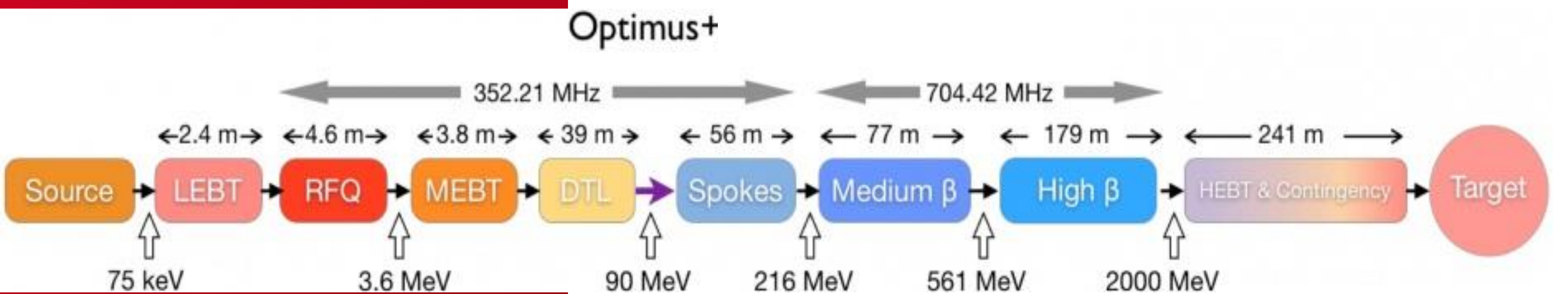
DE LA RECHERCHE À L'INDUSTRIE

SOURCE SIGNAL ESTIMATION AND READOUT SYSTEMS

ESS-0092071 & ESS-0092072
CEA-ESS-DIA-RP-0016 & CEA-ESS-DIA-RP-0017



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www.cea.fr

OUTLINE

I. Source signal estimation

  a. Model
  b. Assumptions
  c. Results

II. Readout systems

  a. Conductive strips
  b. MCP and conductive strips
  c. MCP, Phosphor Screen and Camera
  d. Silicon pixelated sensor and TimePix3

I. SOURCE SIGNAL ESTIMATION

Ionization

- Goal: estimate the number of ionized ion/electron pairs created

- $N_{ionization\ pairs} = N_{beam} \cdot \frac{1}{W} \cdot \frac{dE}{dx}$
  - $\frac{dE}{dx}$ ➔ESS stopping power
  - W ➔Energy to produce a pair
  - N_{beam} ➔ Number of protons in one pulse beam

- To quantify the stopping power➔Bethe-Bloch

A. MODEL

Bethe-Bloch

$$\frac{dE}{dx} = K \cdot \rho \cdot \frac{Z}{A} \cdot \frac{z^2}{\beta^2}\left[\frac{1}{2} \cdot \ln \frac{2 \cdot m_e \cdot (\beta\gamma)^2 \cdot T_{max}}{I^2} - \beta^2\right]$$

- Stopping power of heavy charged particle in a medium
- Constants
- Medium ➔ Most valuable parameter: density of medium
- Incident particle ➔ Most valuable parameter: energy of particle

B. ASSUMPTIONS

Medium: ESS Vacuum

- Perfect gas mixture:
  - 79% H_2
  - 10% CO
  - 10% CO_2
  - 1% N_2
- At 10^{-9} mbar ➔ Low density !

Particle: Protons Beam

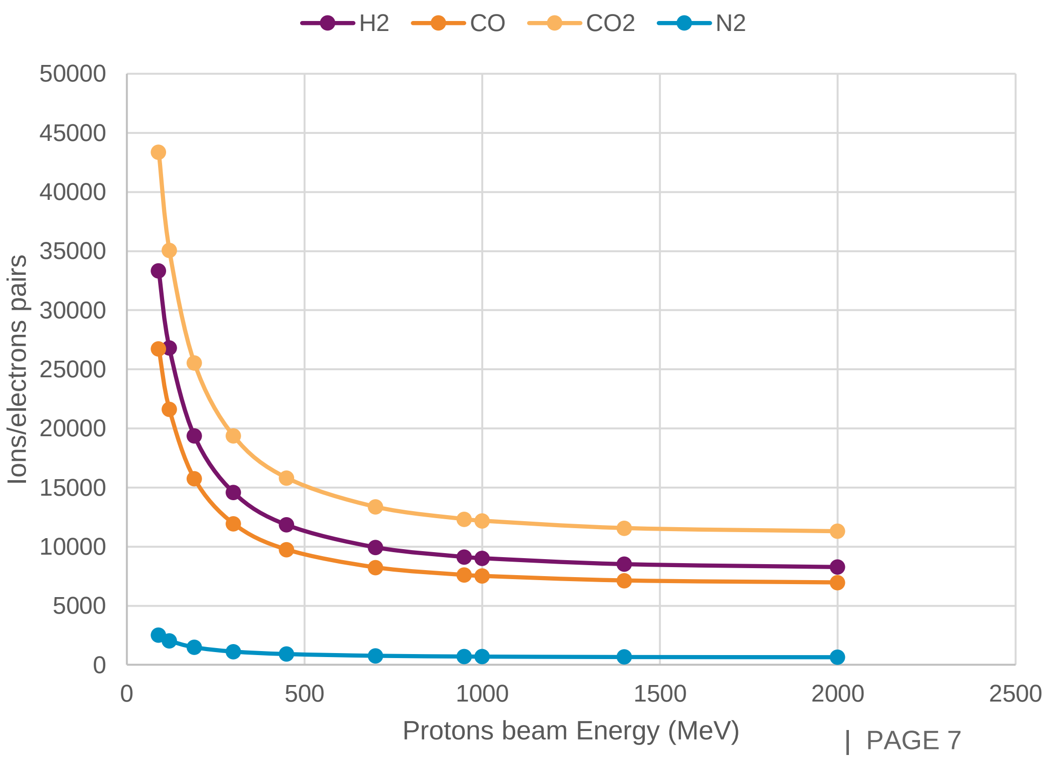
- Protons
- From 90MeV to 2GeV
- Pulse length: 2.86ms
- Pulse repetition: 14Hz
- 62.5mA ➔ 10^{15} protons per pulse

C. RESULTS

Energy (MeV)	Ions/Electrons per pulse per cm	Charge (fC)	I(pA)
90	105986	17	5.94
200	60159	9.6	3.35
500	36622	5.87	2
1000	29463	4.72	1.65
1500	27717	4.44	1.54
2000	27224	4.36	1.52

Gas	Proportion %	Contribution %
H_2	79	30
CO	10	25
CO_2	10	40
N_2	1	5

- Signal expected is very low
- Contribution != Proportion
- Independent to readout !



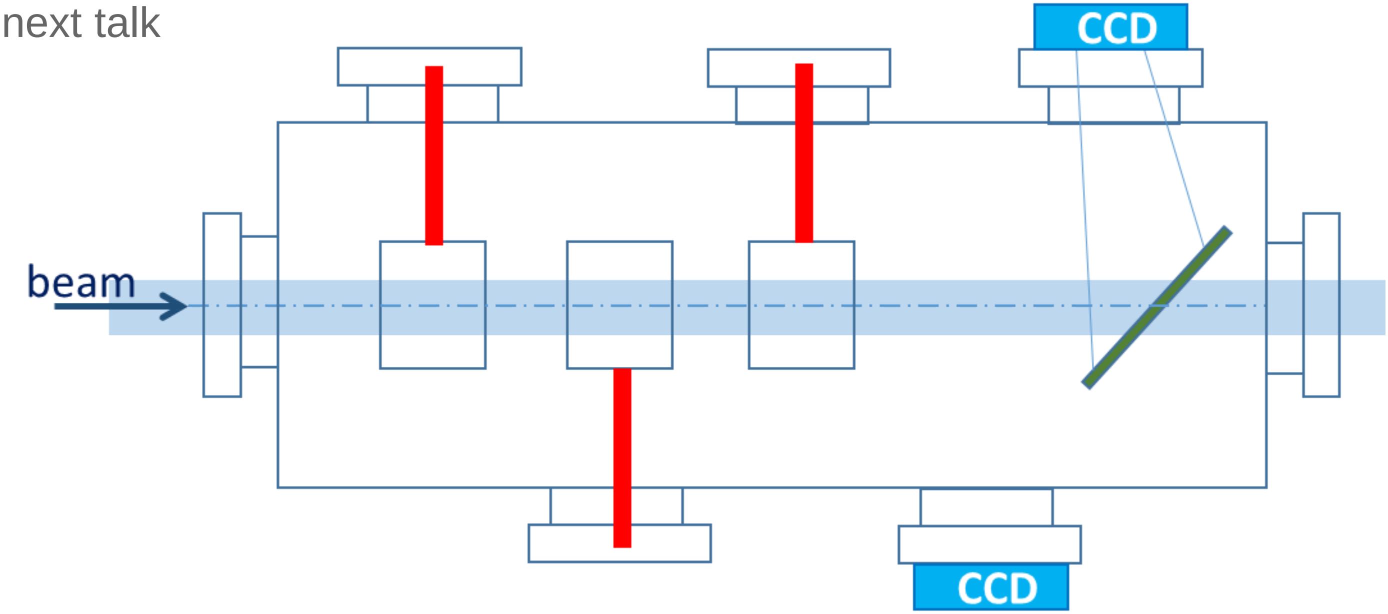
II. READOUT SYSTEMS PRESENTATION

Requirements

- ESS facility ➔ Reliable readout system
  - Radiation hard
  - Ageing of device
  - Low outgassing materials compliant to ESS rules
- Low Signal ➔ High Sensitive readout
  - Measure at beam intensity 62.5 mA down to 6 mA current
- Speed:
  - Pulses (integration)
  - Pulse
  - Bunches (pulse behavior)
- Ions detection ➔ Readout should work either with ions or electrons
- Electronics integration

Several readouts

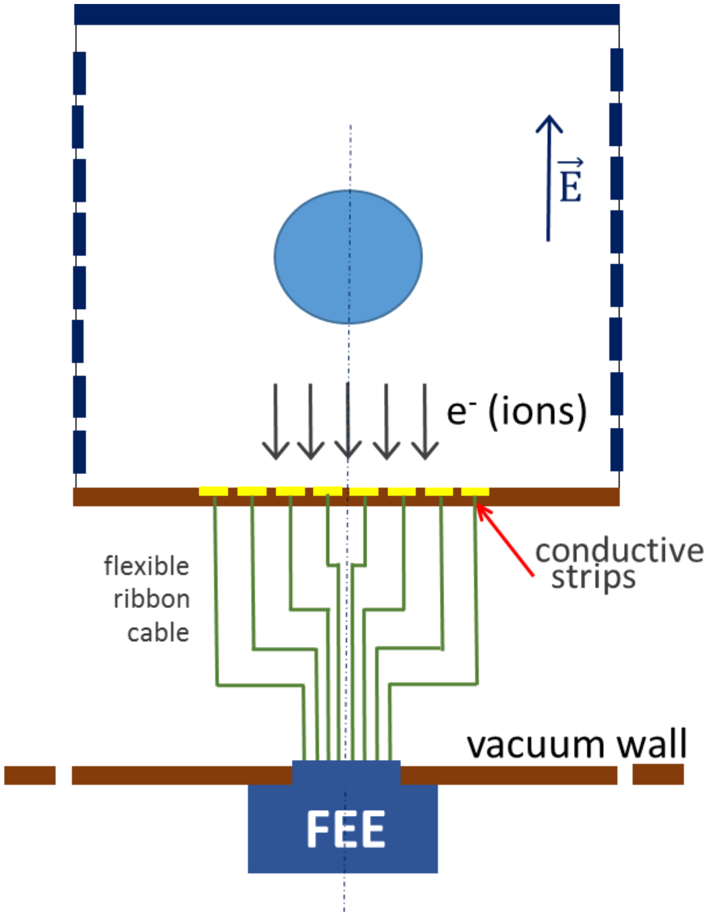
- Many requirement ➔test several readouts in order to find the best one
- Four interesting readout has been selected
- We will be able to test several readout (at least 3) with one test bench
- See more on next talk



A. CONDUCTIVE STRIPS

Principle of operation

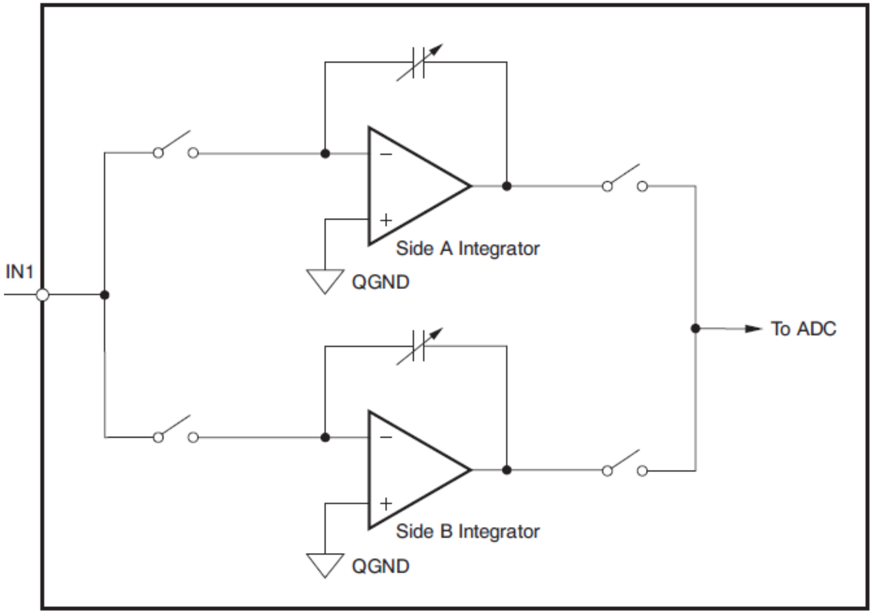
- Ceramic PCB with conductive strips
- Charge in motion induces current on strips
- Integrator or transimpedance amplification



Electronics

TEXAS INSTRUMENTS

- Existing solution: the DDC chips family from TI
- Double integrator for continuous integration + ADC
- Multichannel (2 up to 64)
- Integration range:
  - Time: 10µs to 1s
  - Selectable range: 3pC up to 350pC
  - Noise: few ppm decades of FSR (see next slide)

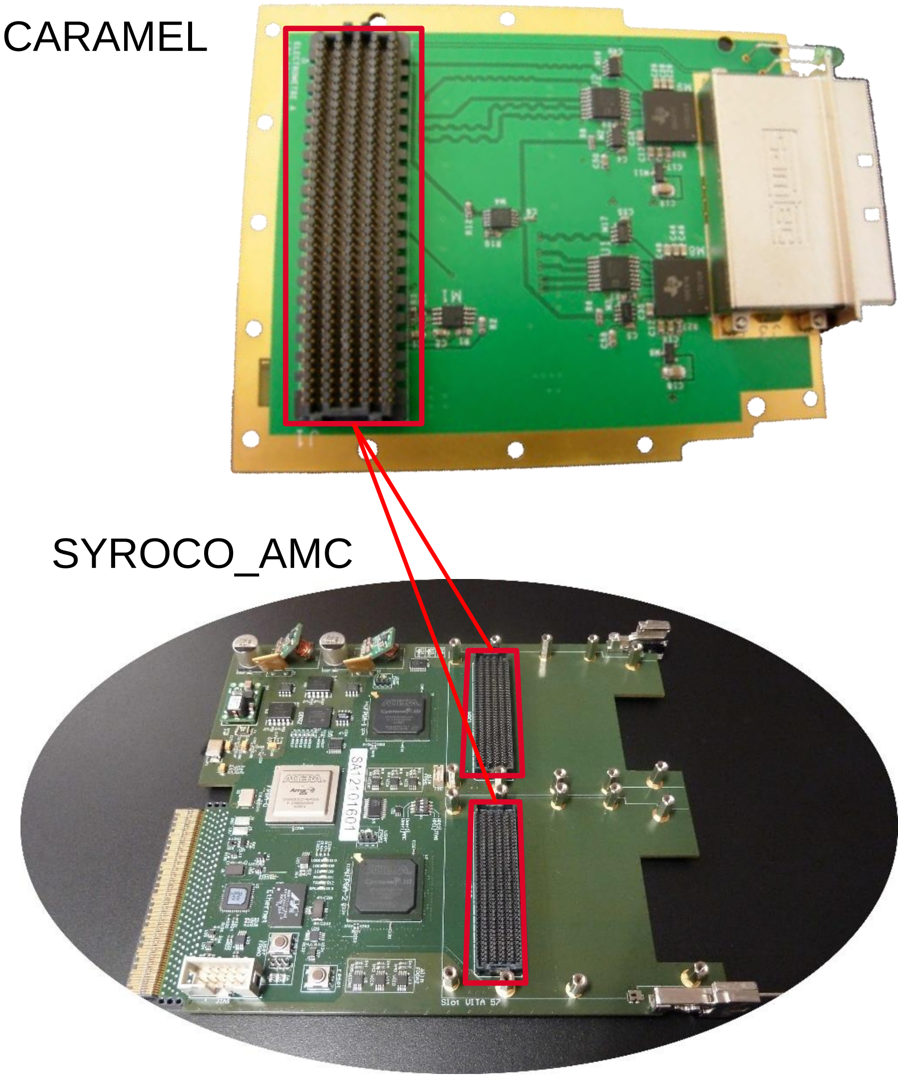


http://www.ti.com/product/DDC264

A. CONDUCTIVE STRIPS

Electronics

- DDC family is already used in Nuclear Instrumentation
- CARAMEL Board by LPC (Caen, France)
  - http://faster.in2p3.fr/
- CARAMEL ➔ 2 × DDC316
  - 32 channels
  - 16 bits
  - Range: 3pC up to 12 pC
  - 10 µs to 1 ms
- µTCA solution:
  - CARAMEL (DAQ)
  - SYROCO_AMC (CS)



Electronics (Noise)

- Noise with DDC depending on:
  - Range selected
  - Sensor capacitance
- Example with DDC316 (see Table)
- Signal is in noise

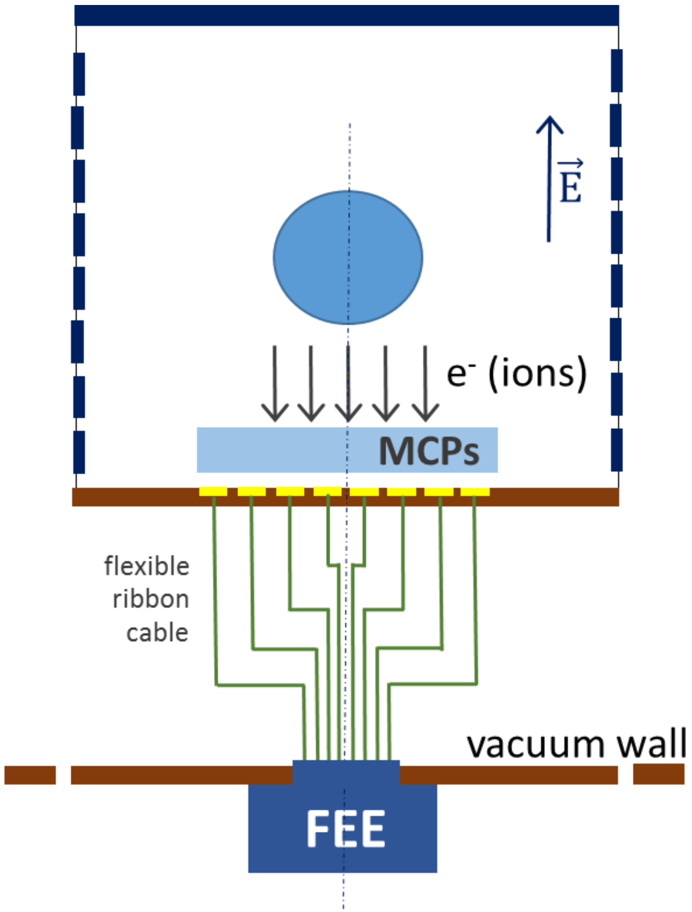
To go away from vacuum (and rads)
2 meters of cable ~ 100pF

Range selected	Noise in fC (C_{sensor} =20pF)	Noise in fC (C_{sensor} =50pF)	Noise in fC (C_{sensor} =100pF)
-0.046 to 3pC	0.6	1	1.57
-0.18 to 12pC	0.93	1.17	1.7

B. MCP AND STRIPS

Principle of operation

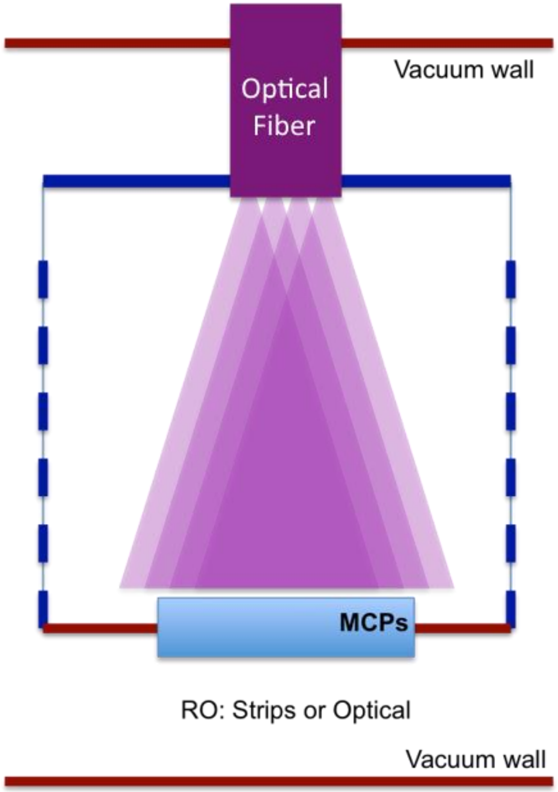
- MCP multiplies ions/electrons
- Use MCP to increase signal on strips
- Typical gain of a MCP:
  - Single: 10^4
  - Double (stack): 10^6
- For 4fC as MCP input ➔ $4 \times 10^4 \times 0.6 = 24$pC
- So readout electronic can be the same as previously !



MCP Ageing

- MCP drawback: Ageing
- Depending of gain
- Data on ageing from Hamamatsu
- E.g. gain: 10^4, at 90MeV: 105k ions/e-
  - At t = 0 gain = 100%
  - At t = 1,4 years gain start to decrease
  - At t = 14 years gain = 80%
  - Gain should be optimized
- A calibration system is also considered
  - Uniform UV light + OF
  - RO offline correction

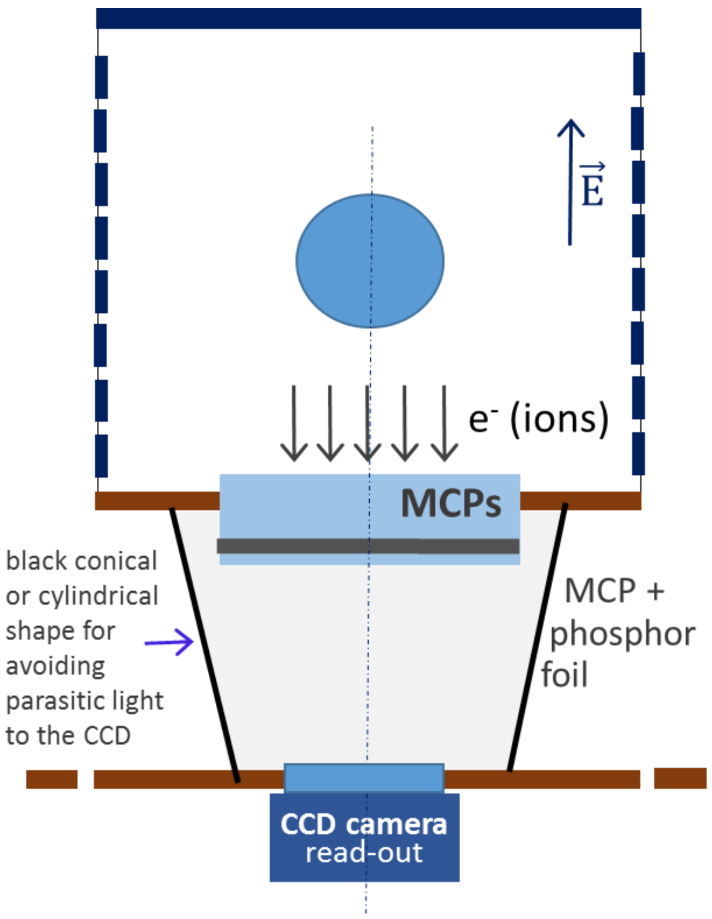
Calibration system



C. MCP + PHOSPHOR SCREEN AND CAMERA

Principle of operation

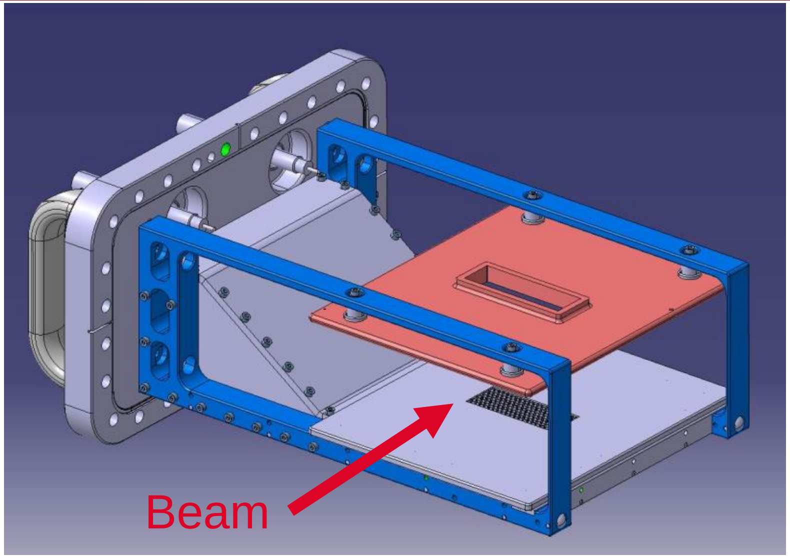
- Use phosphor screen instead strips (P-MCP)
- Phosphor screen: electrons➔ light
- Shield against background photons
- Camera can be deported with coherent OF bundle
  - To be define (radiations, location)
- Calibration also required
  - P-MCP ageing

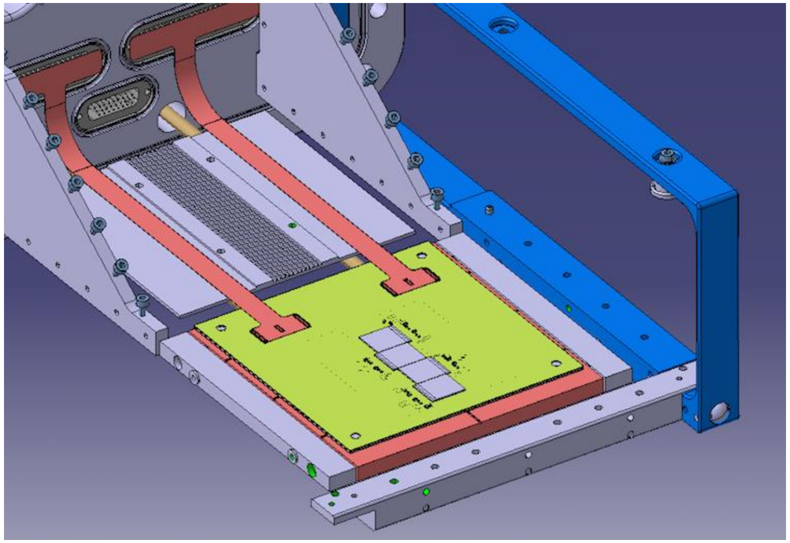


D. SILICON PIXELATED SENSOR AND TIMEPIX3

PS NPM (PS-BGI)

- Project for the PS at CERN
- 4 Timepix3 = 56.3mm x 14mm total surface
- High sensitive and fast NPM
- 55µm spatial resolution
- Cooling system are required
- Collaboration since October 2016



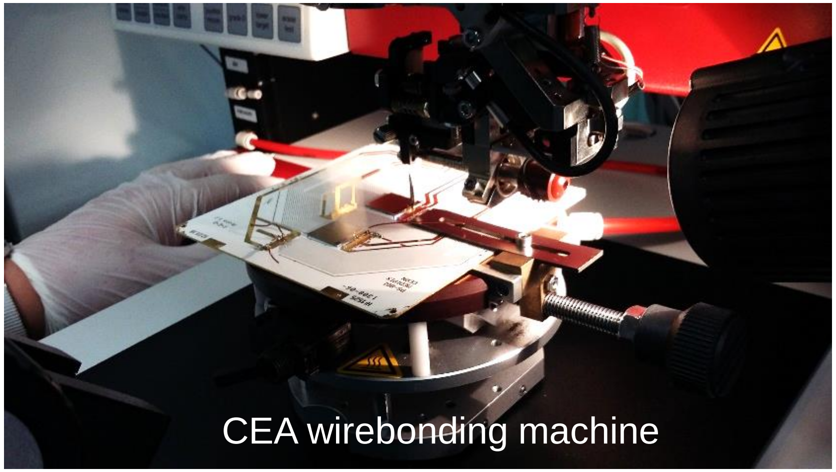


Storey, J.; Bodart, D.; Dehning, B.; Levasseur, S.; Pacholek, P.; Rakai, A.; Sapinski, M.; Schneider, G.; Steyart, D. & Satou, K.
Development of an Ionization Profile Monitor Based on a Pixel Detector for the CERN Proton Synchrotron
IBIC2015, Melbourne, Australia, **2015**

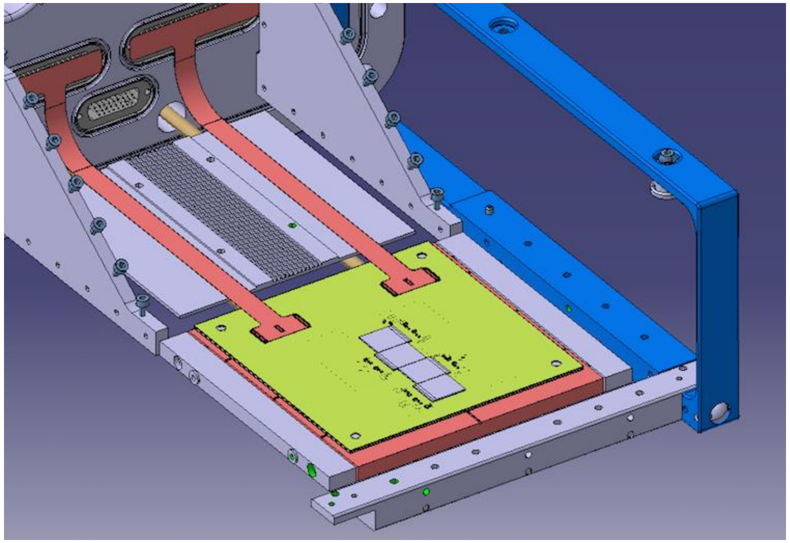
D. SILICON PIXELATED SENSOR AND TIMEPIX3

Collaboration

- Process is difficult
  - Complex PCB vacuum compatible
  - 100 wirebonding per chips
  - Critical chips placement
- CERN Team provide us:
  - A lot of information
  - A PCB
- Wirebonding at CEA-Saclay if possible:
  - Gold bonding on TP1➔OK
  - Next attempts on TP3
  - Try to perform reliable and automatic process



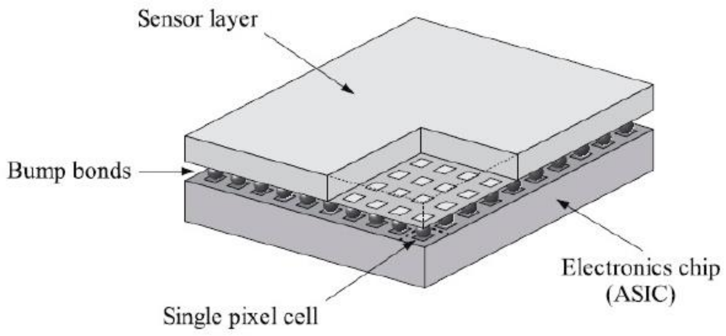
CEA wirebonding machine

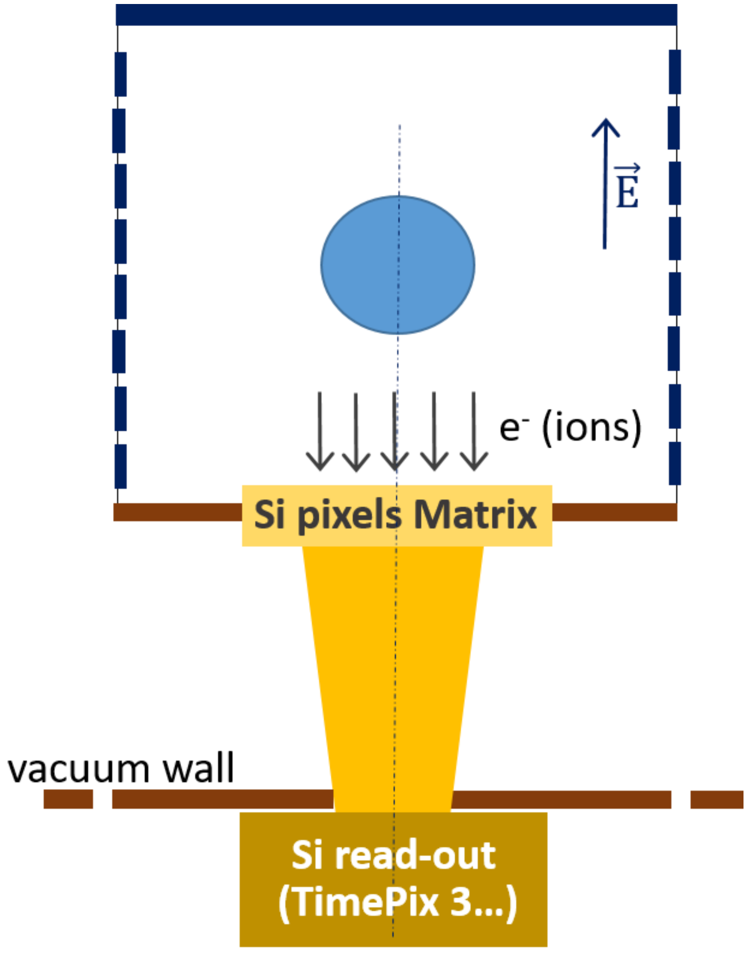


D. SILICON PIXELATED SENSOR AND TIMEPIX3

Silicon sensor

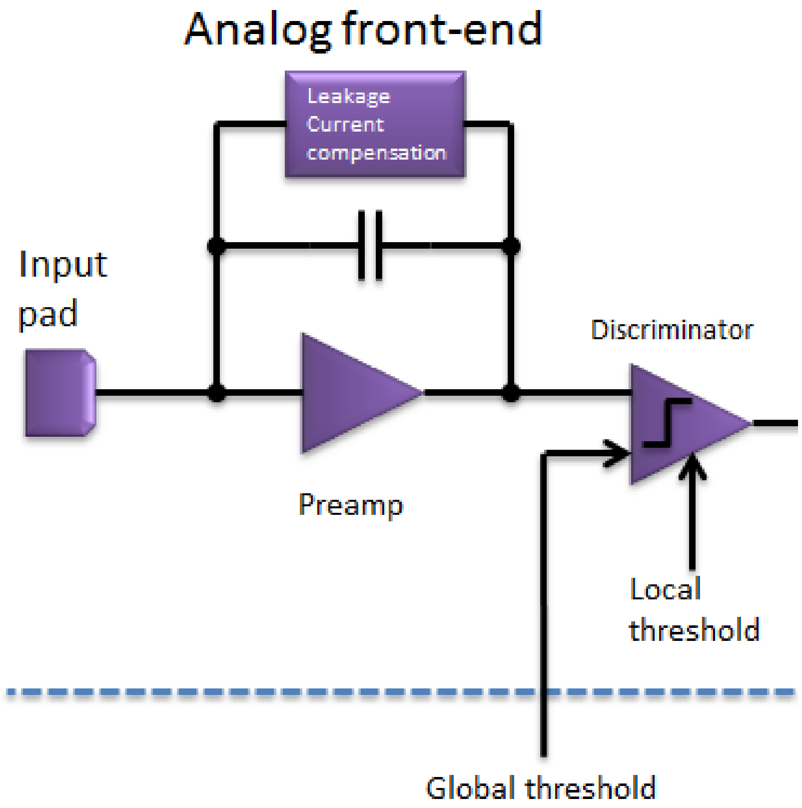
- Silicon pixelated detector
  - Great spatial resolution
  - Silicon is versatile SC
- 1 electron at 5keV ➔ 1400 pairs in silicon
- Ions at keV are completely stop in few hundred nm
  - To be tested !





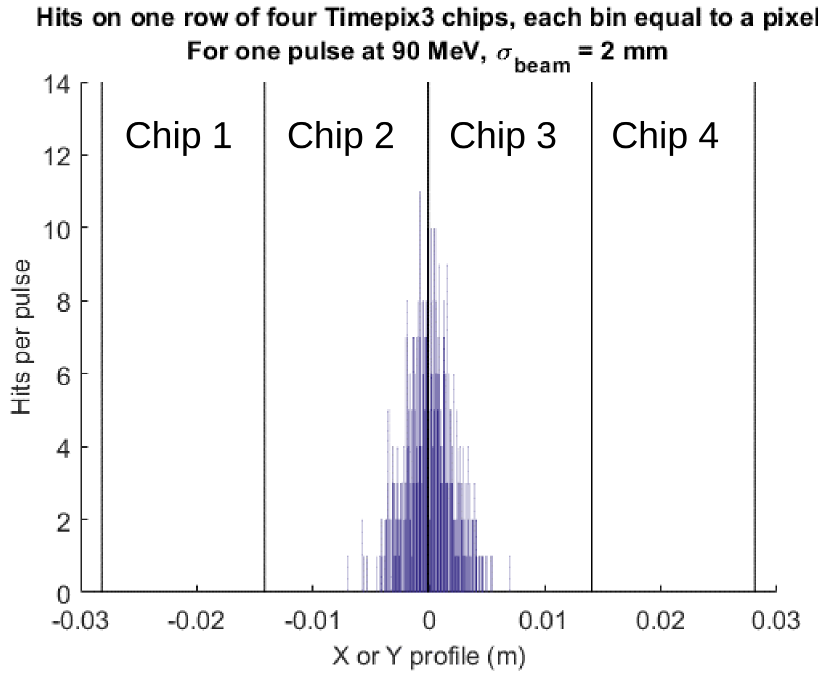
TimePix3

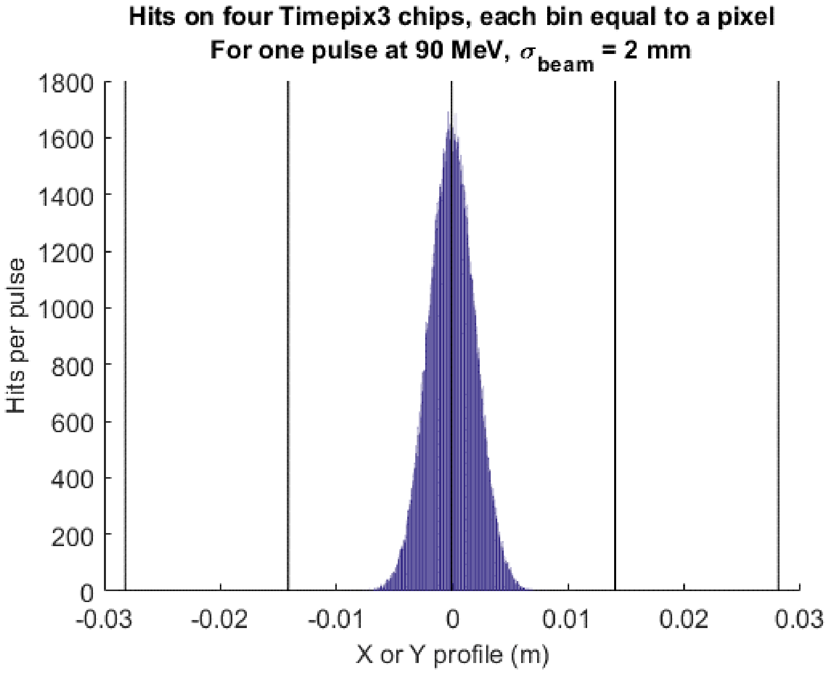
- 256x256 55µm pixel readout chip for Hybrid Pixel Detector
- Still work after 4.5 MGy
- Noise is about 500 electrons
- Three different measure modes:
  - Time of Arrival
  - ToA + Time over Threshold
  - ToT + Events counting
- Two different read modes:
  - Frame based
  - Data driven



TimePix3

- Maximum hit rate without dead time:
  - 80 MHits/s per chip
  - 50 kHits/s per pixel
- ~140 pixels are hit more than once/pulse
  - 5kHits/s max per pixel





D. SILICON PIXELATED SENSOR AND TIMEPIX3

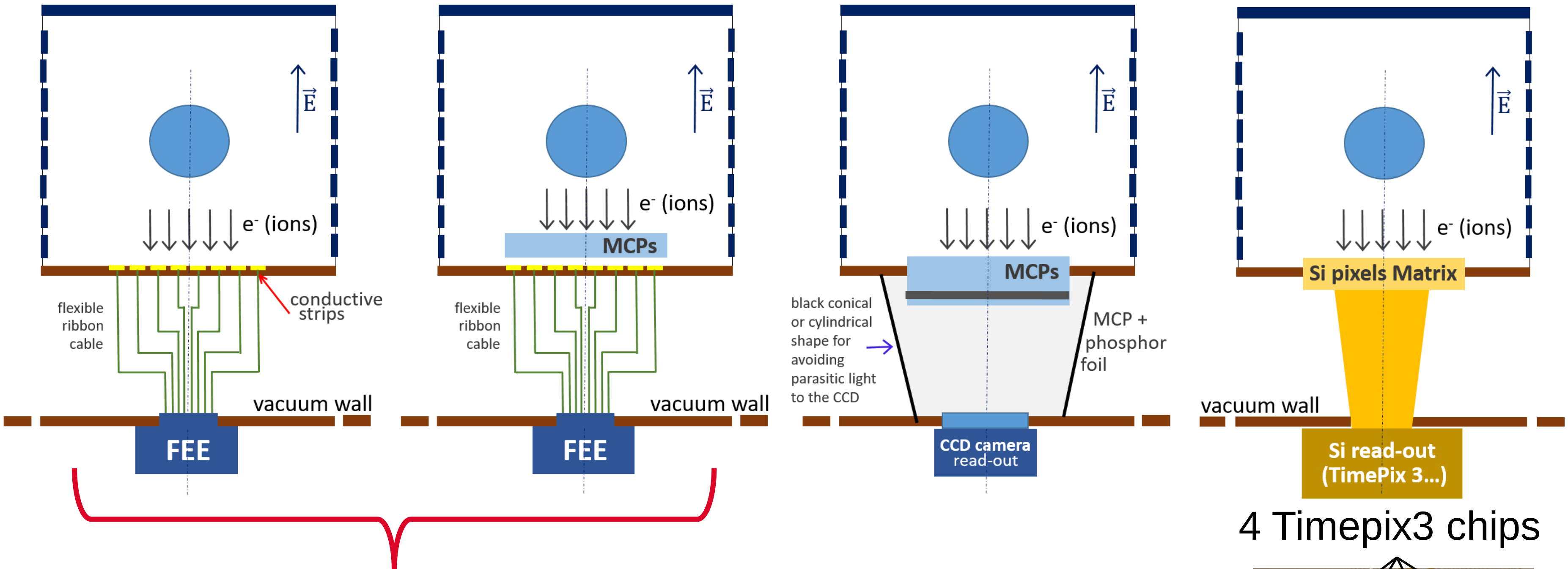
Electronics

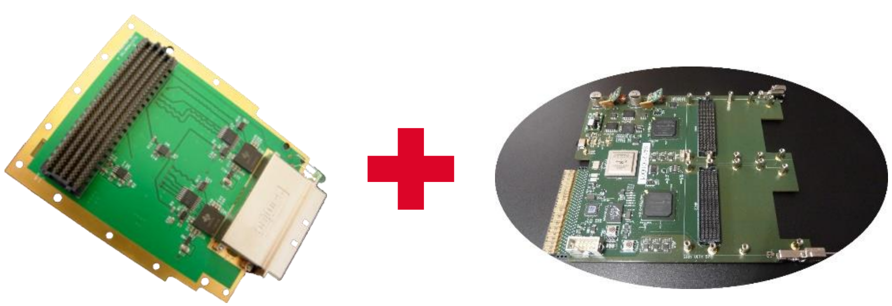
- TimePix3 need a CS electronics
- FitPix: Commercial solution
  - Advacam/WidePix
  - General purpose use ➔ Limited
  - We will use it for tests
- CERN Team custom solution
  - In development
  - Based on GEFE Board
  - Dedicated to NPM usage

http://www.ohwr.org/projects/gefe/

CONCLUSION - SUMMARIZE

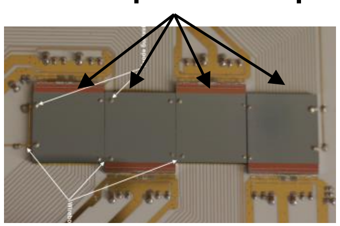
CONCLUSION - SUMMARIZE





TBD

4 Timepix3 chips



THANKS FOR YOUR ATTENTION

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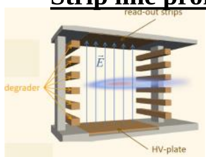
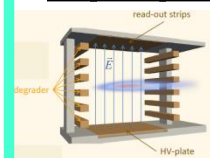
QUESTIONS ?

BACKUP SLIDES

Strip line profiler



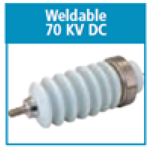
Strip line profiler



+

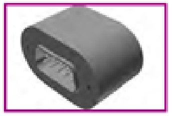
microchannel plate (MPC)

70kV HT



BNC HT

Sub-D connector



Transimpedance readout amplifier

ADC

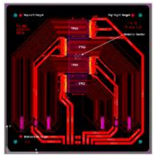
Current-Input Analog-to-Digital Converter

Caramel

+

SYROCO_AMC

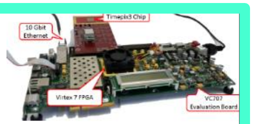
Timepix3



BNC HT
Cooling
Sub-D connector

GEFE

+



FitPIX

Optical

Double chevron microchannel plate (MPC)

Posphor foil

CCD Camera read-out

TIMEPIX 3 MODES