Picosec Activities Status

INFN & Università Pavia

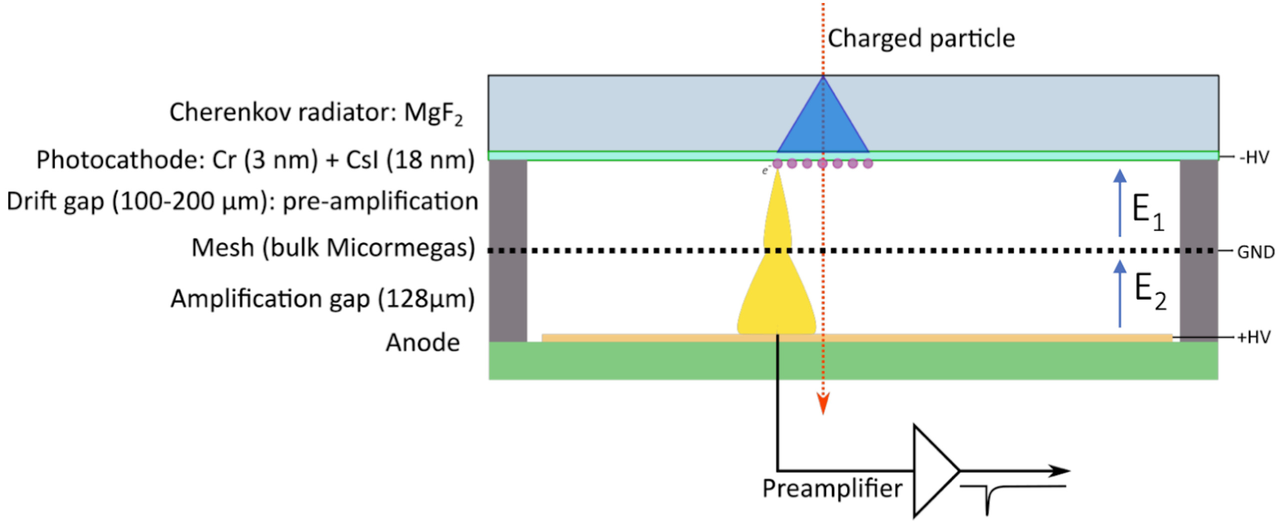
Manpower & financial situation 2022

Ricercatori						
	Nome	Età	Contratto	Qualifica	Aff.	%
1	Aimè Chiara		Associato	Dottorando	CSN I	30
2	Calzaferri Simone		Associato	Dottorando	CSN I	30
3	Chiesa Mauro		Associato	Ricercatore A Tempo Determinato Tipo A	CSN IV	10
4	Fiorina Davide		Associato	Dottorando	CSN I	20
5	Piccinini Fulvio		Dipendente	Dirigente di Ricerca	CSN IV	5
6	Riccardi Cristina		Associato	Prof. Associato	CSN I	30
7	Salvini Paola		Dipendente	Ricercatore	CSN I	25
8	Valle Nicolo'		Associato	Assegnista	CSN III	20
9	Vitulo Paolo		Associato	Prof. Associato	CSN I	30
			Numero Totale Ricercatori	9	FTE: 2.00	

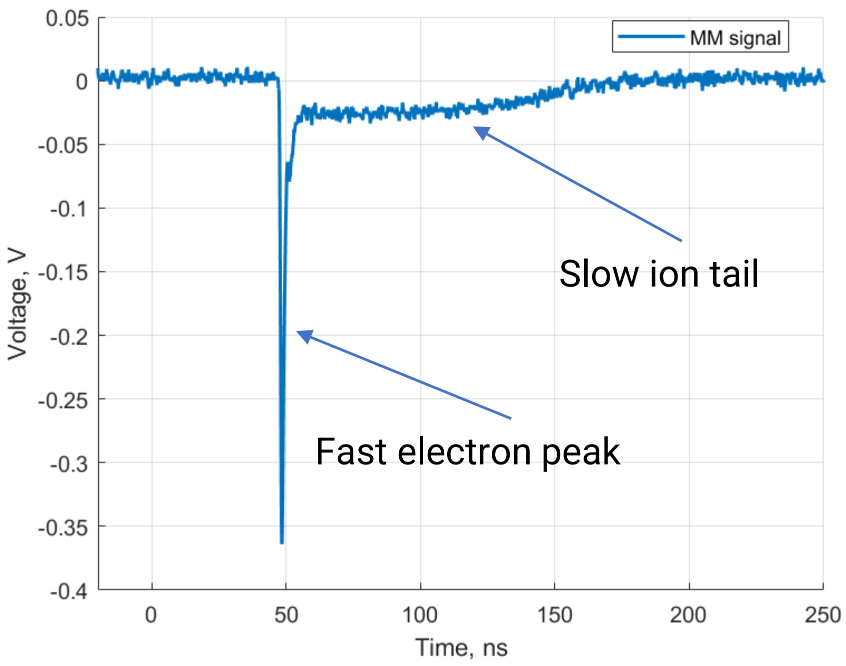
Tecnologi						
	Nome	Età	Contratto	Qualifica	Aff.	%
1	Vai Ilaria		Associato	Ricercatore A Tempo Determinato Tipo A	CSN I	30

Funds: 12k€ 10x10 picosec prototype

Picosec principle of operation



- Cherenkov light emitted during the MIP passage is converted into electrons on the photocathode
- Mean free path of electrons is way smaller than MIPs
- Time resolution independent from the MIP first interaction statistics



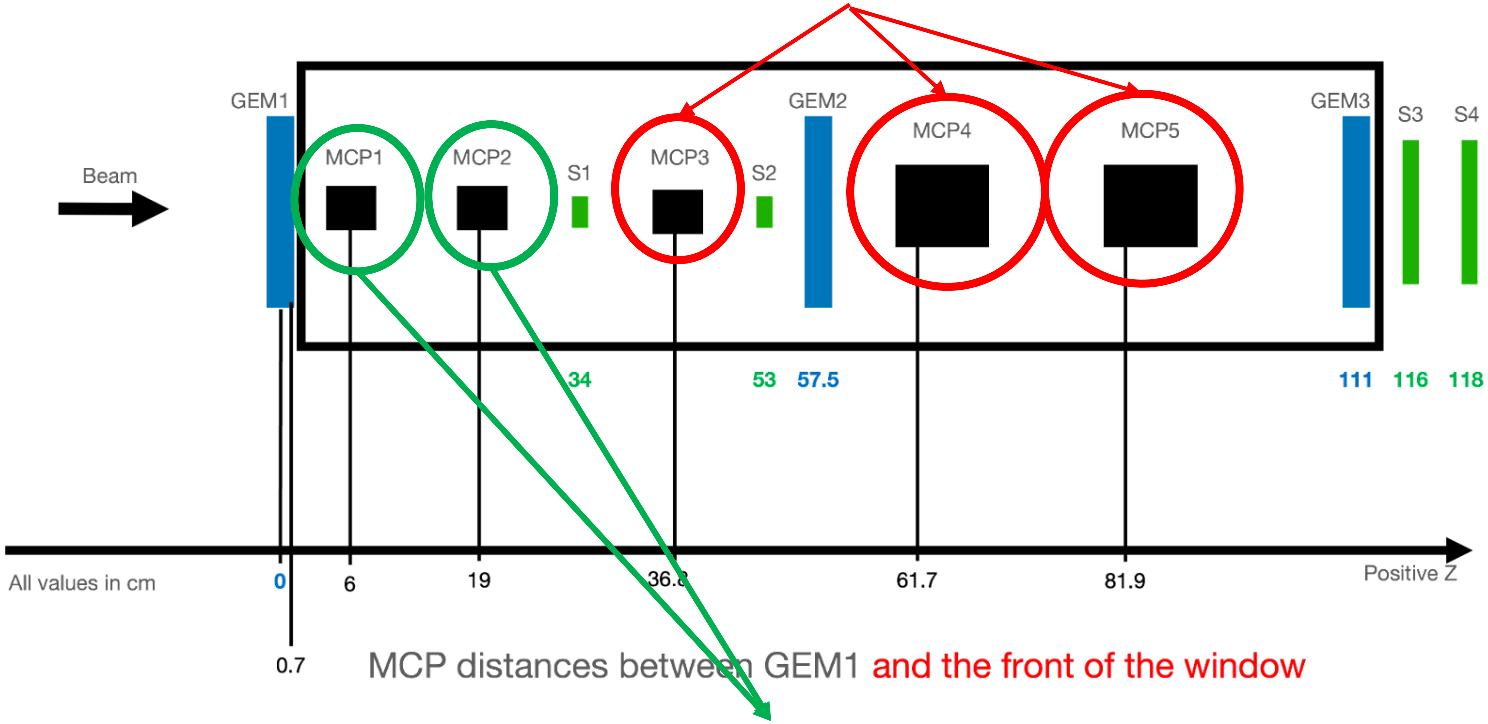
- Readout via MicroMegas
- 2-step amplification, also the drift gap is used in multiplication mode → higher gains and control on ion-backflow
- Fast electron peaks carry the info about the timing
- Readout via a linear amplifier to preserve the timing information

Pavia team activity in 2022 so far was focused mainly on two items:

1. Gaining expertise on Picosec working with the RD51 collaboration
2. Procurement of the Pavia Picosec prototypes

1 - Gaining expertise on Picosec working with the RD51 collaboration
RD51 testbeams setup

Slots for Picosecs



Micro Channel Plate PMT (MCP) for time reference ($\sigma_t \approx 5ps$)

→ 1 MCP from Pavia group (8ps, but not used at 100% HV value)

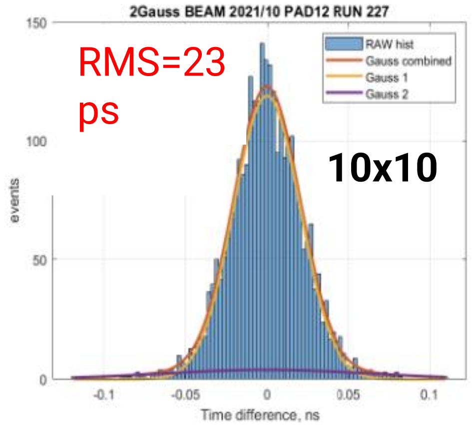
We participated in 3 RD51 testbeams with the following measurement plans:

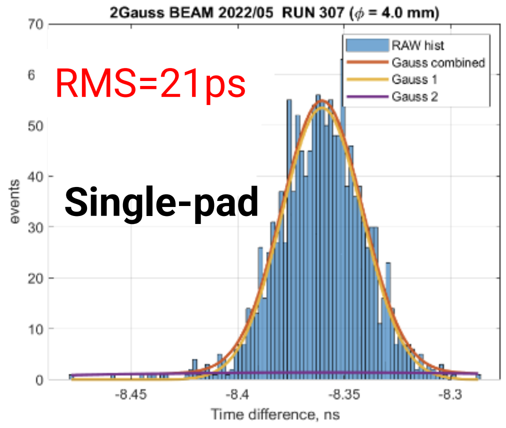
1. **April**
   - Measure the time response of MCP for the next testbeams
2. **May**
   - Test new photocathode (B4C) – thin mesh/gap – resistive MM
   - Test new custom preamplifier
   - 10x10 uniformity – SAMPIC digitizer readout (64ch)
3. **July**
   - Test new photocathode (B4C different thickness, DLC without Chromium)
   - SAMPIC digitizer 256ch full 10x10 readout
   - Picosec for the electromagnetic calorimeter

1 - Gaining expertise on Picosec working with the RD51 collaboration
Some results of interests for MuColl

- **Thin Gap**
- B4C and DLC photocathodes
- Custom preamplifier
- SAMPIC digitizer

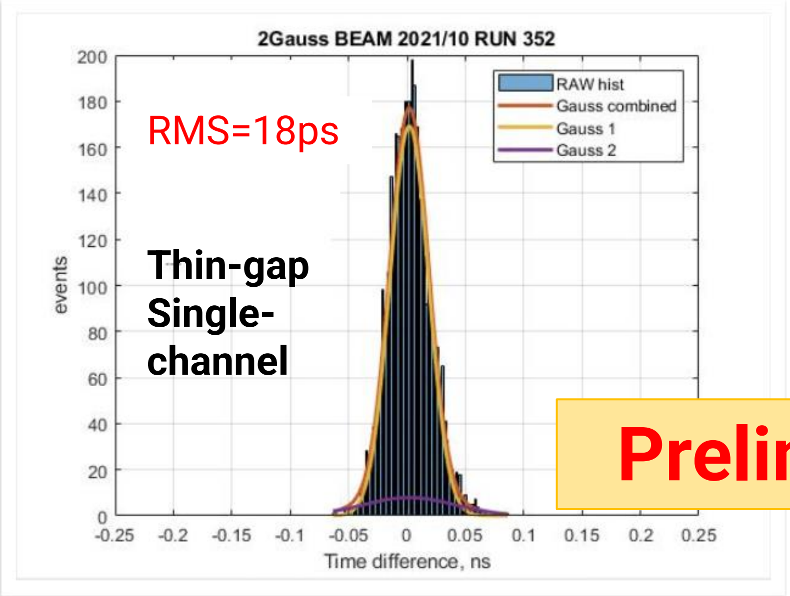
Baseline detector – REFERENCE PLOTS

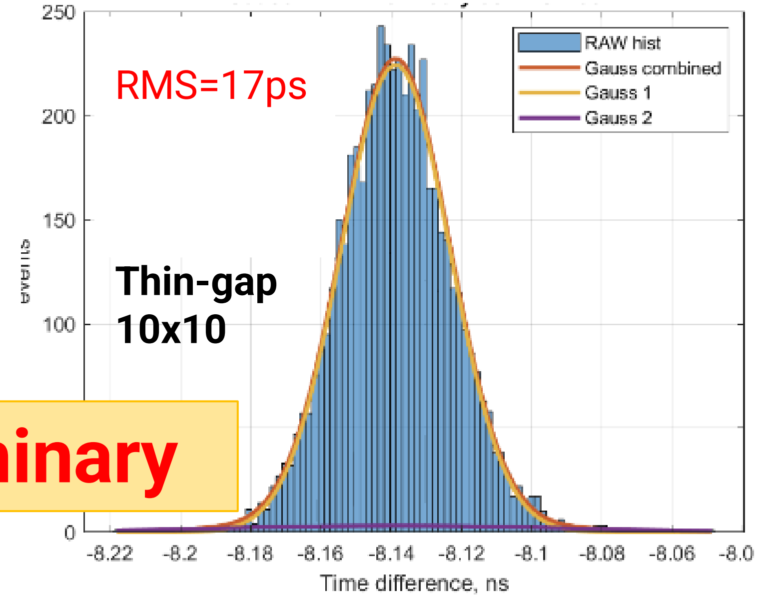




Thinner gap (200um→140um) provides:

- Early start of the avalanche and better time resolution
- Smaller energy deposit by Heavily Interacting Particles
- However, it can be more unstable in high fields



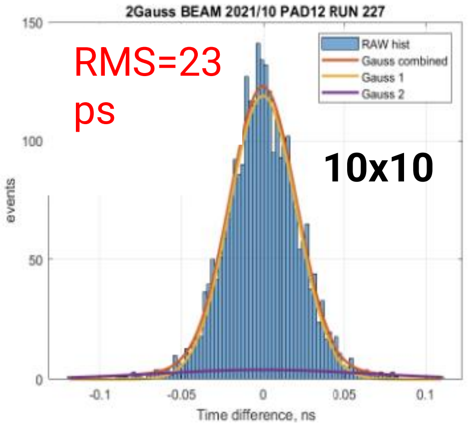


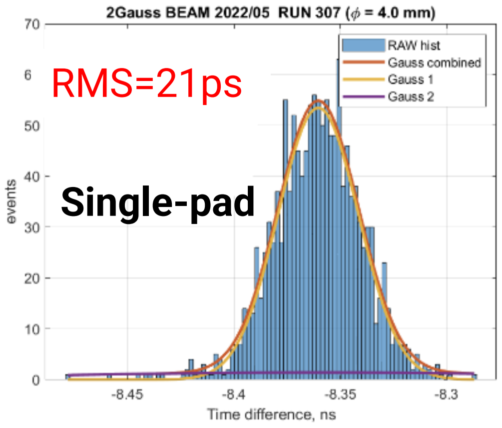
Preliminary

1 - Gaining expertise on Picosec working with the RD51 collaboration
Some results of interests for MuColl

- Thin Gap
- **B4C and DLC photocathodes**
- Custom preamplifier
- SAMPIC digitizer

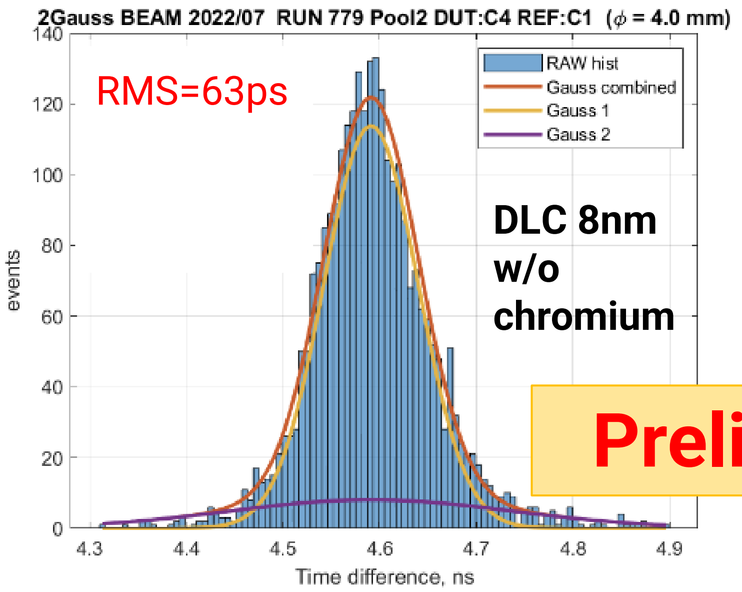
Baseline detector – REFERENCE PLOTS



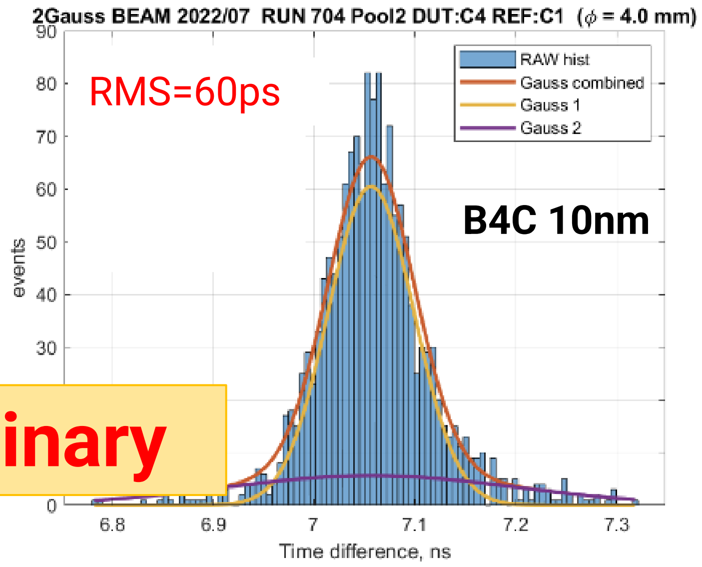


Resisitive photocathodes (instead of CsI) provide:

- Resistance to ion-backflow damage
- Resistance to discharges
- No damage from humidity (as CsI)
- Possibility to operate in higher-fields
- However: **lower time resolution**



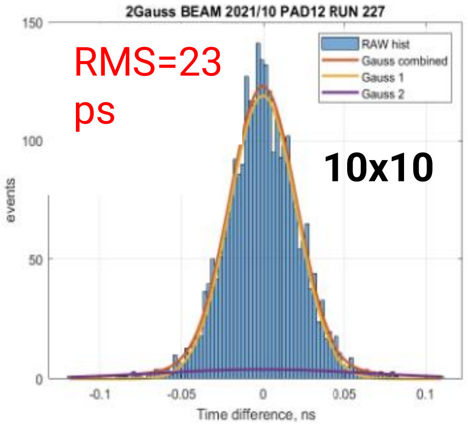
Preliminary

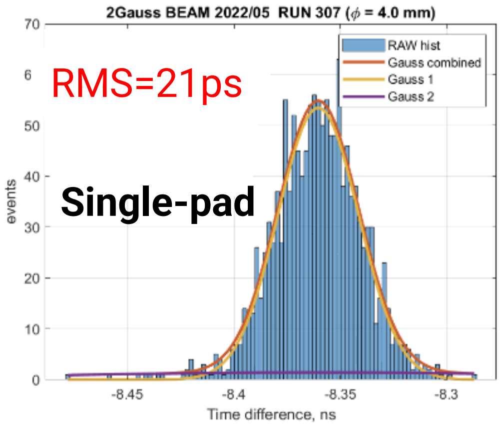


1 - Gaining expertise on Picosec working with the RD51 collaboration
Some results of interests for MuColl

- Thin Gap
- B4C and DLC photocathodes
- **Custom preamplifier**
- SAMPIC digitizer

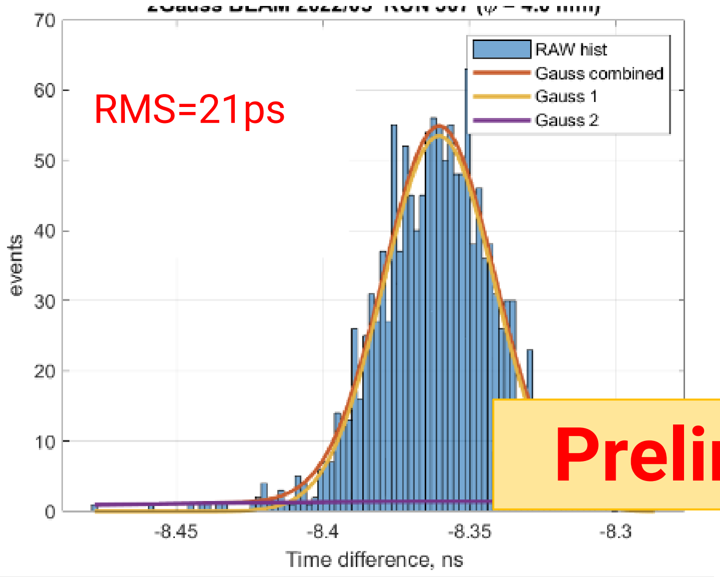
Baseline detector – REFERENCE PLOTS





Custom preamplifier **(Saclay+GDD idea)**
instead of Cividec:

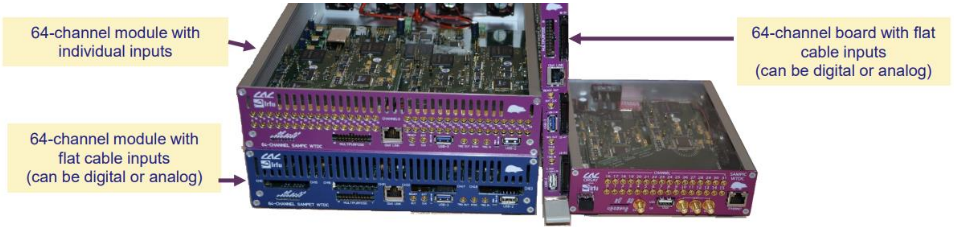
- Scalable to 10x10 easily
- Optimized for picosec signal

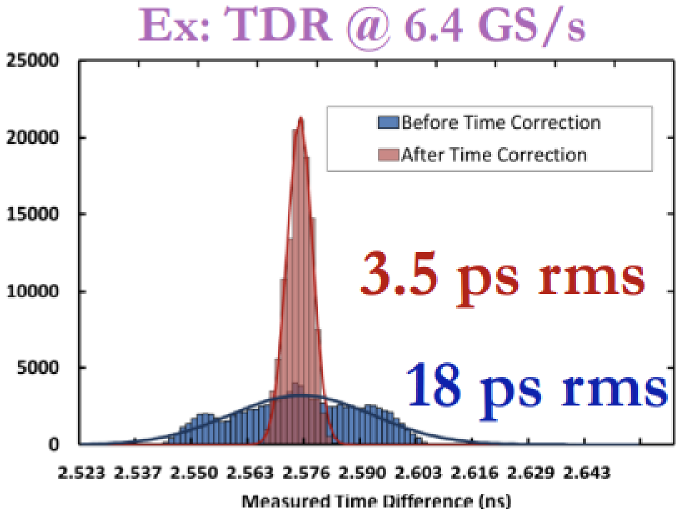


Preliminary

4-pad average of 10x10

- Thin Gap
- B4C and DLC photocathodes
- Custom preamplifier
- **SAMPIC digitizer***






256-channel mini-crate

Preliminary

- Power consumption: 10mW/channel
- 3dB bandwidth > 1 GHz
- Discriminator noise ~ 2 mV RMS
- Counting rate > 2 Mevts/s (full chip, full waveform), up to 10 Mevts/s with Region Of Interest (ROI)

Full 10x10 read in last testbeam (100 channels) data analysis still ongoing…

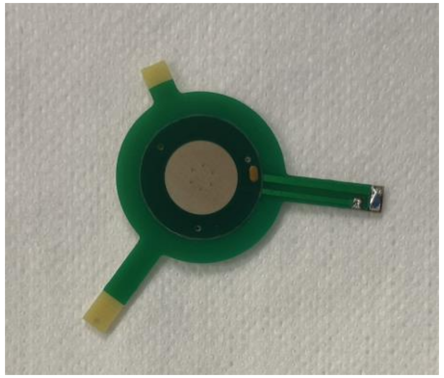
*https://ieeexplore.ieee.org/document/7431231

2 - Procurement of the Pavia Picosec prototypes

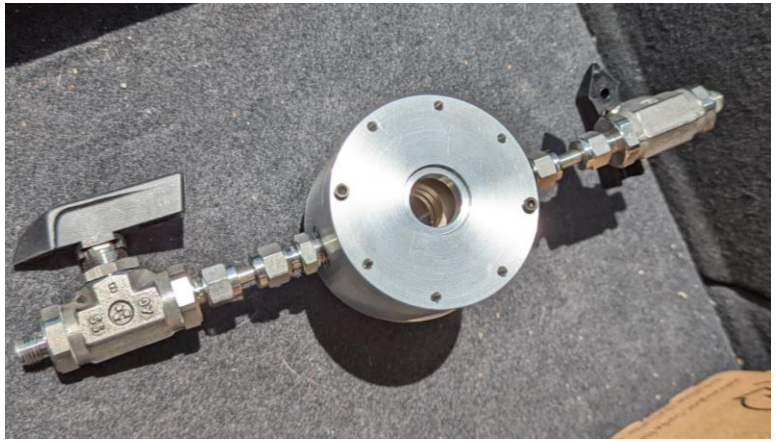
International MUON Collider Collaboration

Istituto Nazionale di Fisica Nucleare
Sezione di Pavia

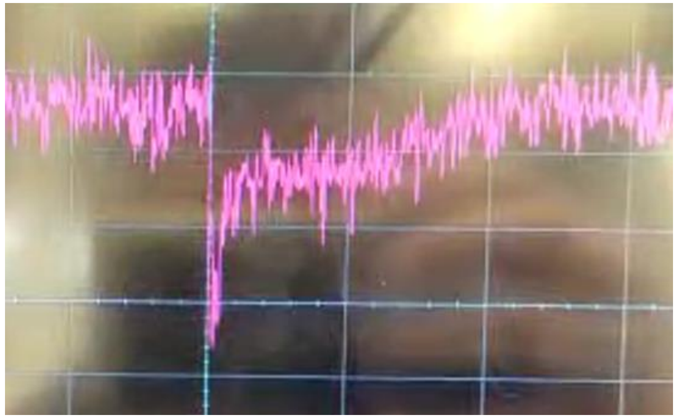
- **10x10 detector already ordered** (Rui lab) production ongoing → expected September

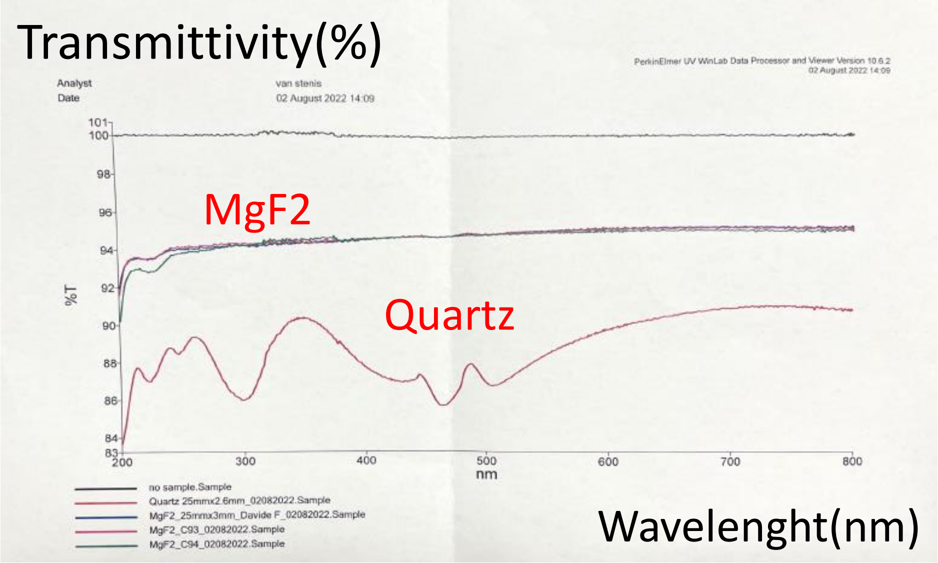


- Meanwhile, we **assembled a single-channel detector** with:
  - MM from RD51
  - Radiator paid
  - Mechanics from spare material



  - Radiators tested @ CERN dedicated lab (see transmissivity plot)
  - Chromium photocathode (calibration configuration)





Plan for single-channel tests

New radiators

- **MgF_2 is the most UV trasparent material but:**
  - High cost, Fragile
  - Non perfectly stable during material deposition (imperfection on half of the samples)
- **Investigate:**
  - CaF_2, BaF_2, sapphire
  - **Quartz → the most promising for large areas, low cost and robustness (lower transparency)**

New photocathodes

- CsI has the best performance in terms of time resolution, resistive photocathodes are more promising for the long term and robustness
  - B_4C and DLC
  - (Graphene and nanodiamonds trials by RD51)

New Gases

- Baseline $Ne/C_2H_6/CF_4$ 80/10/10 – Flammable, High GWP, High cost!
  - Removal of CF_4
  - Substitution of C_2H_6 (ethane) with C_4H_{10} (isobutane) or even better CO_2
  - Look for a Neon substitute (very difficult…)

Every of these comes with a price to pay in terms of time resolution and/or stability

To-Do list

Participate in the October test beam (19Oct-31Oct) with single-channel:

- MgF2 and Quartz **radiator** comparison (different WP)
- CsI, DLC and B4C, Chromium **photocathodes** comparison (different WP)
- Cividec and RF **amplifier** comparison (different WP)
- Timing resolution at different **sampling rates** (only with scope 1-40 Gs/s)
- Help to develop DAQ for **SAMPIC** (RD51 10x10)
- Only premixed bottles during testbeam → no test on gas

From November in Pavia, single-channel gas tests:

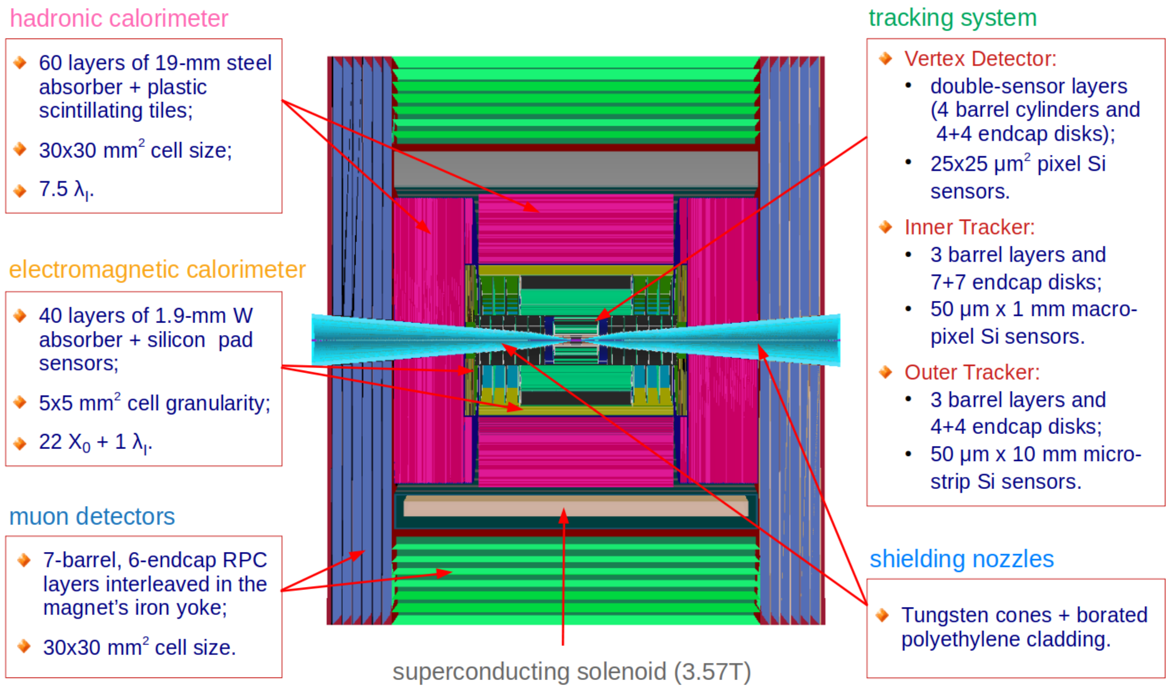
- Test w/o CF4, change of quencher

10x10 detector tests in the GDD lab start:

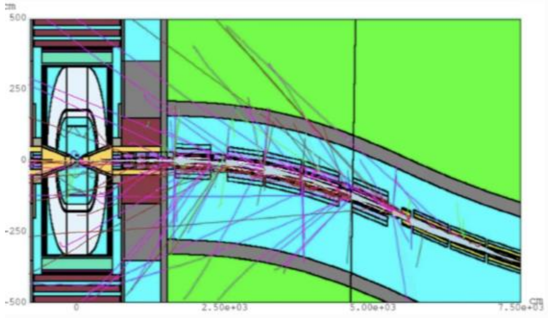
- Time uniformity response test with ultrafast laser
- CsI and DLC test on large areas
- Preparation for next testbeam

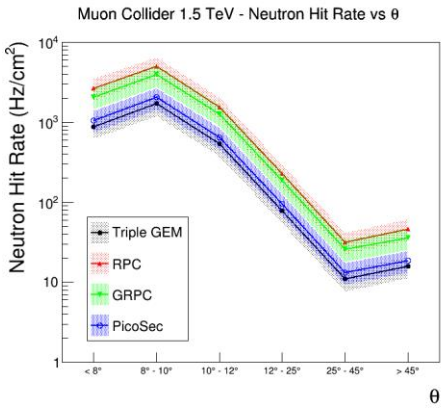
BACKUP

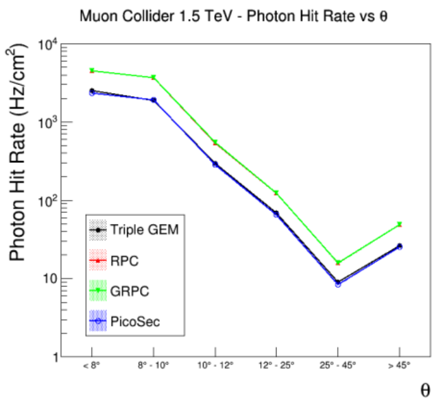
Muon Collider



- The baseline is the **CLIC design** BUT new detectors have been proposed for each subsystem!
- For **muon endcap,** we want to propose **Picosec** for muon tracking and triggering
- The enhanced time resolution used in the standalone reconstruction of muons will improve the Tracker performance
- Shielding from Beam Induced background (from decaying muons) limits the coverage in eta (<8° η<2.7 available)







- Background interaction with detector was simulated in Geant4
- Convoluted with the response of different gaseous detector technologies (hit when a charged particle is found in the drift gap)
- Simulated Picosec: 3mm MgF2 radiator, 10nm CsI photocathode, 200um drift gap
- **Picosec can operate in high rate environment and give timing information with higher precision wrt other technologies**

Challenges i.e. Pavia Group R&D

Detector Operation:

1. **Gas** has to be safer and, why not, cheaper: CF4 has to go or alternatives have to be found, hydrocarbon can stay maybe but in low concentration and only if they don't cause aging
2. **Radiator** cost and fragility: MgF2 alternatives?
3. **Photocathode** needs to survive in the high rate environment without degradation

Spatial resolution:

- Baseline for application: 1 Picosec timing layer + tracking layers (GEM or equivalent)
- The required spatial resolution is under study

Scalability (1 endcap layer ≈ 130m2):

- Large area detectors