Meeting of PS Users

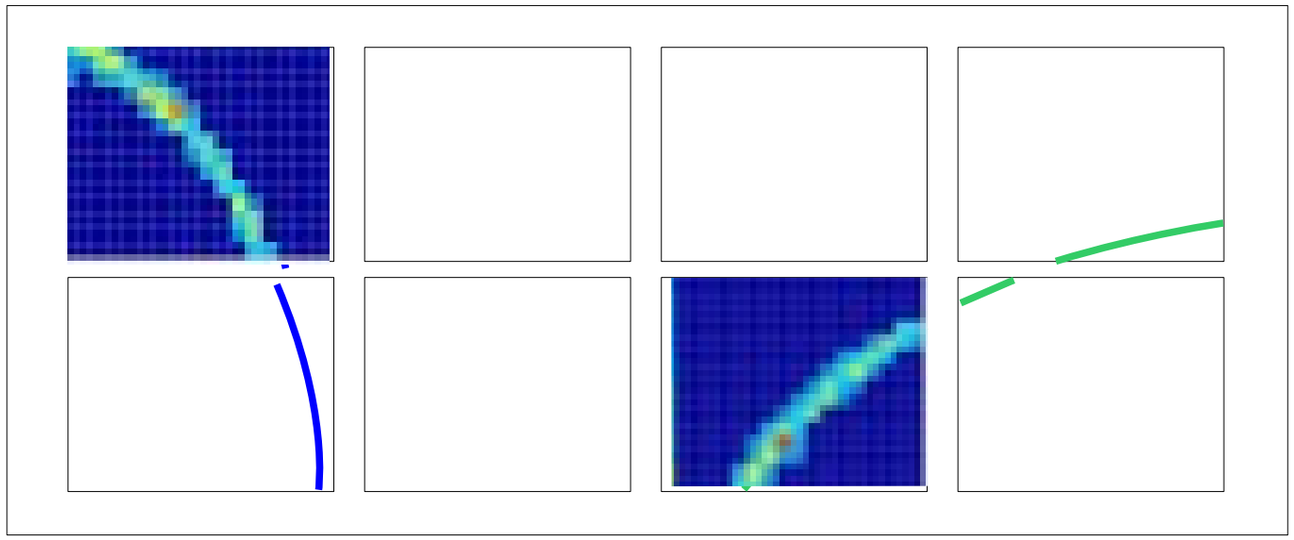
2022 March 17th

Test Beam @ PS T9 for the new gas HA-TPC ND280 upgrade / Neutrino Program NP07 Experiment

G.Collazuol (University of Padova and INFN)
On behalf of the TPC group - ND280-Upgrade – NP07 collaboration

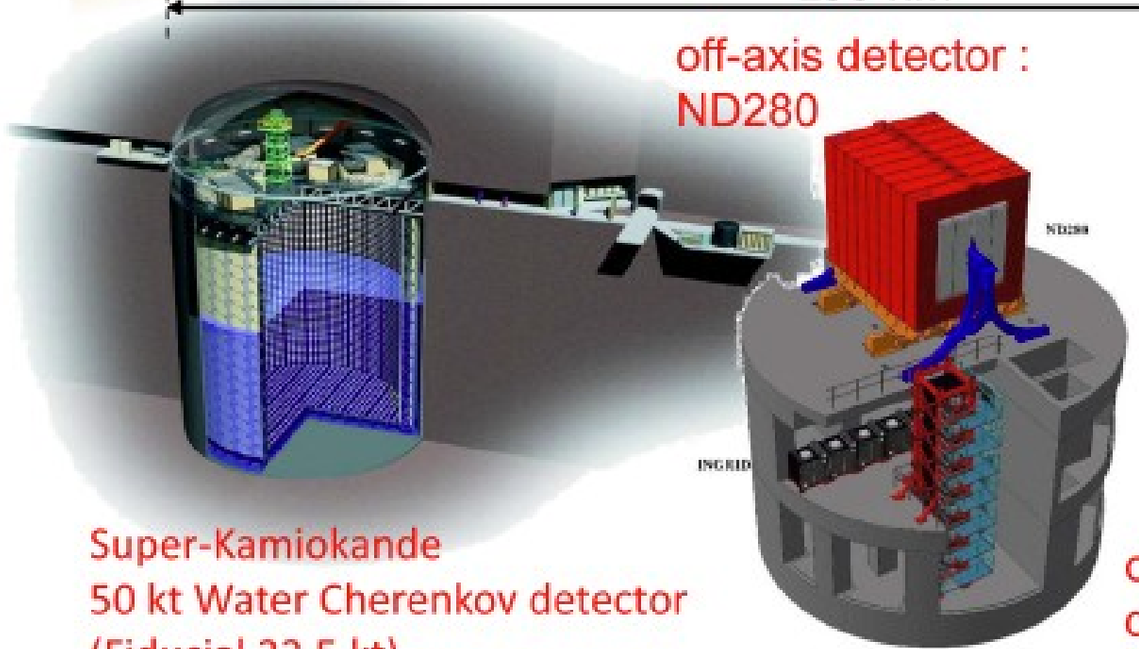
Overview

- Test Beam goals
- Detectors and Setup
- Beam Requirements
- Infrastructure Requirements



T2K Near Detector Upgrade

~1ν/cm²/s at T2K Far detector(295km away) @750kW proton beam power)

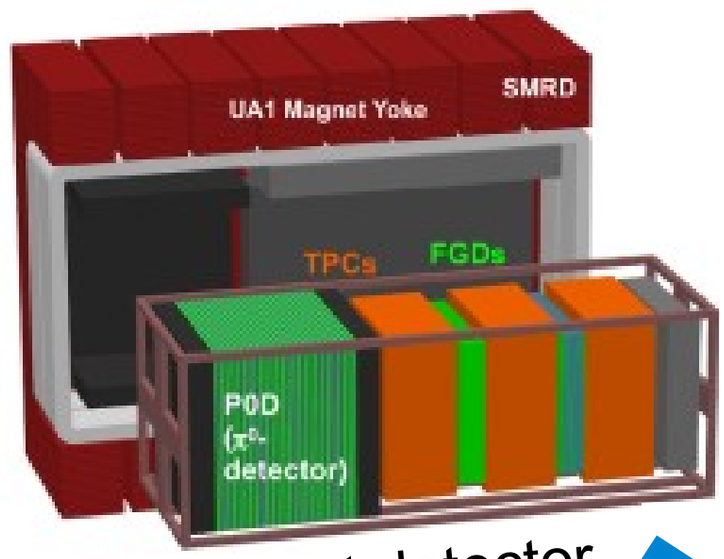


The upgraded ND280 design

The new detectors configuration is very efficient for high angle tracks

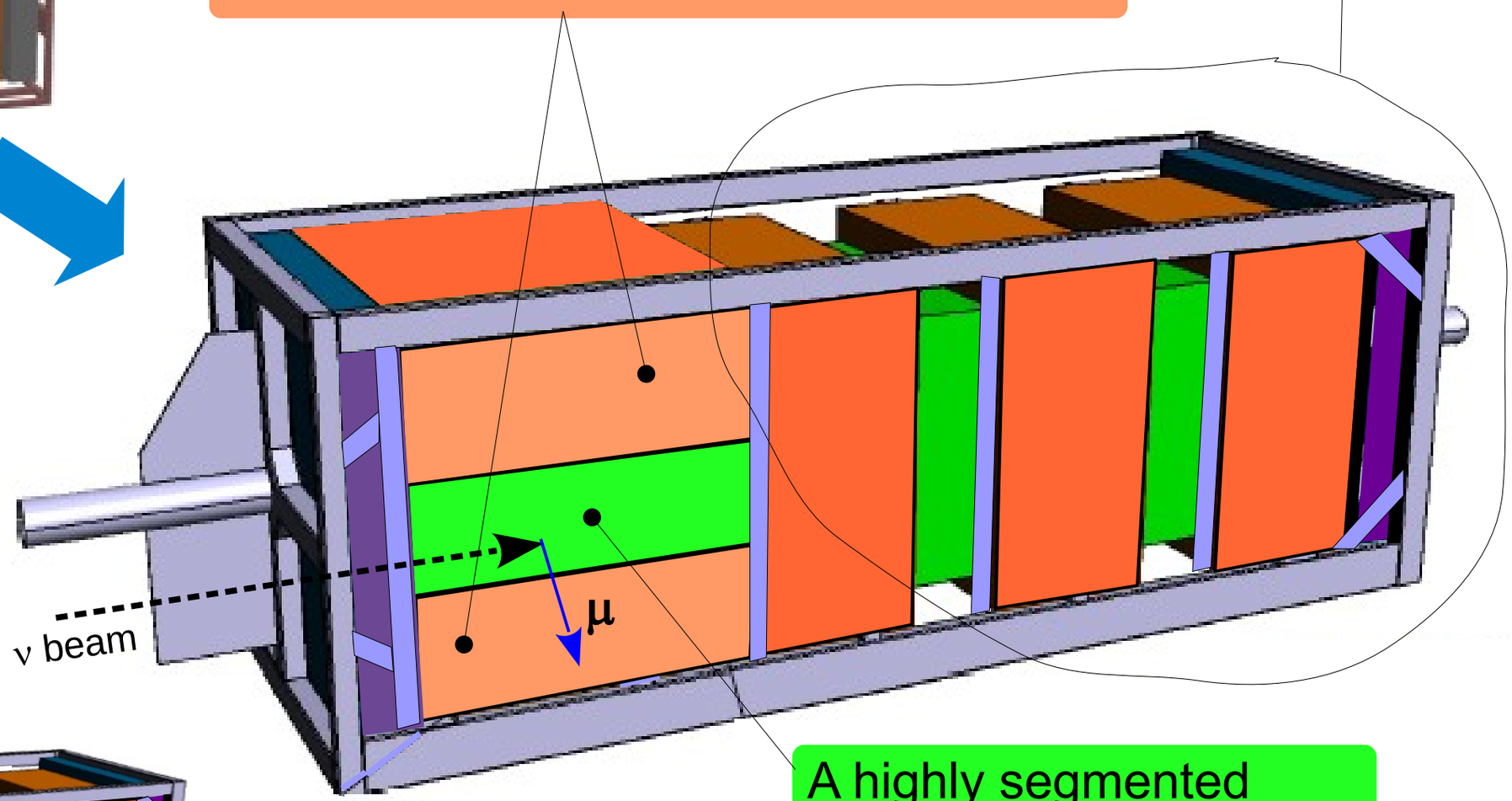
No changes to other detectors

UA1 Magnet CERN

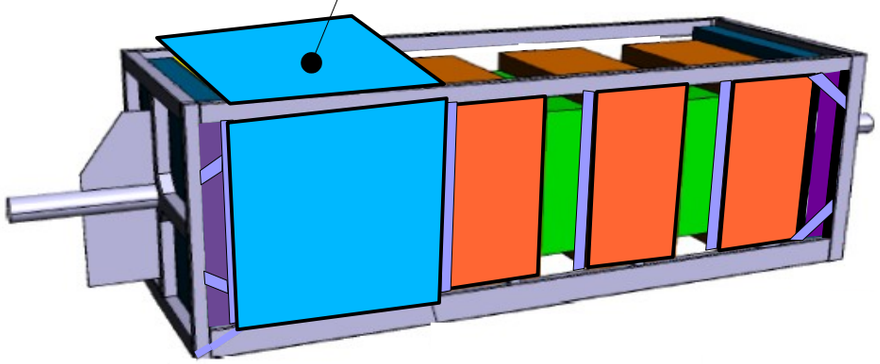


Present detector configuration

Two new High-Angle Time Projection Chambers (HA-TPC)



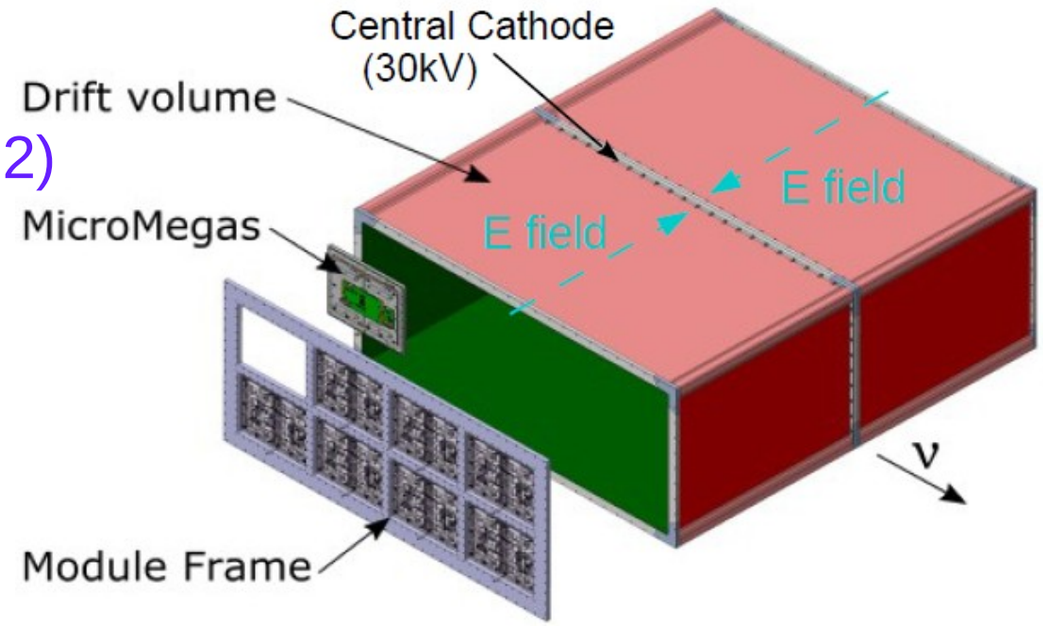
Six ToF Scintillator planes all around



A highly segmented scintillator active target (SuperFGD)

Test Beam Goals

- commissioning with beam (ship it to Japan Sept. '22)
  - characterization of final detector
  - measurements with ½ TPC configuration

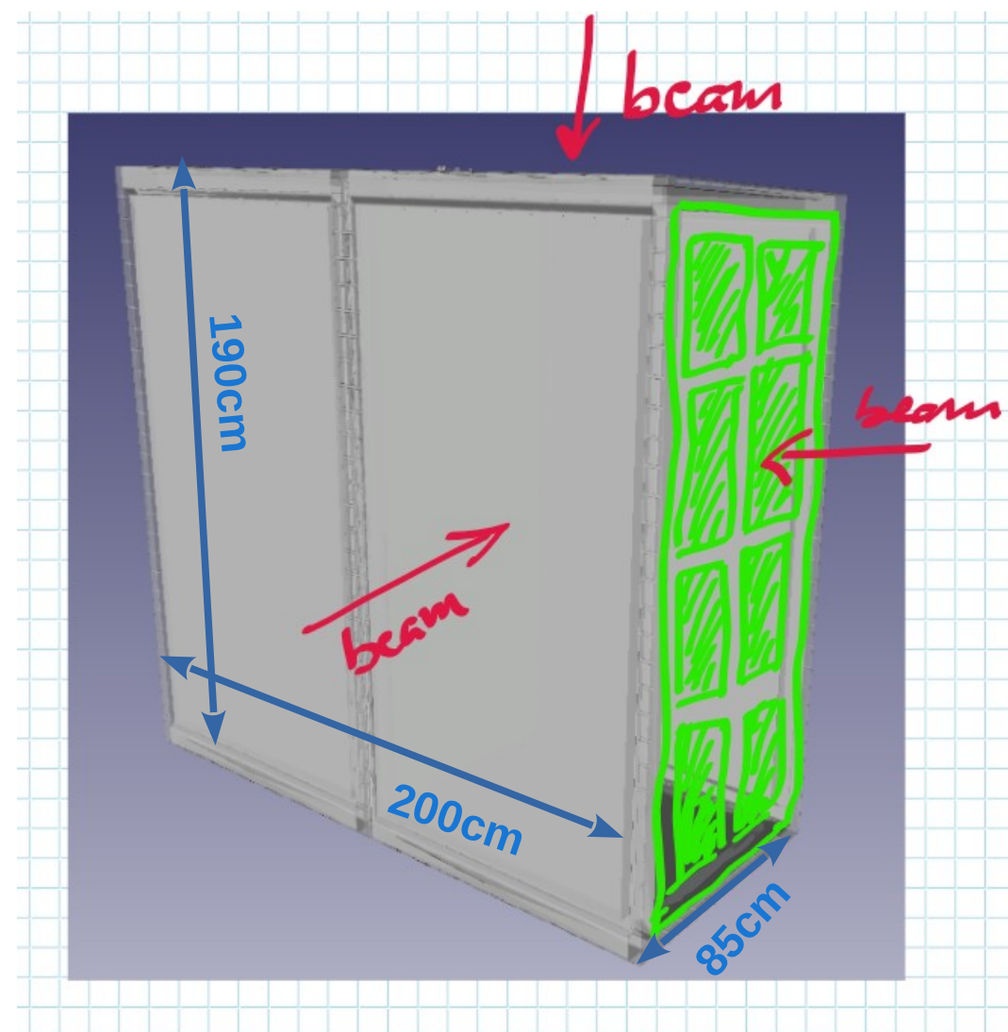


1) Track spatial resolution (with zero B field)
  - with lever arm ~ 70cm to 150cm
  - scan along drift distance (100cm)
  - Inclined tracks (θ, ϕ) wrt drift direction

2) track dE/dx resolution & PID capability
  - e, μ, π, K, p momentum range 0.4 – 2GeV

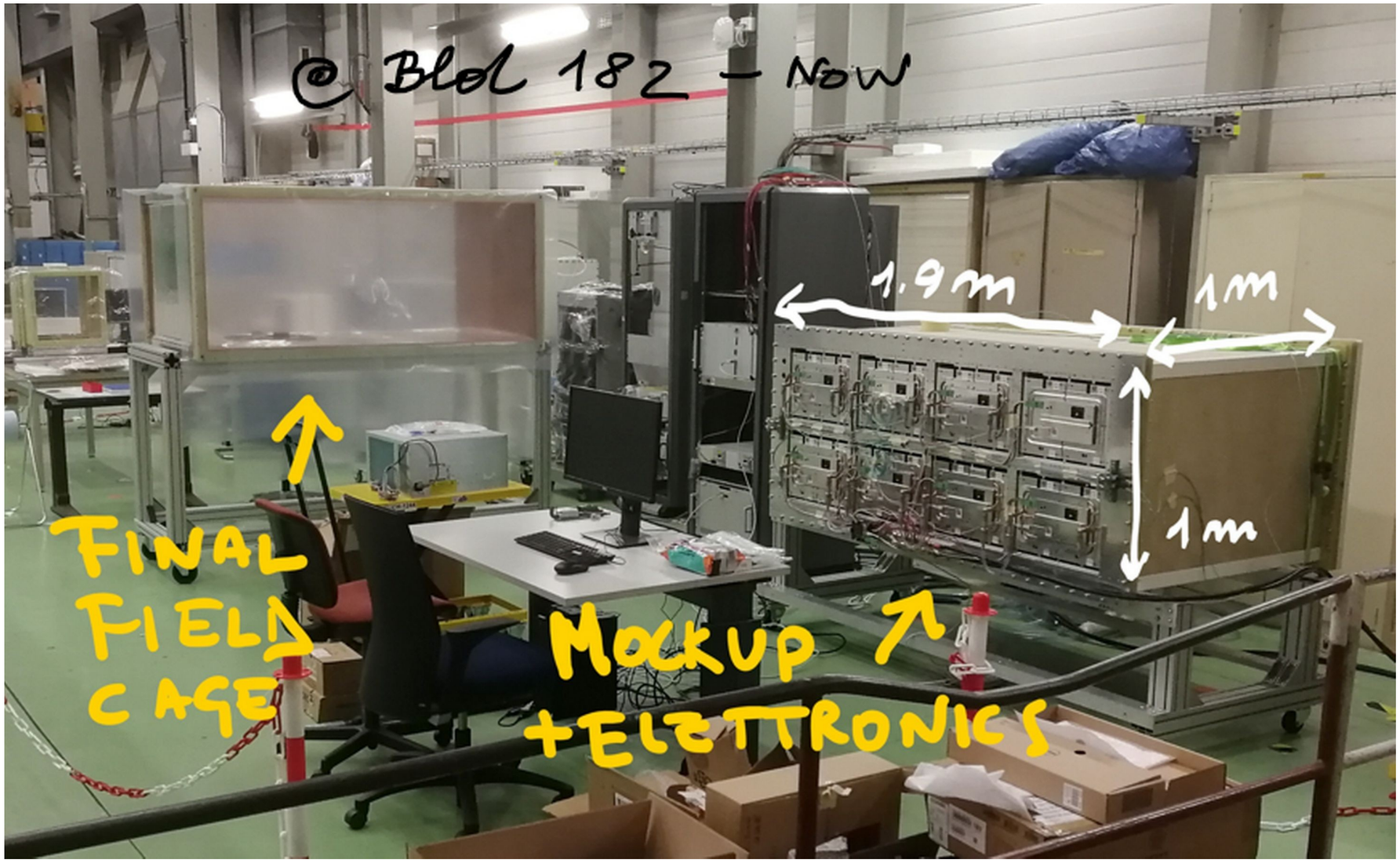
3) Electric Field & geometry distortions
  - E field transv.< 10^{-3} & longit. ~ uniform< 10^{-3}
    → probing near walls & corners
    → probing uniformity of drift time
  - Spatial & Timing alignment of 8 sensors

4) assess multiple scattering across walls

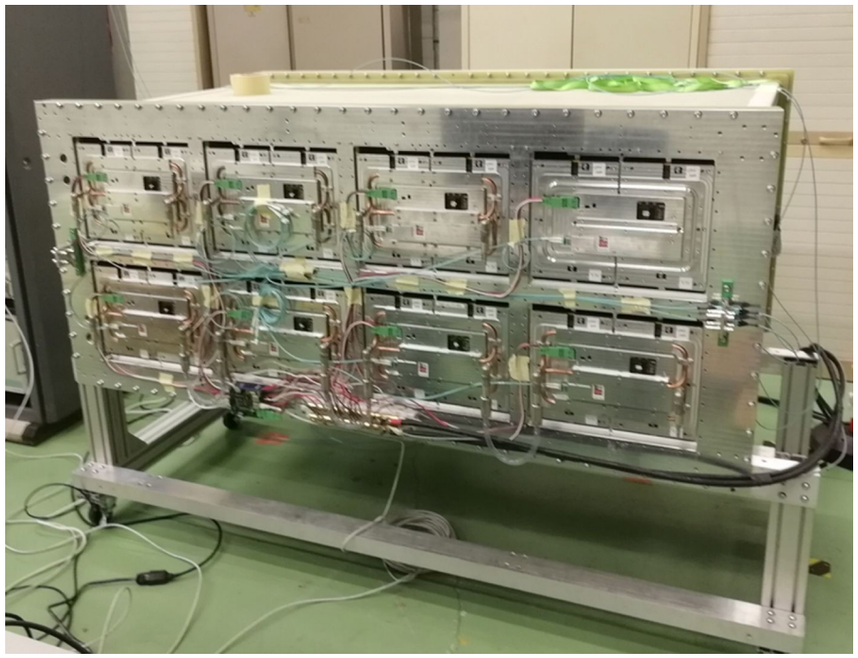


Detectors & Setup

- Main detector under test → large volume TPC
  ½ HA-TPC → **1.9m x 1m x 1m → ~ 200kg**
  - Equipped with 8 ERAM mods. (1 anode side instrumented only)
  - Cathode → **- 30kV**
  - T2K gas mix ($Ar:CF_4:iC_4H_{10}$ =95:3:2) → premix bottles
    → operating at **1bar** in overpressure by **~ 5mbar**
    → gas flow **~50L/h**
  - Must perform preliminary purging @ PS hall
    → we will procure the gas in proper amount (bank 12 bottles)
  - ? preliminary data taking downstream T9 control room with muons ? 1 week in advance ?



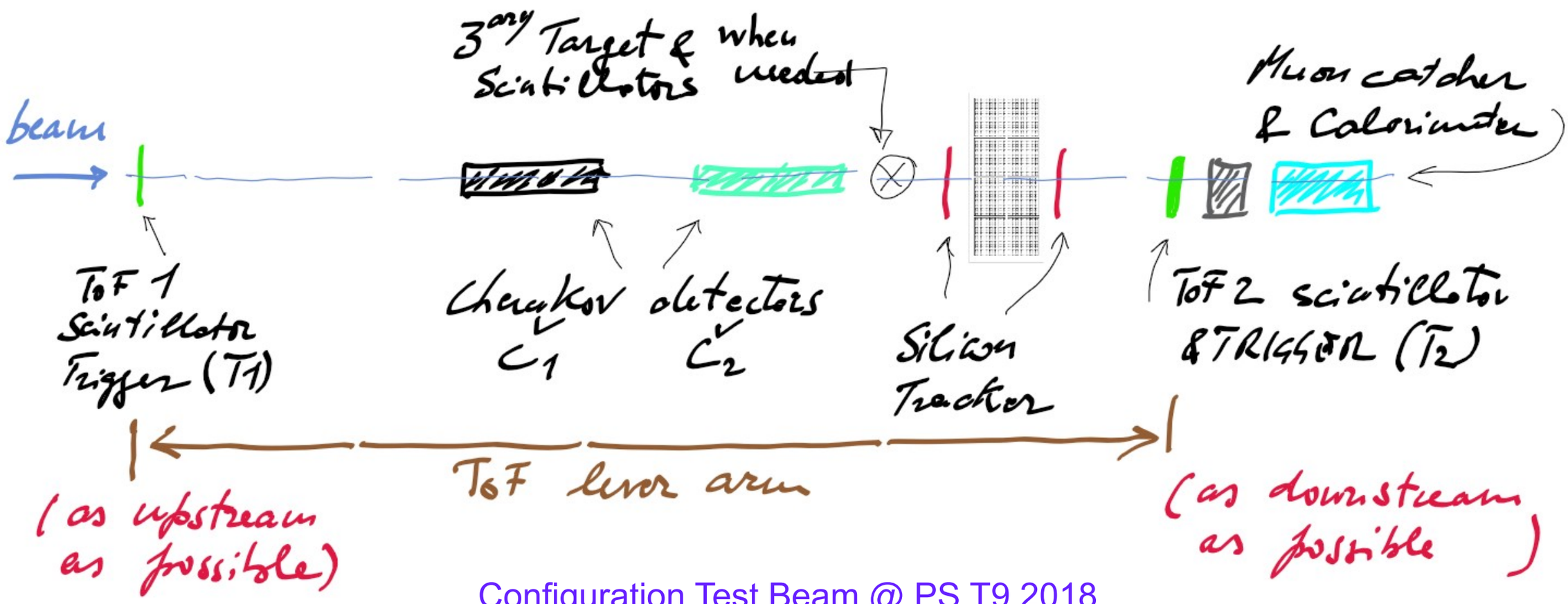
Detectors & Setup



- Main detector under test → large volume TPC

- Ancillary detectors (beam line)
  - 2x Thr. Cherenkov Counters → crucial to test PID
  - Beam trackers → XDC ? access to signals ? To our DAQ ?

- Ancillary detectors (ours)
- - TPC prototype → external tracker (300μm resolution) → tested at SPS Test Beam Nov. '21
  - Silicon strip tracker stations (10x10cm^2) → external tracker (30μm resolution) → "
  - Scintillators → TOF system to select particles (e,mu/K/p) at trigger level: Level Arm ! → Scint. location ?
  - Lead-glass blocks → calorimeter / muon catcher



Configuration Test Beam @ PS T9 2018

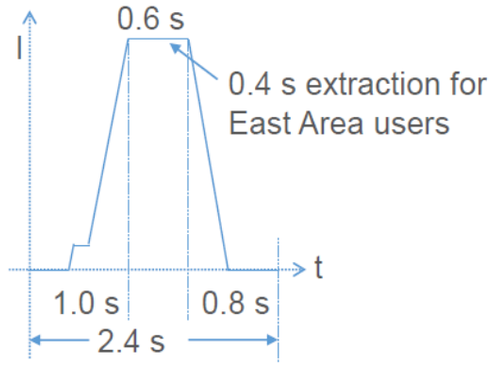
Test Beam at T9

Primary Beams

- Primary beam parameters

Parameter	Value
Proton beam momentum [GeV/c]	24
Maximum flux per PS spill	$5\ 10^{11}$
Maximum # spills per super-cycle	6
Duration of super-cycle [s]	45.6
Maximum # protons per second	$6.7\ 10^{10}$
Maximum number of days per year	200
Assumed efficiency	90%
Maximum number of super-cycles per year	340'000
Maximum number of protons per year	10^{18}

- East Area Cycle



- F61D (Dump, max. 2 of 6 cycles)
- Target A (T9, typ. 3 of 6 cycles)
- Target B (T10/T11, typ. 3 of 6 cycles)
- T8 (Irradiations, max. 6 of 6 cycles)

Trigger & Readout conditions:

- limited by readout deadtime ~ 3ms

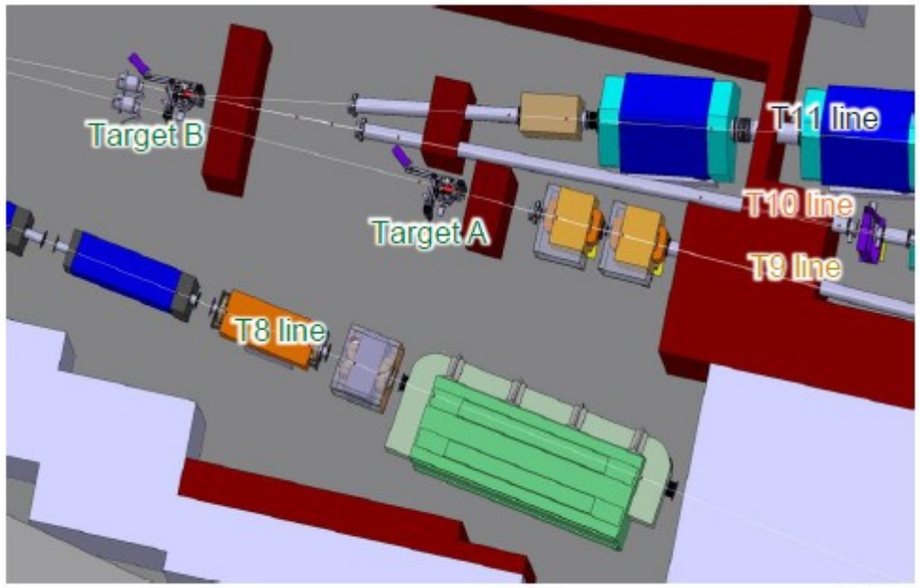
→ readout less than 100 triggers / spill → intensity ~ O(10^2 pps)
→ need selective beam conditions → use hadron enriched / electron enriched
→ need selective trigger conditions → use ToF & Cherenkov & muon catcher
→ good e / μ / π / K / p separation at trigger level
… but → need x100 higher beam rate for K and p → intensity O(10^4 pps) for some runs

Note: * Pile-up → would prefer to avoid 2 particles within 50μs → max rate ~ 10^4 pps
* also we must avoid space charge effects → max rate ~ 10^4 pps

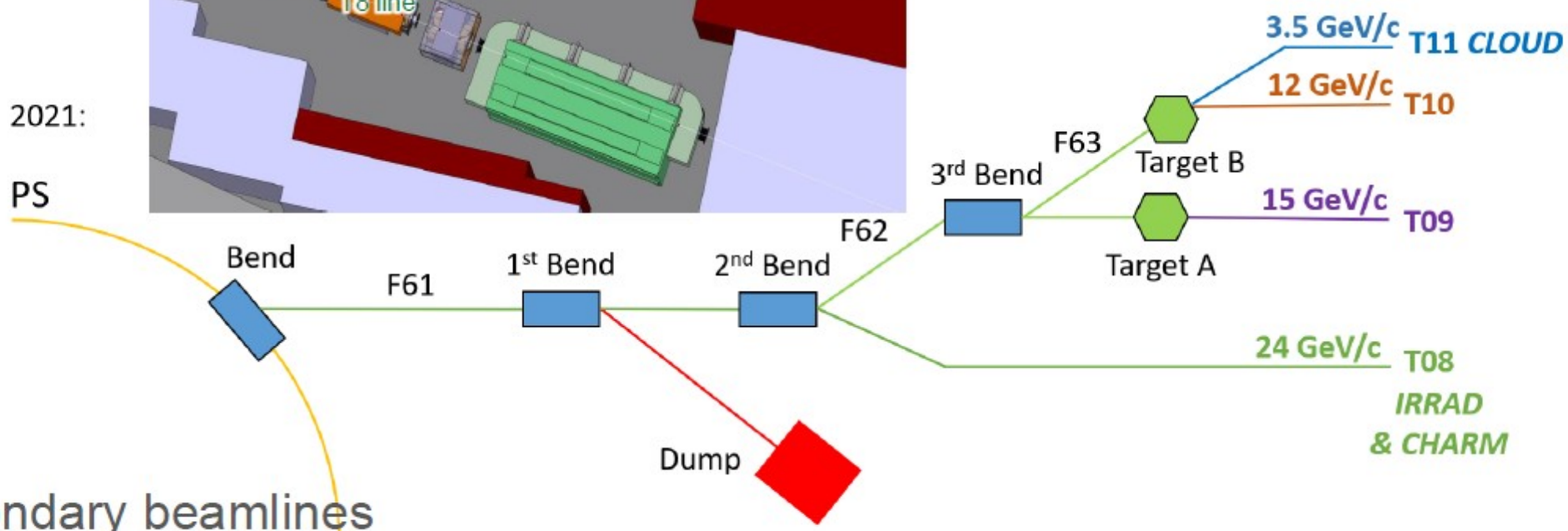
→ with 3 spills/Super-Cycle x 1800 SC/day x 50 trigg/spill → ~300k triggers/day → OK
… but would it be possible to have more than 3 spills per super-cycle ? (max is 6 ...)
(or extract 600ms instead of 400ms ? → lower instantaneous intensity)

Secondary Beams

Target Head	Material	Length (mm)	Diameter (mm)	Comments
1	Be W	200 3	10	Electron enriched
2	Al Be	100 3	10	Electron enriched
3	Al	200	10	Hadron
4	air	-	-	Empty
5	AL	20	10	Hadron (thin target)



2021:



- Secondary beamlines
  T9/T10/T11 with options for pure $e^{+/-}$, pure hadron and pure muon beams

- T9 beam more suitable for pure e+/- / hadron / muon @ lowest momenta

- Would it be possible to minimize material budget (+ evacuate Cherenkovs') along the beam line for improving very low p hadron beams (intensity & p spread) ?

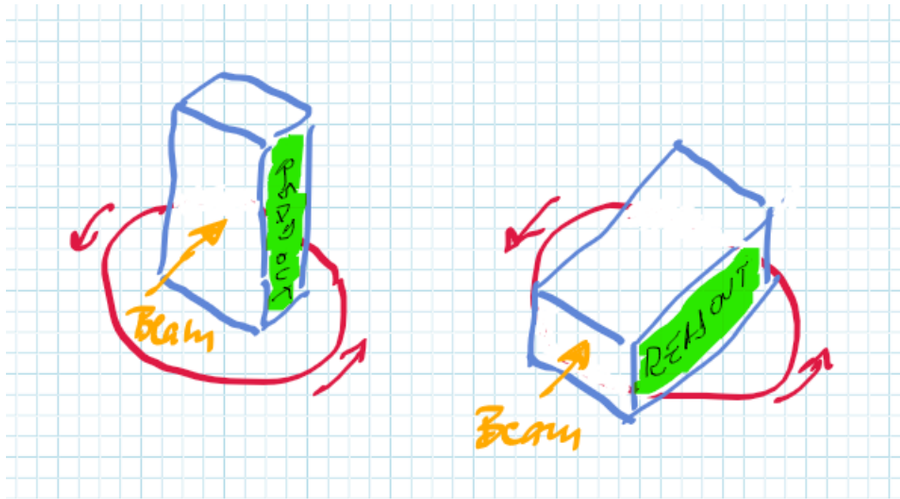
Infrastructure needs

- Cabling
  - main reaodut → x2 optical fibers (special filbers)
  - trigger & control signals in CR (i/o) → about x10 coax. cables
  - ethernet cables x5 for DAQ & HV / LV Power Supplies control

- HV & LV PS
  - Cathode HV = -27kV (< 50μA current)
  - Micromegas HV = +400V (< 5nA current)

- Gas → operating at 1bar (5mbar over-pressure)
  - main gas → T2K premixed bottles (ours)
  - Is N_2 available for purging ? In the area ? Outside T9 ?

- Platforms / structures (ours)
  - our dedicated turn-table



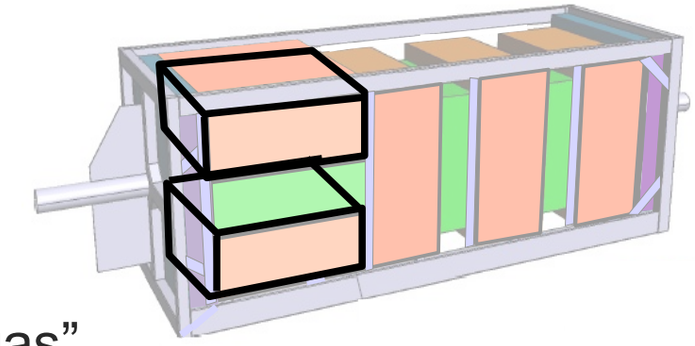
- Racks
  - 1 gas rack (ours)
  - 1 electornics rack (ours)
  + 1 additional

- Water chiller
  - ours

Additional Material

Design considerations – new HA-TPCs

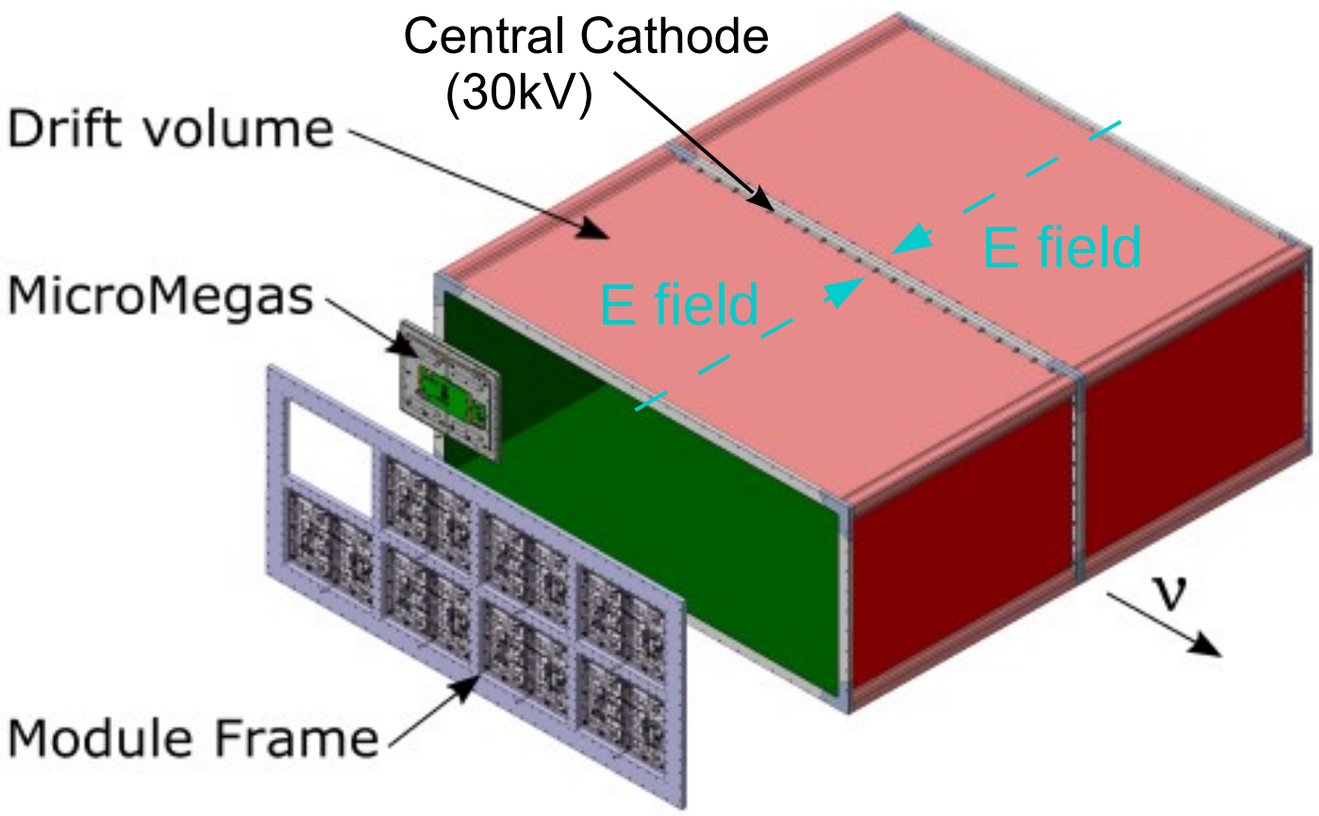
new Field Cage → thin & low density walls
→ thin walls made of solid insulator walls (composite material)
→ minimize dead space & maximize tracking volume



High Angle TPCs to measure charged particles (E~200MeV-2GeV) exiting the new active target (superFGD)

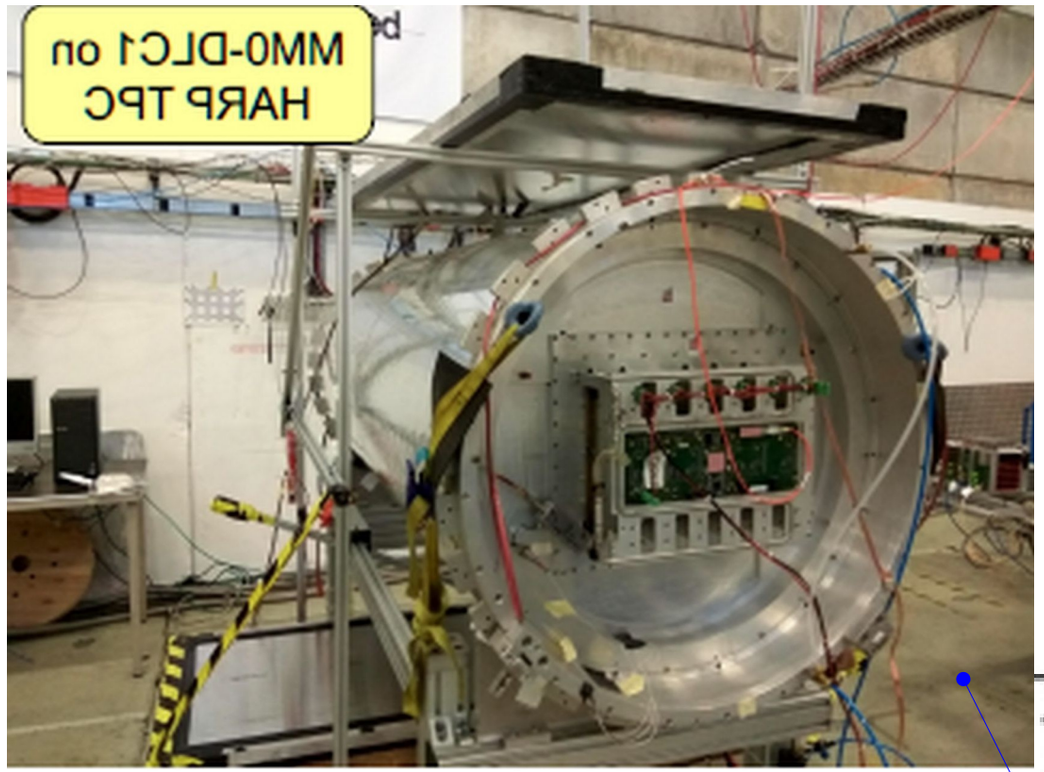
new Micromegas sensors → new "Embedded Resistive Anode Micromegas"
→ charge sharing: same spacial resol. with lower pad density
→ intrinsic spark protection: simplified FE electronics

Parameter	Value
Overall x × y × z (m)	2.0 × 0.8 × 1.8
Drift distance (cm)	90
Magnetic Field (T)	0.2
Electric field (V/cm)	275
Gas Ar-CF_4-iC_4H_{10} (%)	95 - 3 - 2
Drift Velocity $cm/\mu s$	7.8
Transverse diffusion ($\mu m/\sqrt{cm}$)	265
Micromegas gain	1000
Micromegas dim. z×y (mm)	340 × 410
Pad z × y (mm)	10 × 11
N pads	36864
el. noise (ENC)	800
S/N	100
Sampling frequency (MHz)	25
N time samples	511

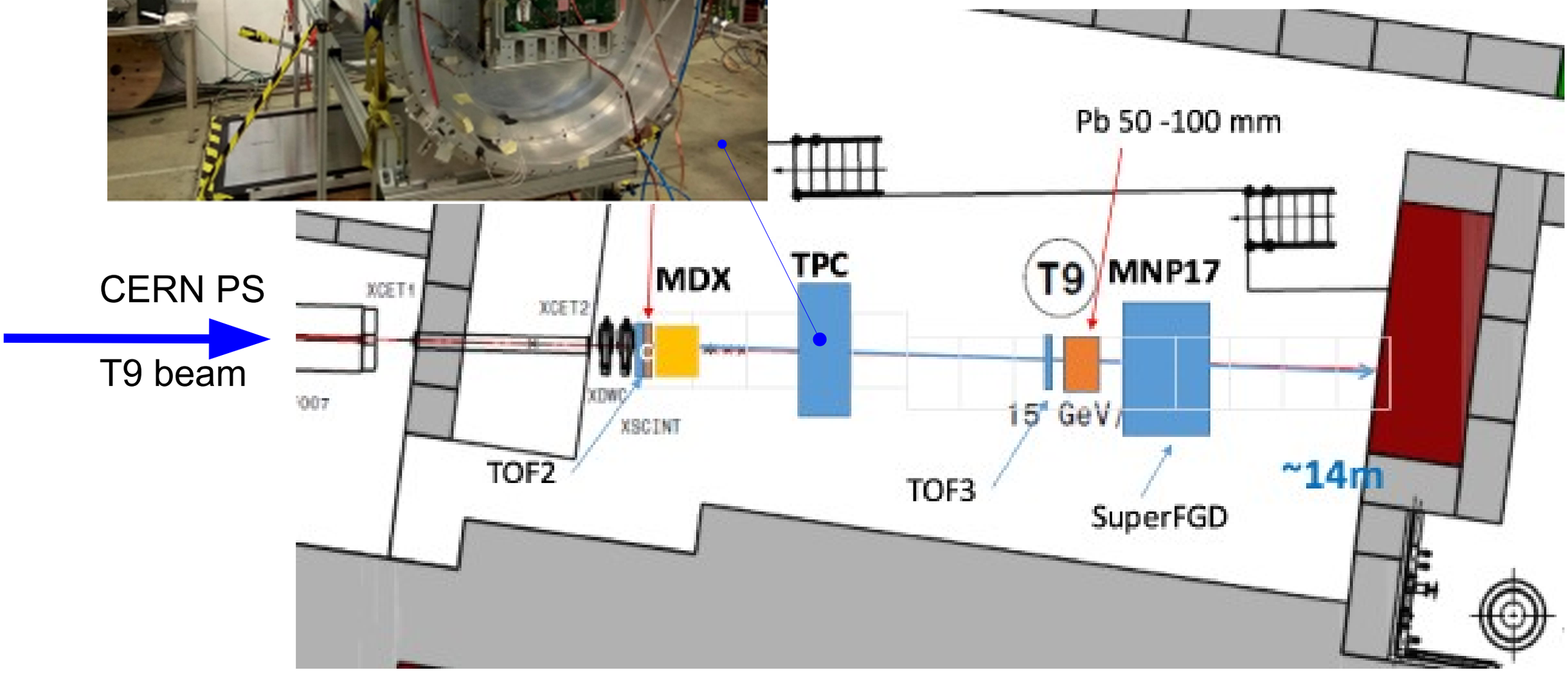


RMM0 & HARP FC → Test Beam 2018 at CERN

- Results of the analysis are published in 2020: NIM A 957, 163286



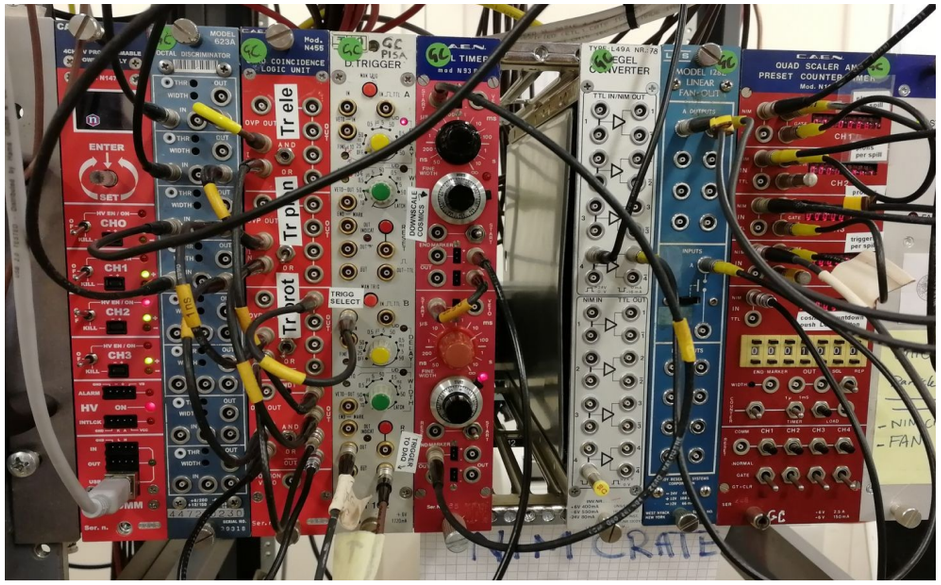
15 Days
@ CERN PS T9 Beam line

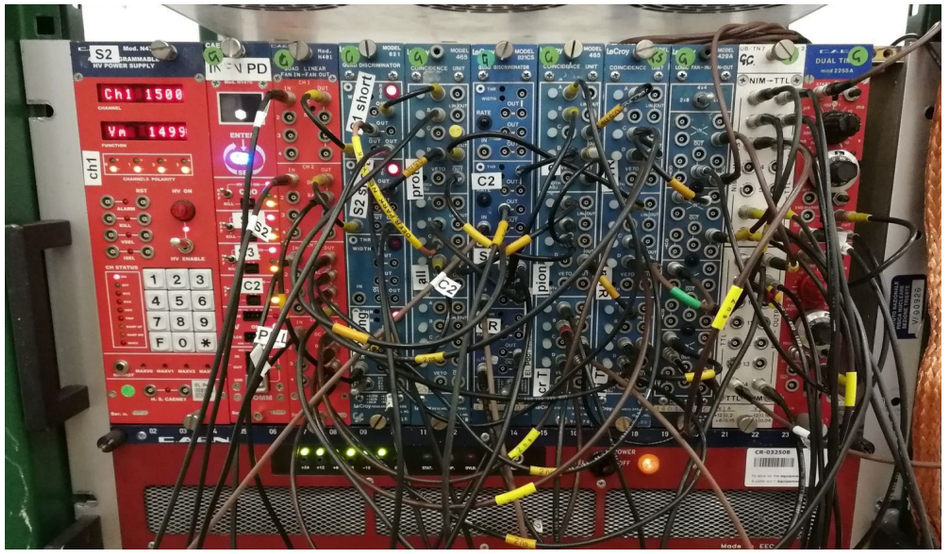


Test Beam 2018

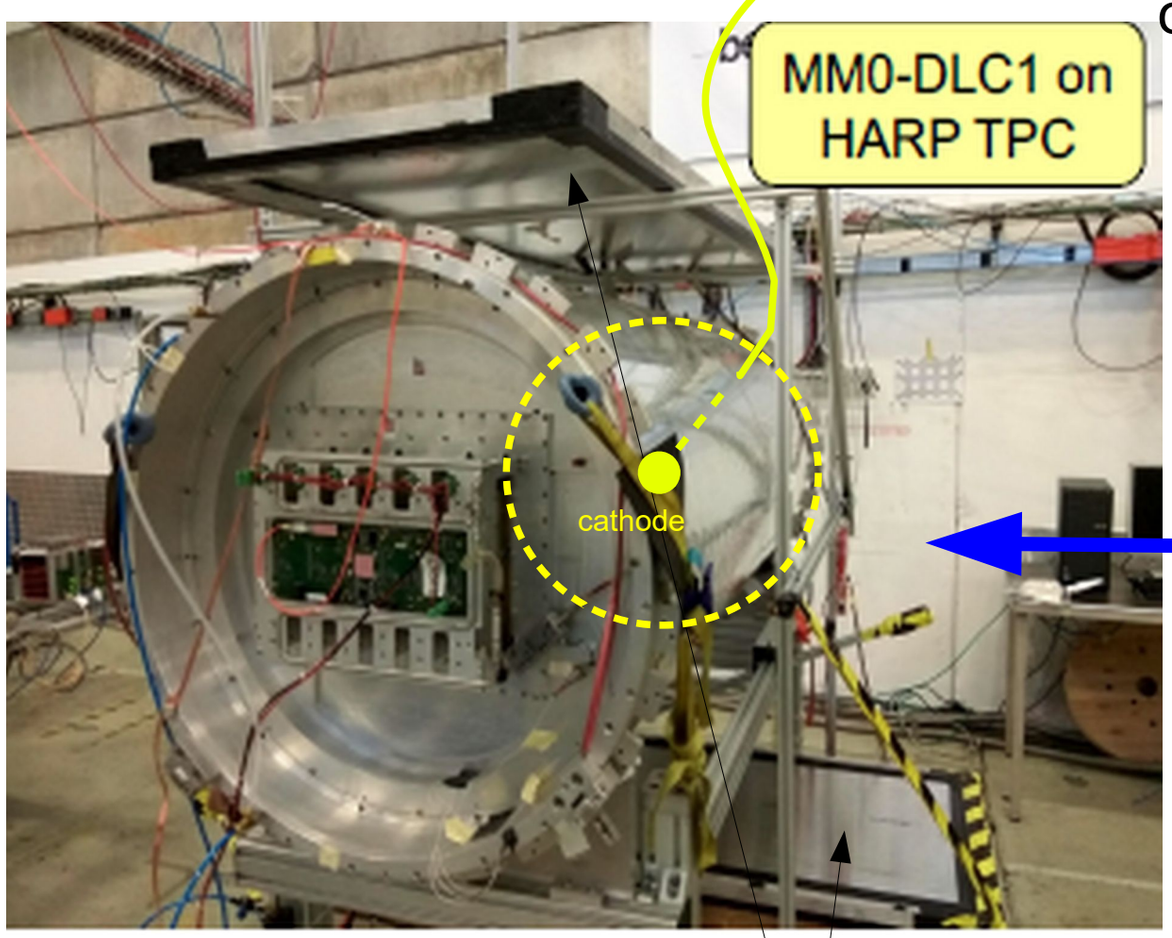
Collected data samples
- **Beam momentum** = +/- 0.5 / 0.8 / 1.0 / 2.0 GeV/c
- **e/π/μ/p** sepatation at TRIGGER LEVEL

BEAM TRIGGER (NIM logic)
selecting particles by combining:
- timing resolved coincidences of scintillators along the beam line → ToF trigger
- threshold Cherenkov counters coincidences with scintillators → Cherenkov trigger
- Muon separation → downstream Muon catcher





^{55}Fe SOURCE
on cathode



Beam

CR TRIGGER
large Horizontal scintillators