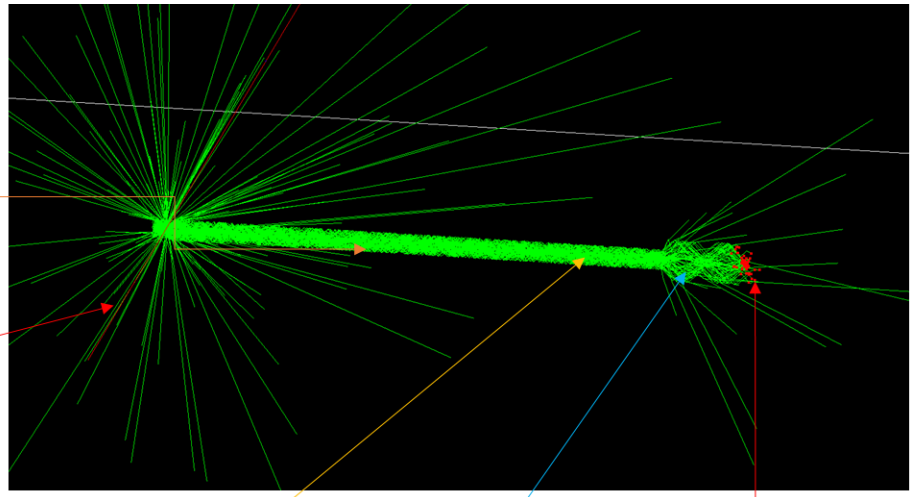


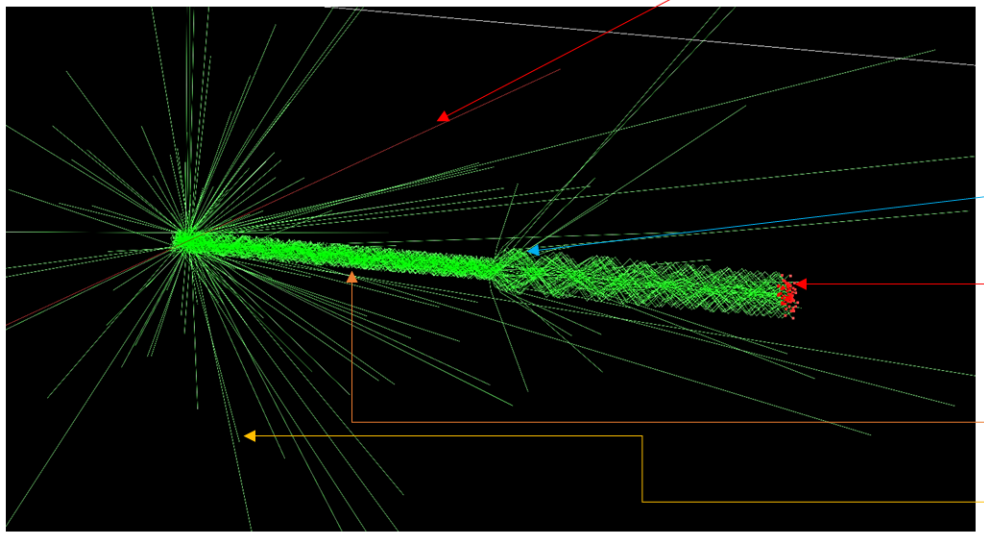


Losses are localized at the particle interaction point

Simulation of a round Quartz bar (2/5)

Simulation of the geometry proposed by the company (reduced diameter)





Diameter of 5 mm (instead of 10) on 80% of the bar length

Incident Proton

Total internal reflections

Shoulder (bar diameter reduction)

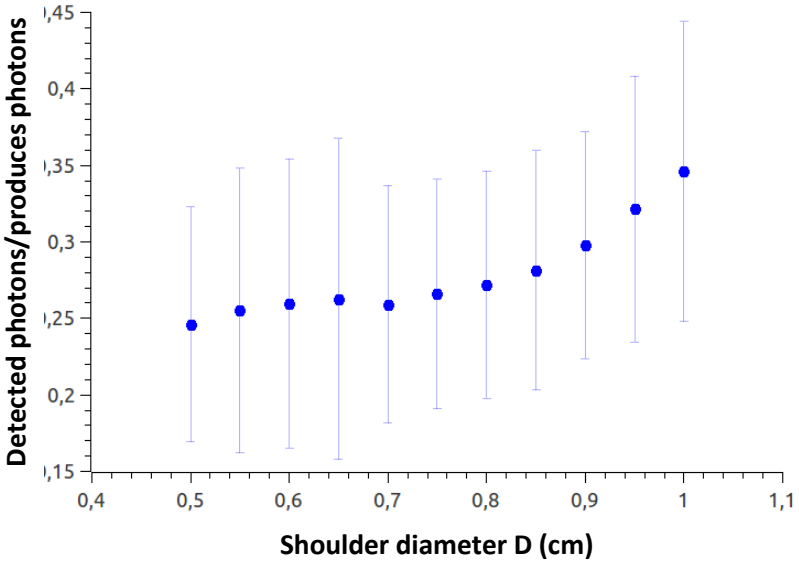
Detected Photons at the PMT surface

Diameter of 5 mm (instead of 10) on 50% of the bar length

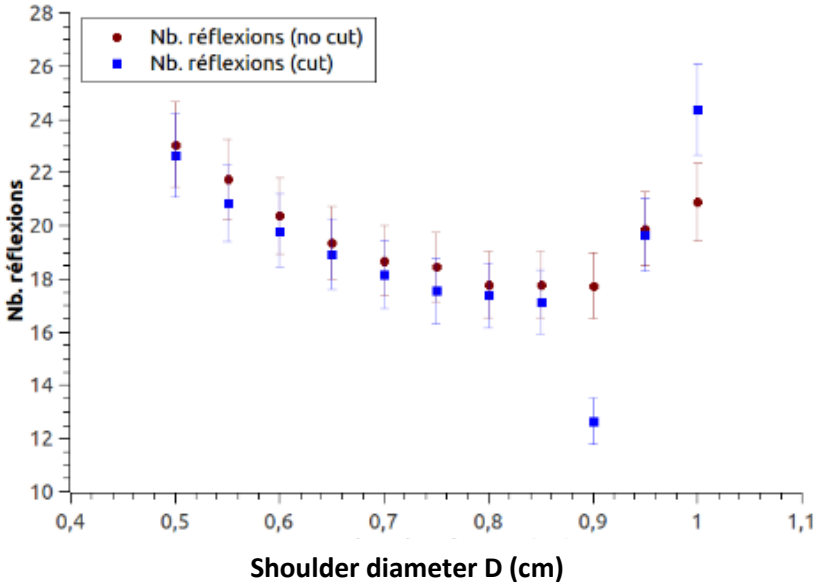
Lost photons

Simulation of a round Quartz bar (3/5)

Shoulder at 50% (diameter reduction over half the length of the bar)



- Nb. produced photons ≈ linear with the penetrated thickness (477 – 231 photons)
- Strong variation of the ratio detected photons/generated photons for D between 8.5 and 10 mm

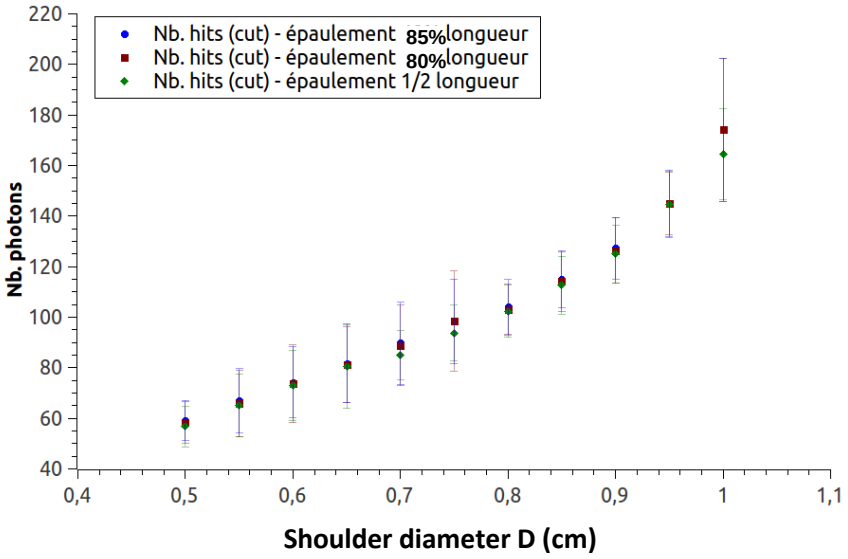


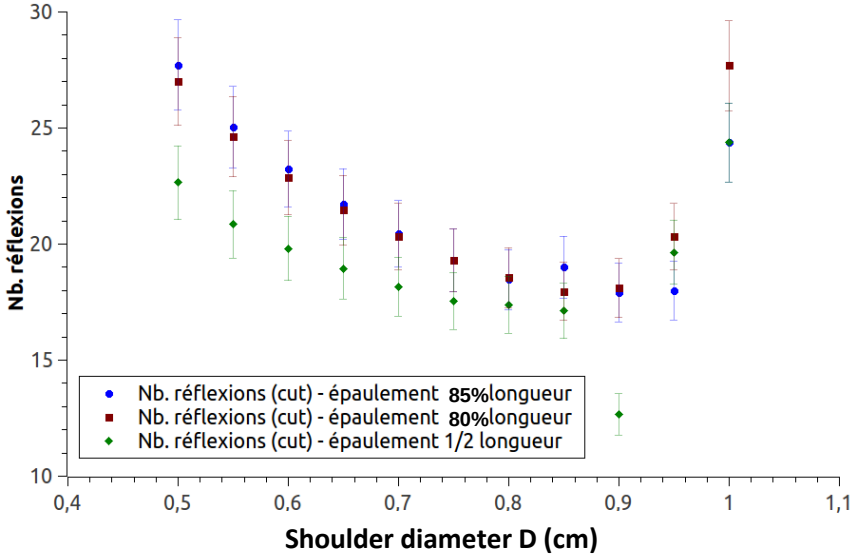
For the detected photons, the minimum of internal total reflections is found at D = 9 mm

* Cut : cut of the end of the bar at 47°

Simulation of a round Quartz bar (5/5)

Shoulder at 50%, 80 %, 85 %

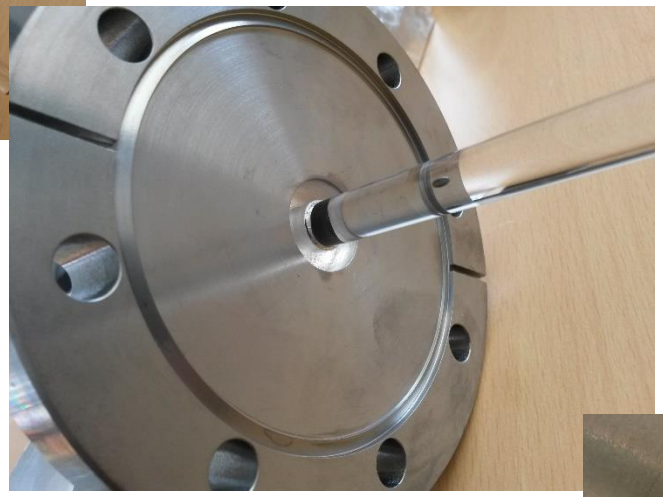




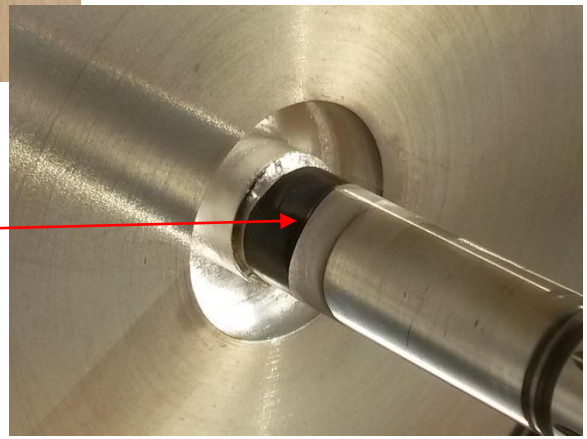
- No variation of the generated photons with the length of the shoulder
- Less reflections with a shoulder over 50% of the surface

First proto: round bar + flange

Good surprise : no breaking of the bar



Bad surprise: possible photon absorber



Metallic pipe (7 mm length x 0.5 mm width)
→ what consequence for the Cherenkov light yield ?

➡ To be measured

Conclusion

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

- R&D mechanical integration: first proto ready, need to try other designs (one of them is the metallic ion implantation at the quartz surface to ease the brazing)
- R&D electronics: on a good way, first block of the ASIC ready but many challenges to be faced
- Quartz polishing quality study: very difficult to find a company that can provide us with quartz samples with specific polishing quality
- Photodetector study on-going: we need detectors at their limits