CERN

Detector development at CERN

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1st Joint Beam Instrumentation group for DUNE-SP and DP

Outline:

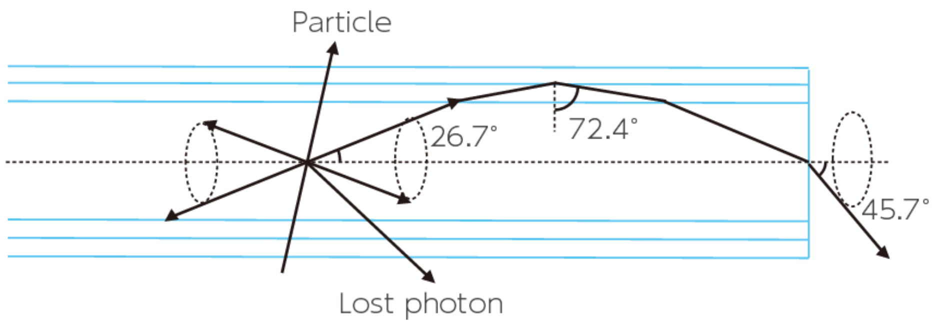
1- Introduction: scintillating fibres, photodetectors, electronics

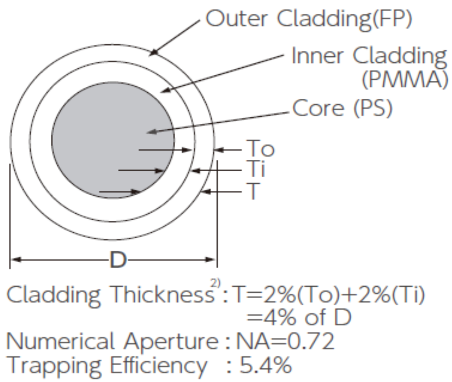
2- Prototype with SiPM

3- EHN1 extension monitor design (neutrino platform)

1- Introduction: scintillating fibres

They are a mix between scintillators and optical fibres



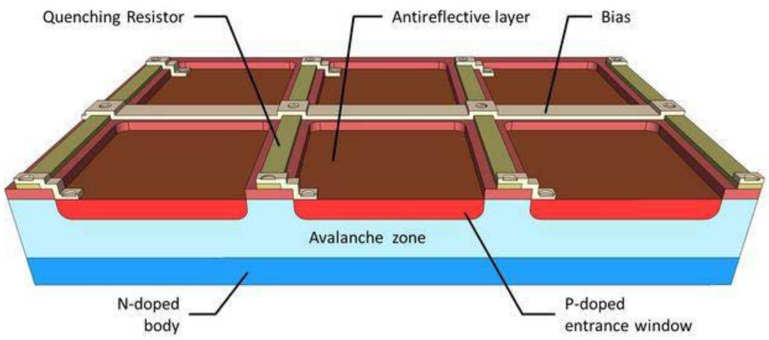


- Light yield ~8000 photons/MeV deposited
- Fast rising and decay times: ~1-3 ns
- Wavelength emission peak: ~420 nm (blue)
- Long attenuation length for blue photons: ~4 m
- Long X_0: low perturbation of the beam
- Radiation damage from kGy absorbed doses

Study of x/X_0

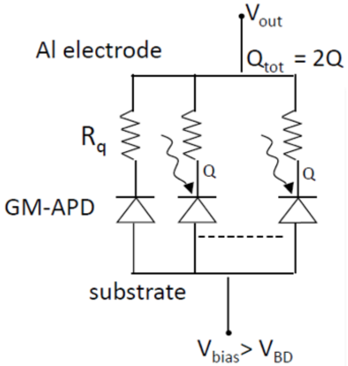
Detector	x/X_0 (%)
Multi-wire analogue chamber	0.34
Delay Wire Chamber	0.25
SciFi 1 mm (2 layers: X & Y)	0.47
SciFi 0.5 mm (2 layers: X & Y)	0.24

Silicon photomultipliers: matrix of avalanche photodiodes connected in parallel



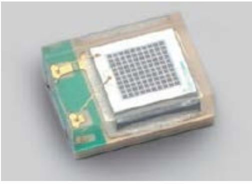
Advantages:

- High gain: 10^6
- High detection efficiency: 40% at 450 nm
- Fast rise time: ~1ns
- Small size
- Low voltage
- Insensitive to magnetic fields
- New technology: further development expected
- Potentially cheap



Drawbacks:

- High dark count rate at room temperature: 100kHz/mm^2
- Work better in low temperatures



<u>Multi-Anode PMT</u>: matrix of PMT sharing a common cathode.

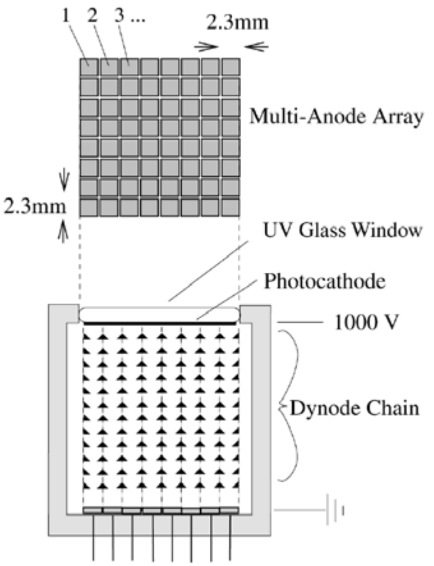
Advantages:

- High gain: 10^6
- High quantum efficiency: ~40% at 420 nm
- Fast rise time: ~1ns
- Short pulse signal: ~15 ns
- Low dark count rate: few Hz
- Compact size

Drawbacks:

- Gain uniformity between channels: can be a factor 3
- Cross-talk
- Sensitive to magnetic fields
- They need high voltage: 1kV

Price per channel similar to SiPM



64-Channel MaPMT:
Hamamatsu R7600-03-M64

Electronics

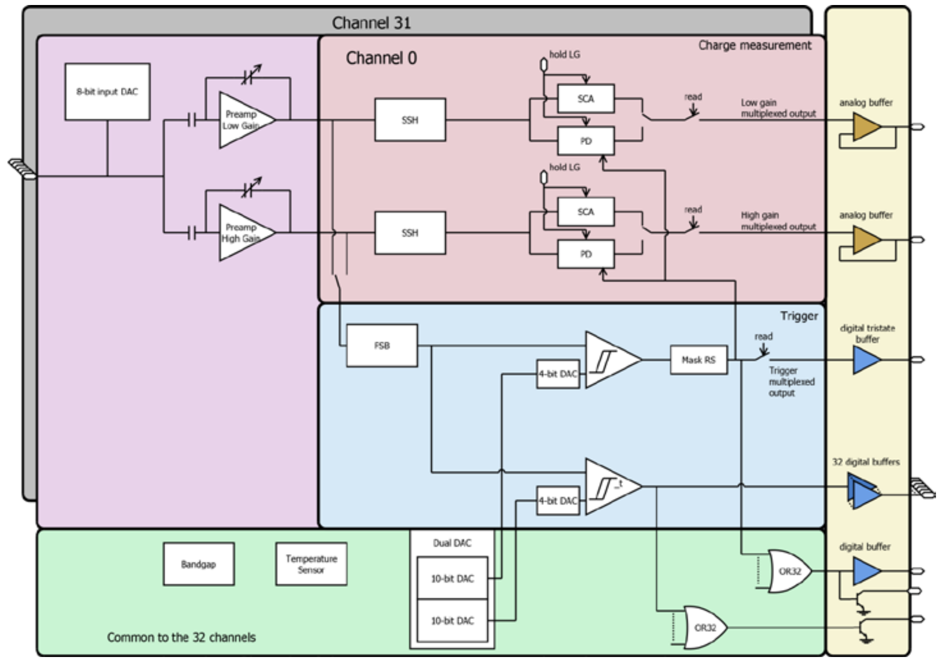
We have studied several ASIC for the electronics readout.

For SiPM: CITIROC, NINO or STiC

For MA-PMT: MAROC or CLARO

CITIROC: an analogue front-end ASIC made by Omega Microelectronics (CNRS-IN2P3-Ecole Polytechnique)

- 32 channels with adjustable SiPM voltage
- Adjustable preamplifiers
- Variable slow shapers, track & hold and peak detector for charge measurement
- Variable fast shaper and discriminators for trigger
- Digital output of the trigger signals



CITIROC's Block diagram

3- Prototype with SiPM

A first prototype has been made and successfully tested in the H8 beam line of the North Area:

- Only one plane composed of 64 square fibres of 1mm thickness and no space between them → covered 64mm of the vertical profile
- Fibres Saint-Gobain BCF12, 1mm square, multi-cladding. No coating → there is cross-talk
- Used aluminium mirror on one end to increase light collection
- Read 1 every 2 fibres for simplicity on electronics acquisition → spatial resolution of 2mm
- Hamamatsu MPPC S13360-1350 as photo detector
- Used CITIROC evaluation board for electronics readout: 32 channels
- VME scaler modules for the data acquisition → only profile and intensity measurements
- Integrated in the vacuum tank of the FISC → fibres in vacuum, MPPC in air

Data taking timeline:

20th October – 11th November

- *Z=1 beams: electrons, pions, protons…*
- *Momentums from 20 GeV/c to 180 GeV/c*
- *Intensities from 10^3 to 10^6 particles/spill*

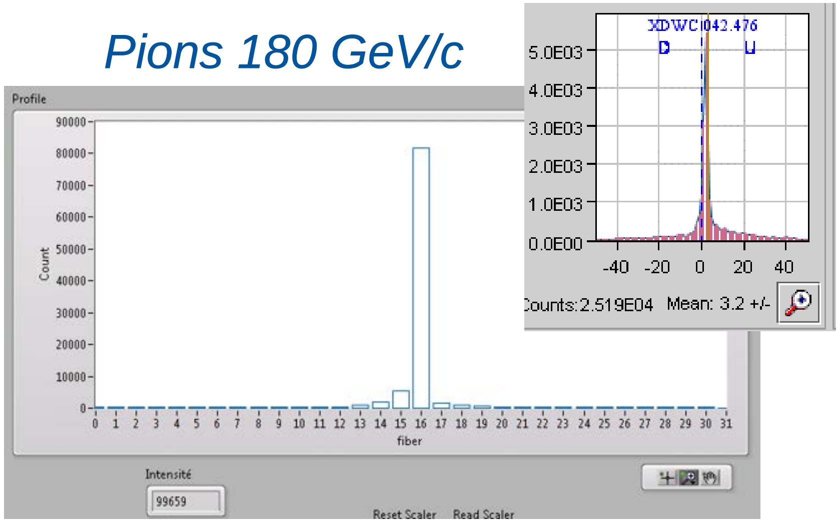
18th November – 30th November

Pb(82,208) ions

Beam profiles in H8

Pions 180 GeV/c

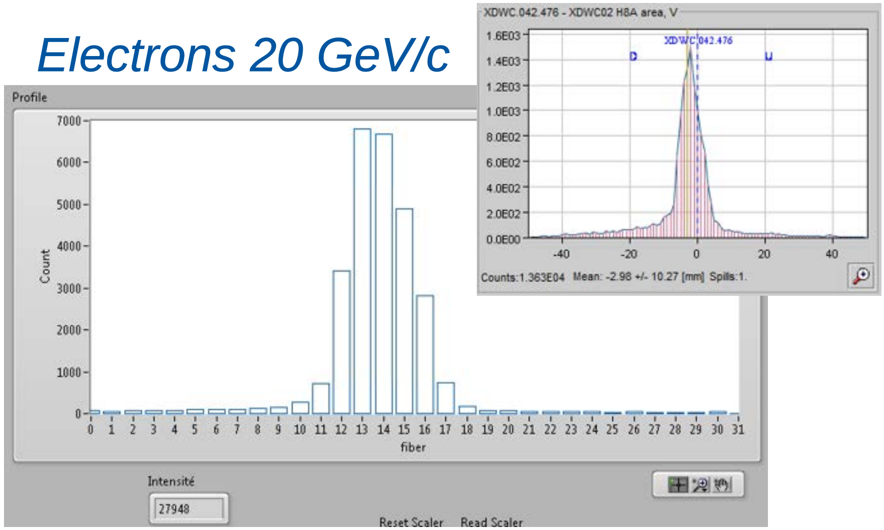
Delay wire chamber



Fibres

Electrons 20 GeV/c

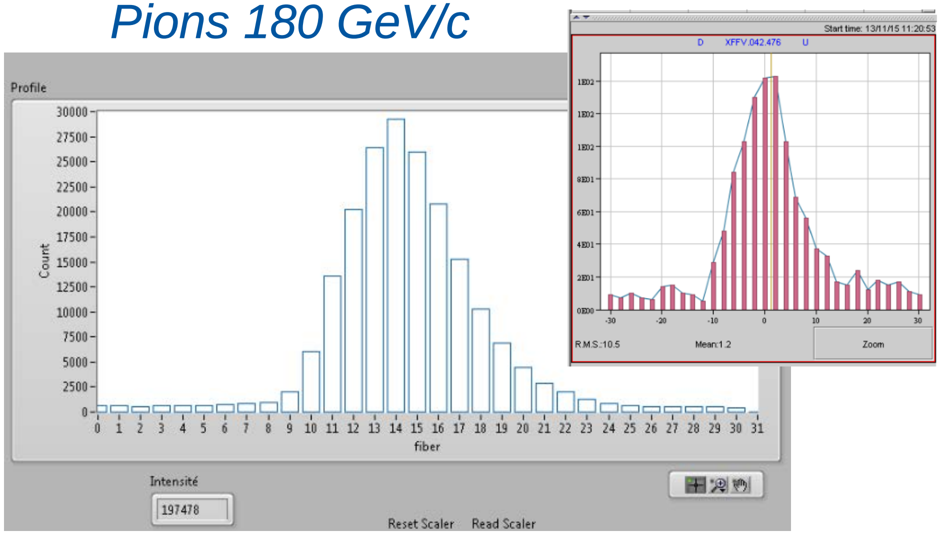
Delay wire chamber



Fibres

Pions 180 GeV/c

FISC



Fibres

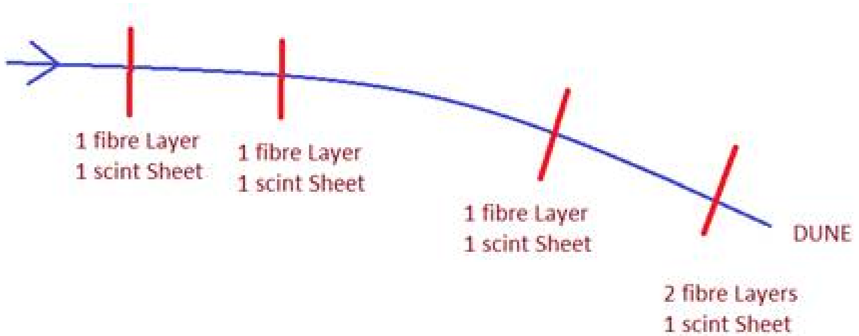
4- EHN1 extension monitor design (neutrino platform)

Several design scenarios. We need to fix one:

- 0.5mm or 1mm square fibres: for 0.5mm -> 400 fibres per plane -> 400 photosensor channels! (x2 the price than 1mm fibres)
- Detector layout:
  - 3 detectors with only 1 layer for the spectrometer and 1 detector with 2 layers for profile reconstruction
  - 4 detectors with 2 layers (X&Y)
  - …

In the case with only 1 layer, a tile of 2mm of an organic scintillator could be added to trigger the fibre detector and reduce the noise.

In the case with 2 layers we could accept only events that have happened in both layers X&Y



Monitor proposal

Overall design:

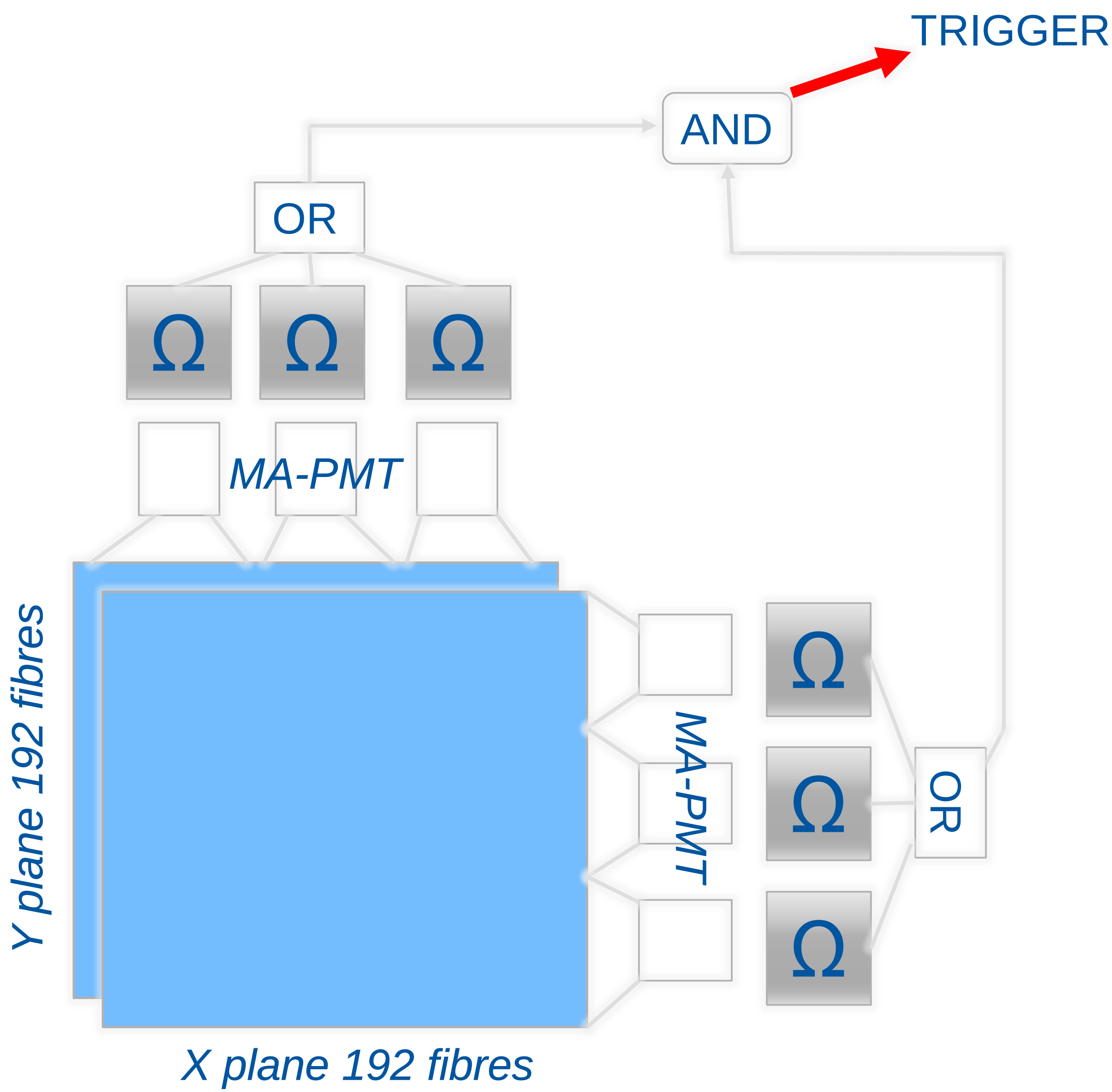
- 1mm square fibres
- 2 planes X&Y: 2mm of Polystyrene per detector.
- 192 fibres per plane with no space between them -> 192mmx192mm covered area
- A mirror on one end to increase light collection
- Light read with MA-PMT
- Front-end electronics including MAROC and FPGA

We can offer a trigger to the experiment:

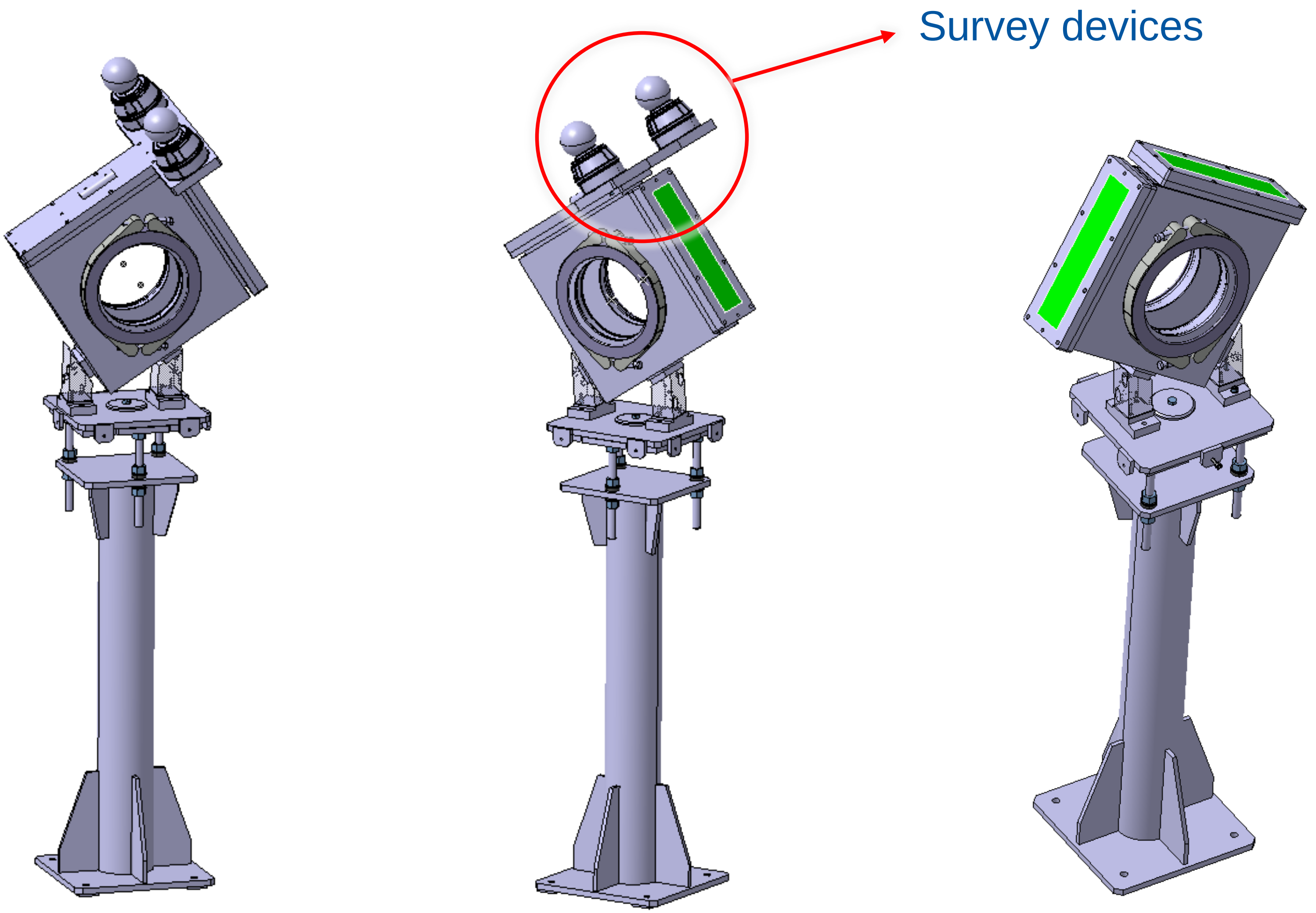
- Required timing?
- Timing precision?

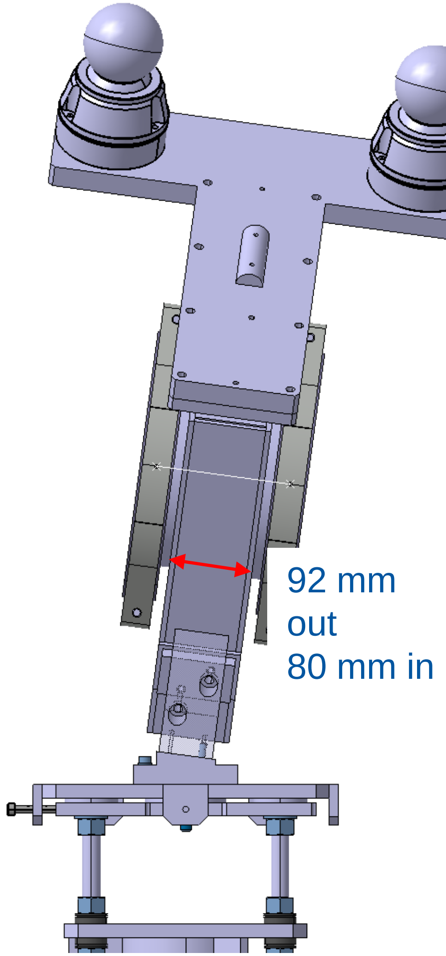
Additionally we can offer:

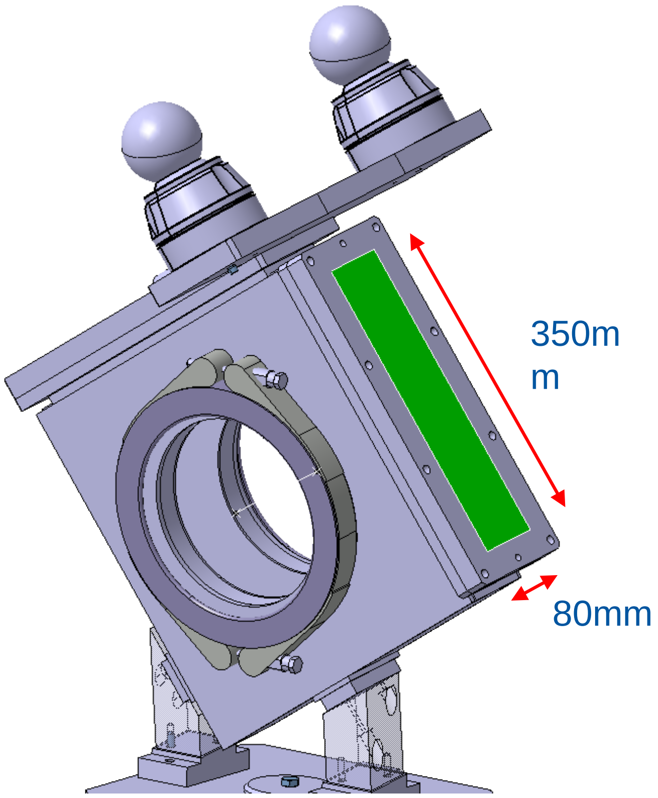
- Time stamp in the events respect to the beginning of the spill with 10ns precision
- Fibre stamp

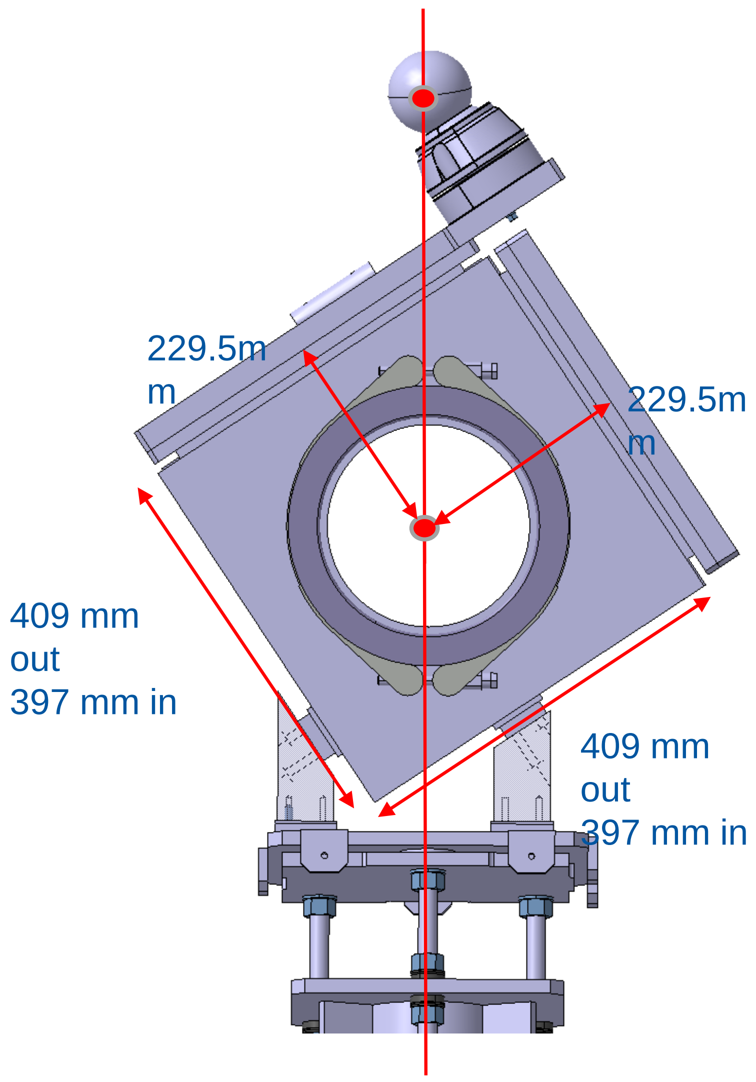


Modular design: planes easily replaceable




92 mm
out
80 mm in


350m
m
80mm


229.5m
m
229.5m
m
409 mm
out
397 mm in
409 mm
out
397 mm in

Thanks for listening

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