BASKET

(“Backward Scattering Electron Tracker”)

Parity violation in backward scattering and the weak mixing angle

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lots of help from P.-F. Giraud (DphP), C.Goblin, A.Bonenfant (DEDIP)

in collaboration with S.Baunack, B.Glaser, **F.Maas**, M.Wilfert et al. (Mainz)

Weak mixing angle

- The angle that defines the physical photon and the Z :

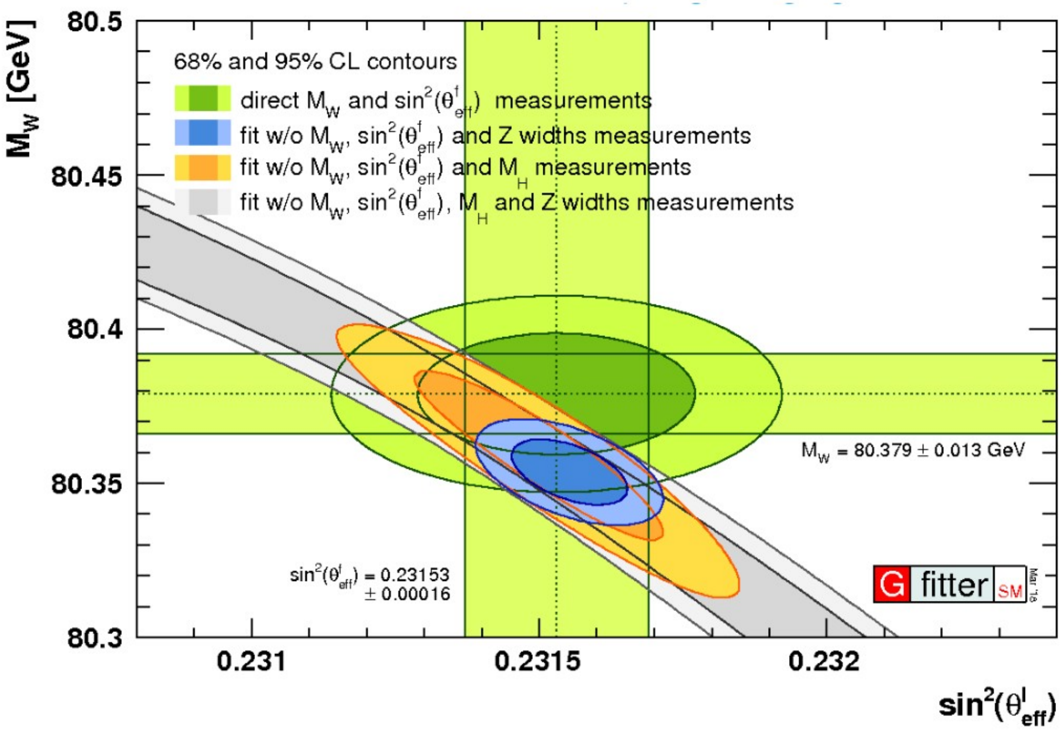
$$\begin{pmatrix} A_\mu \\ Z_\mu \end{pmatrix} = \begin{pmatrix} \cos\theta_W & \sin\theta_W \\ -\sin\theta_W & \cos\theta_W \end{pmatrix} \begin{pmatrix} B_\mu \\ W^3_\mu \end{pmatrix}$$

- Defines the ratio of the W and Z masses

$$\cos^2\theta_W = \frac{M_W}{M_Z}$$

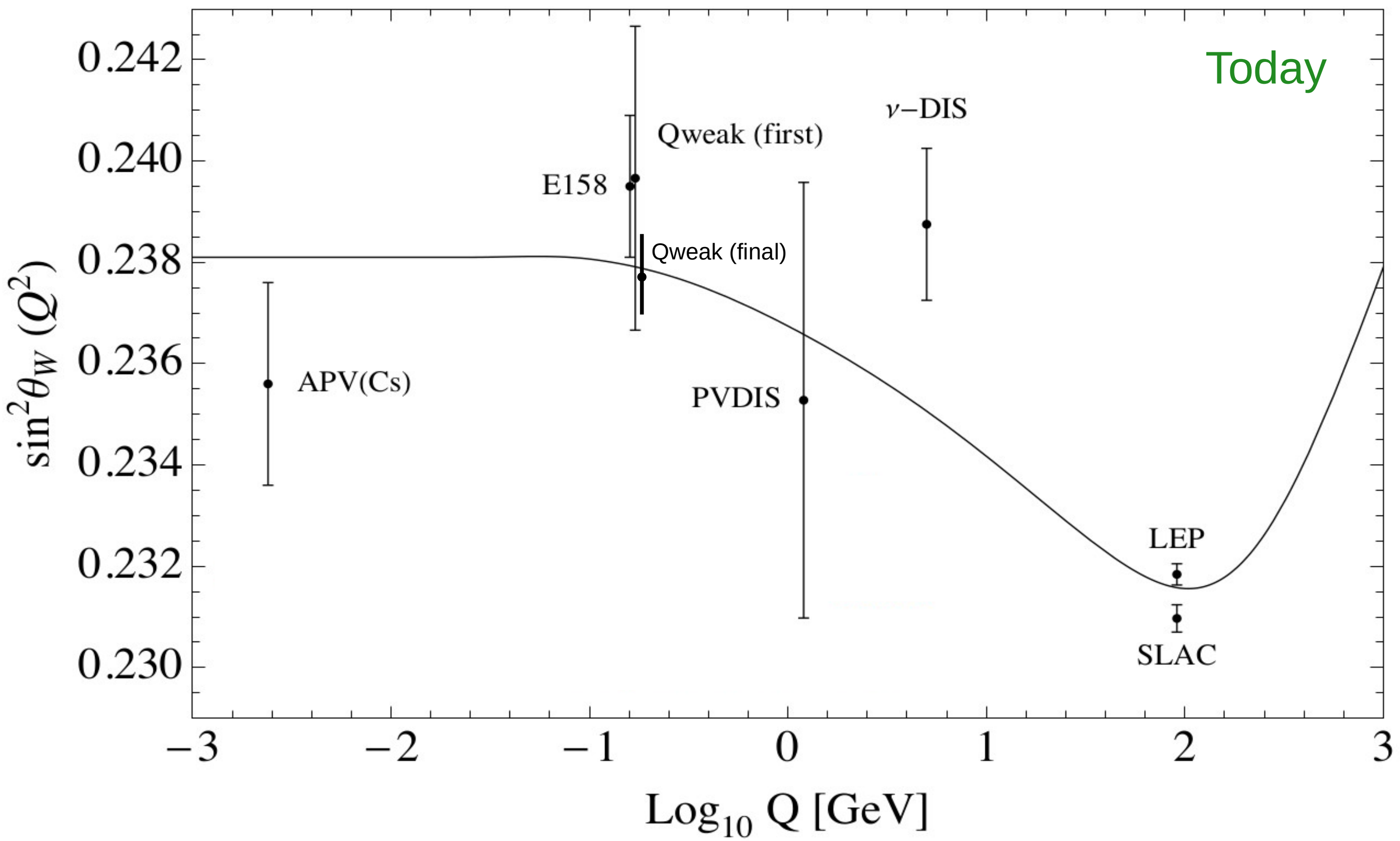
and the couplings of the Z to fermions:

$$c_V = T_3 - 2 \cdot Q \cdot \sin^2\theta_W, \qquad c_A = T_3$$

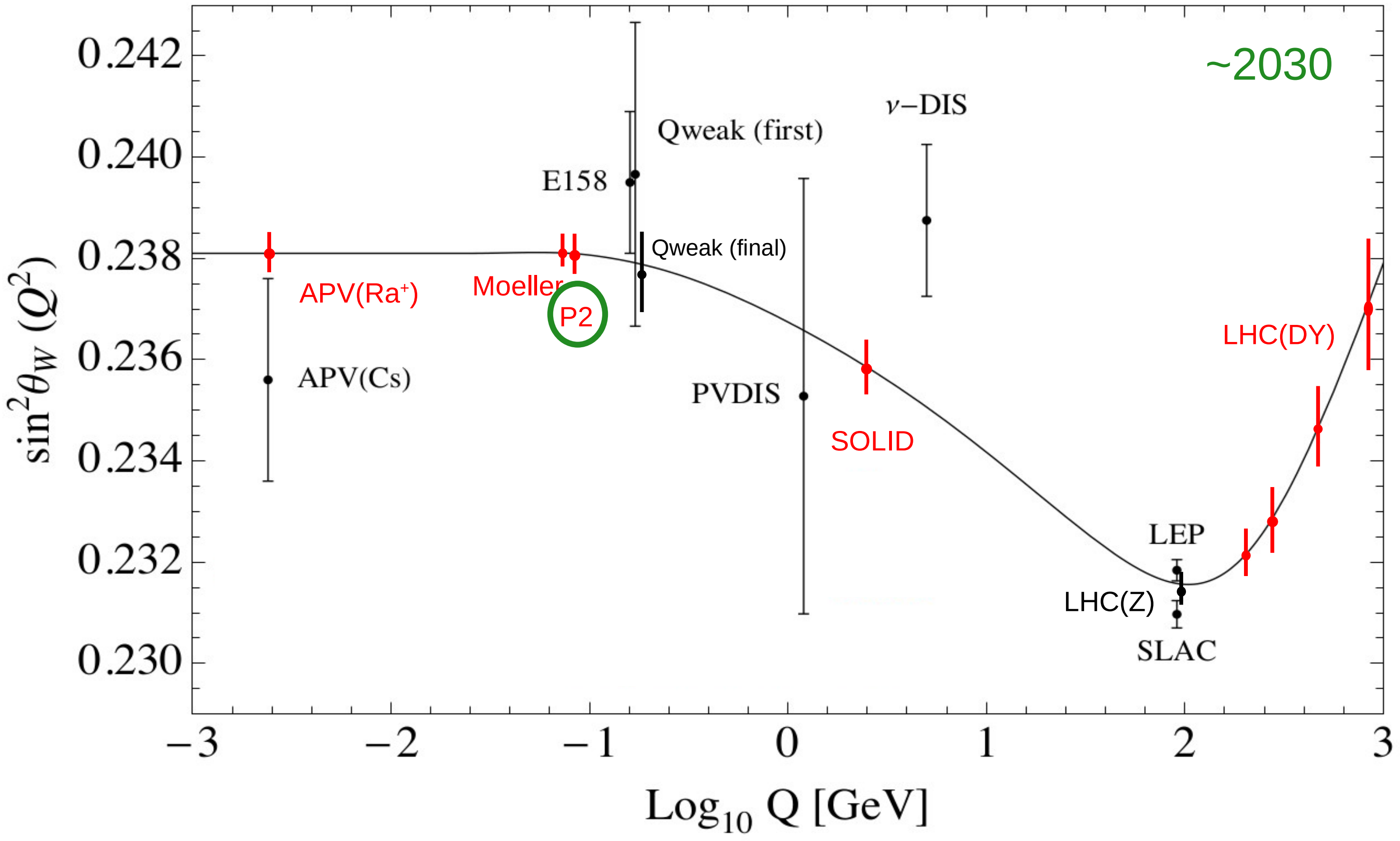


→ can be tested in collisions at the Z pole (forward/backward [LEP], left/right asymmetries [SLC]), and in polarized electron scattering at low energy

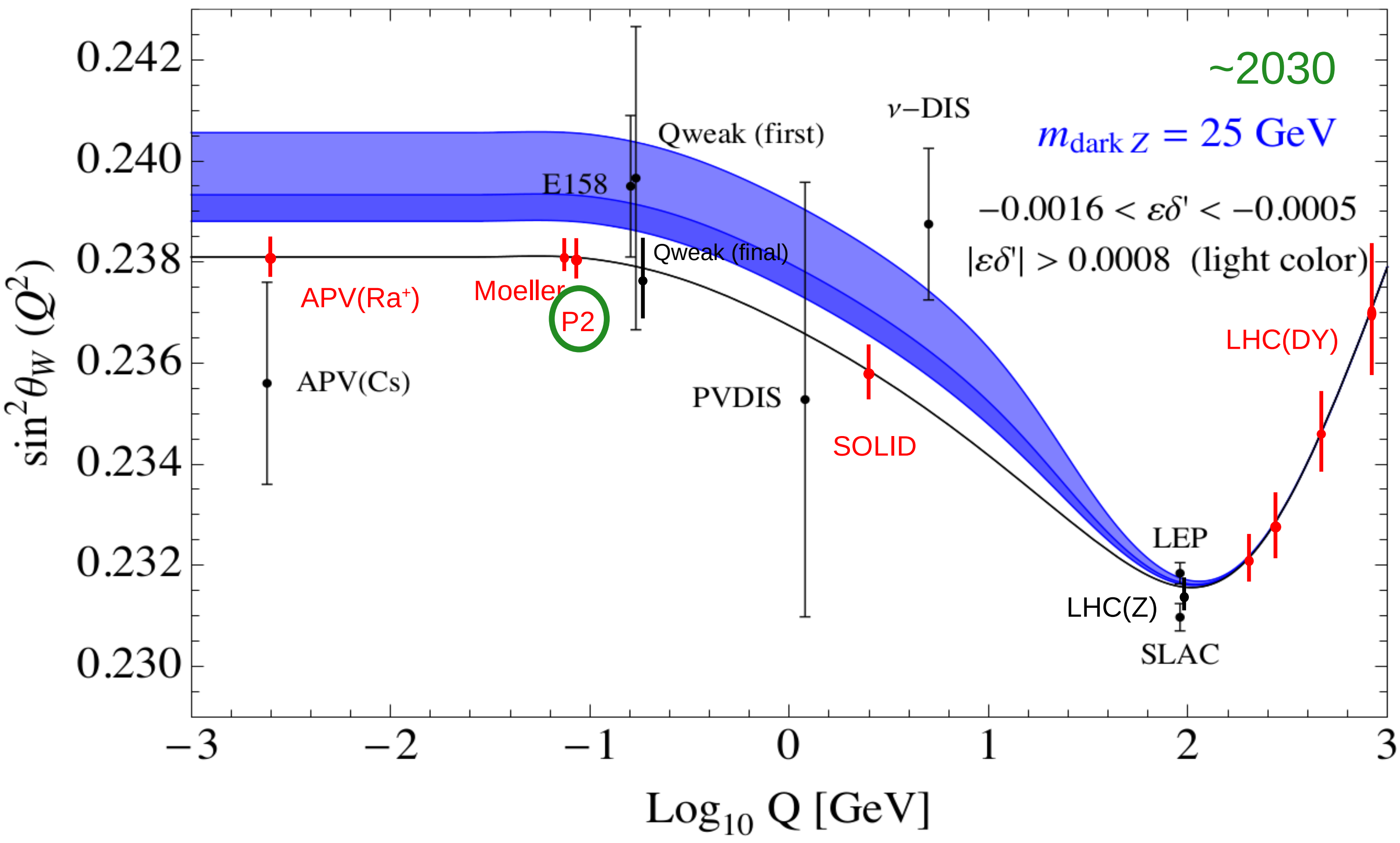
Weak mixing angle



Weak mixing angle

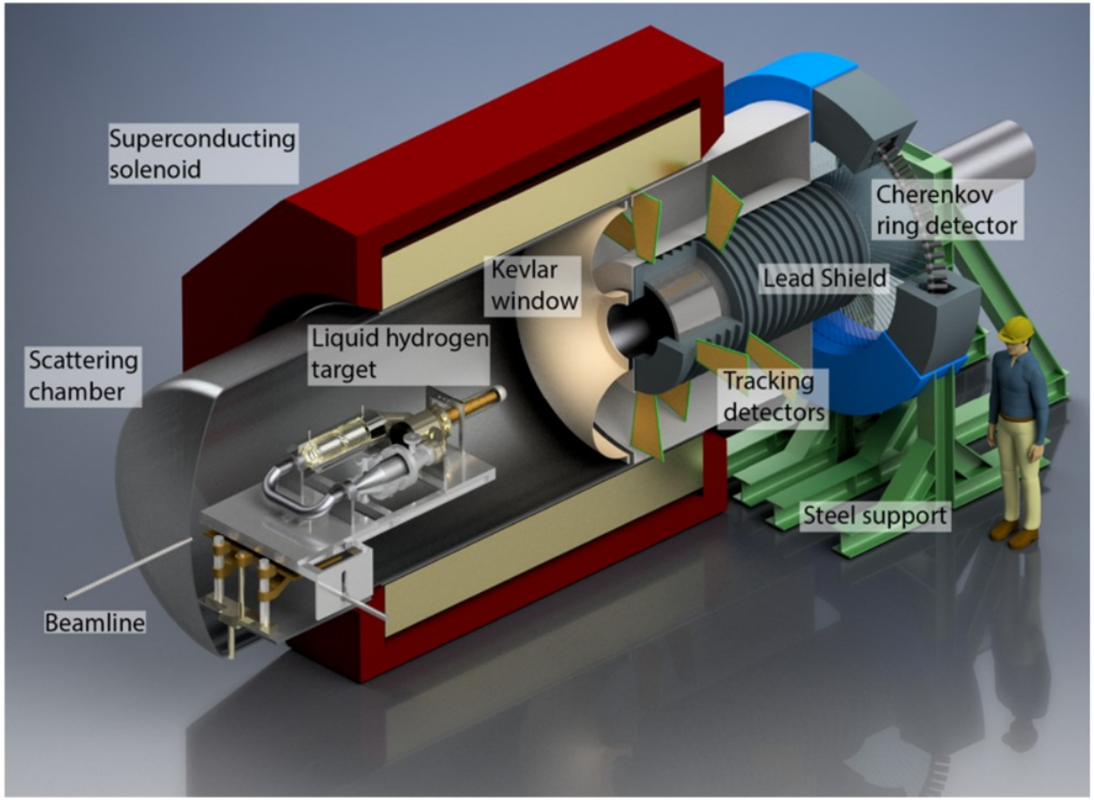


Weak mixing angle



The weak mixing angle at P2

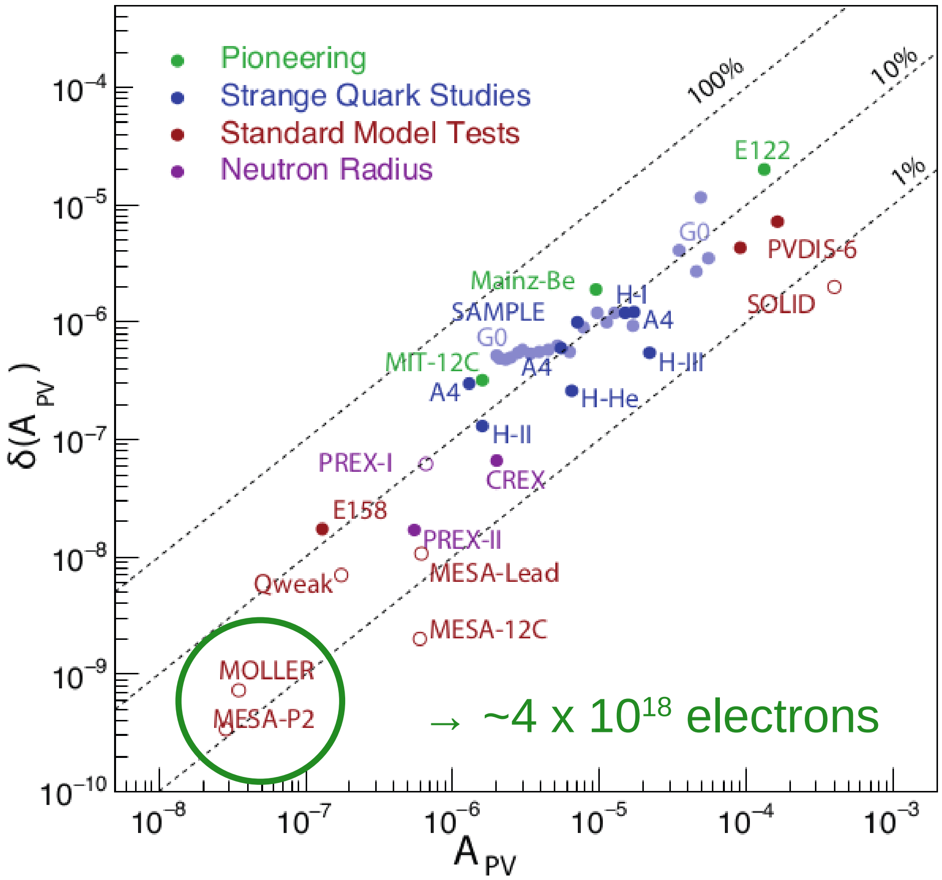
- Project in construction (Mainz):



E_{beam}	155 MeV
$\bar{\theta}_{\mathrm{f}}$	35°
$\delta\theta_{\mathrm{f}}$	20°
$\langle Q^2\rangle_{L=600\,\mathrm{mm},\ \delta\theta_{\mathrm{f}}=20^\circ}$	$6\times10^{-3}\,(\mathrm{GeV/c})^2$
$\langle A^{\mathrm{exp}}\rangle$	-39.94 ppb
$(\Delta A^{\mathrm{exp}})_{\mathrm{Total}}$	0.56 ppb (1.40 %)
$(\Delta A^{\mathrm{exp}})_{\mathrm{Statistics}}$	0.51 ppb (1.28 %)
$(\Delta A^{\mathrm{exp}})_{\mathrm{Polarization}}$	0.21 ppb (0.53 %)
$(\Delta A^{\mathrm{exp}})_{\mathrm{Apparative}}$	0.10 ppb (0.25 %)
$\langle s^2_{\mathrm{W}}\rangle$	0.231 16
$(\Delta s^2_{\mathrm{W}})_{\mathrm{Total}}$	3.3×10^{-4} (0.14 %)

Beam current 150 μA pol. 85%
LH_2 target, 60 cm
→ L = 2.4 10^{39} /cm^2/s

The weak mixing angle at P2



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The weak mixing angle at P2

- Parity-violating asymmetries, the weak mixing angle, and the proton form factors

- Measurement :

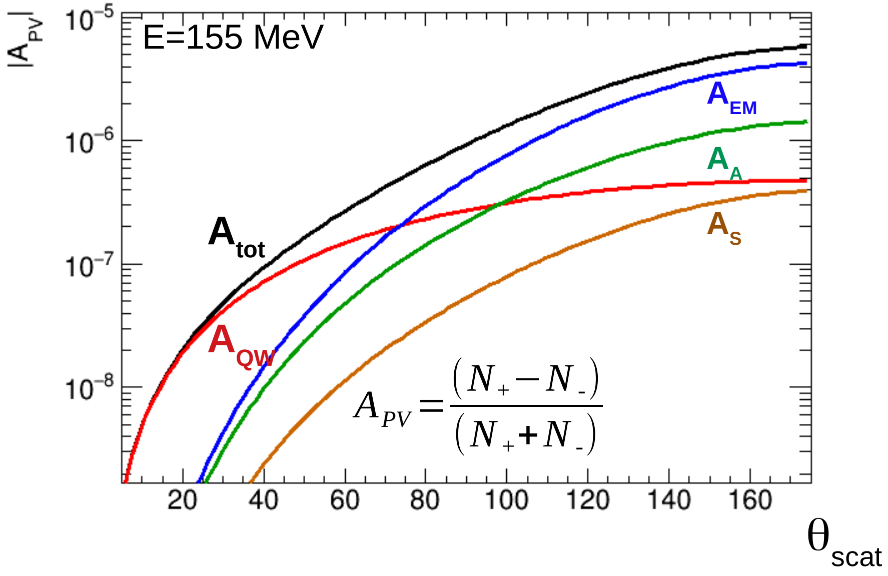
$$A_{PV}^{exp} = \frac{N^+ - N^-}{N^+ + N^-}$$

- Prediction:

$$A_{PV} = \frac{-G_F Q^2}{4\pi\alpha_{em}\sqrt{2}}\left[Q_W^p - F(Q^2)\right]$$

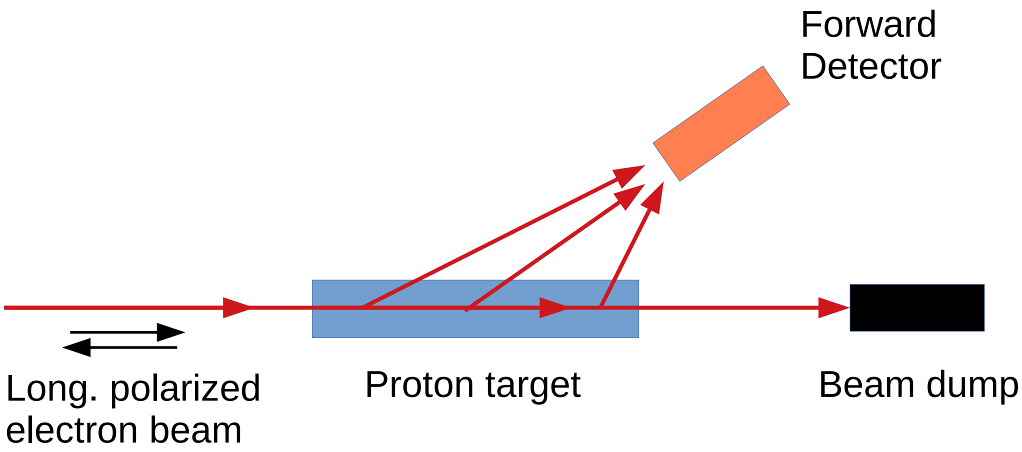
$$Q_W^p = 1 - 4\sin\theta_W.$$

$$F(Q^2) = F_{EM}(Q^2) + F_A(Q^2) + F_S(Q^2)$$

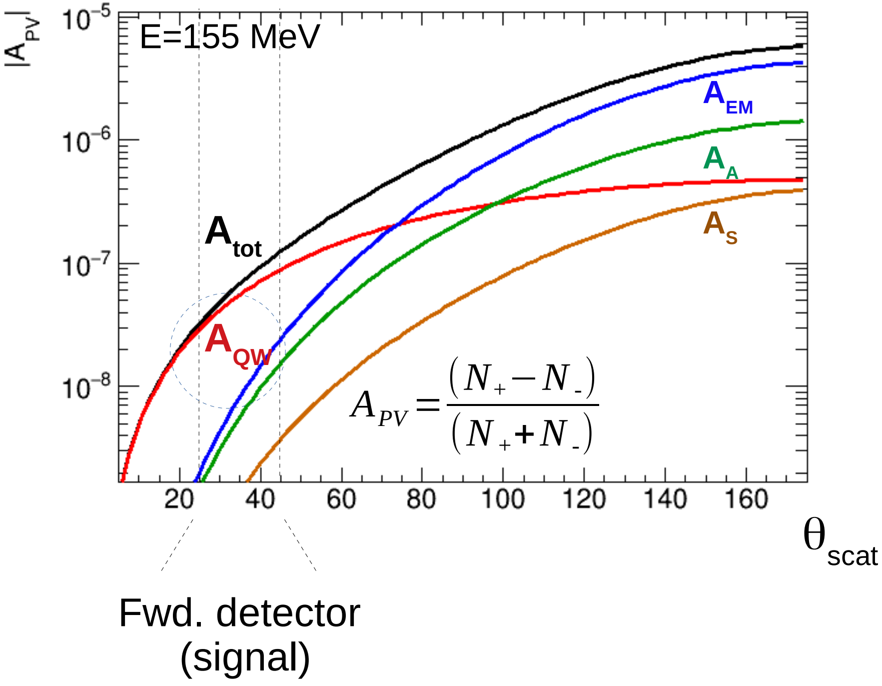


The weak mixing angle at P2

- P2 – Forward-angle measurement :



A_{QW} : "signal", "feels" $\sin^2\theta_W$
A_{EM} : known
A_A, A_S : systematics!!

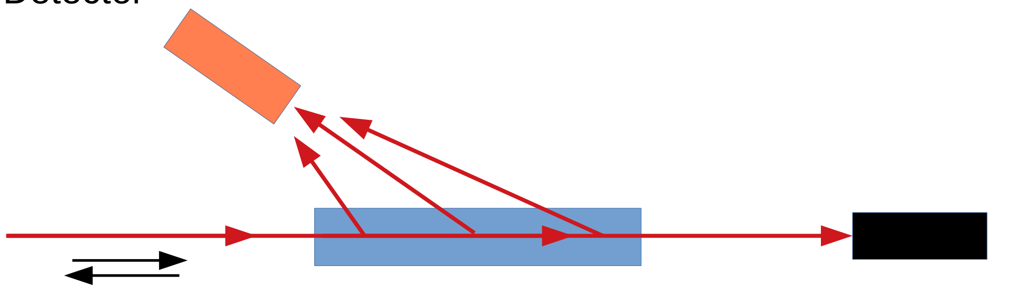


$$A_{PV} = \frac{(N_+ - N_-)}{(N_+ + N_-)}$$

25 < θ < 45 deg.
Total signal rate ~ 100 GHz
→ integrating detectors
→ ~10000 hours; ~4x10^{18} electrons

The weak mixing angle at P2

- **BASKET** :



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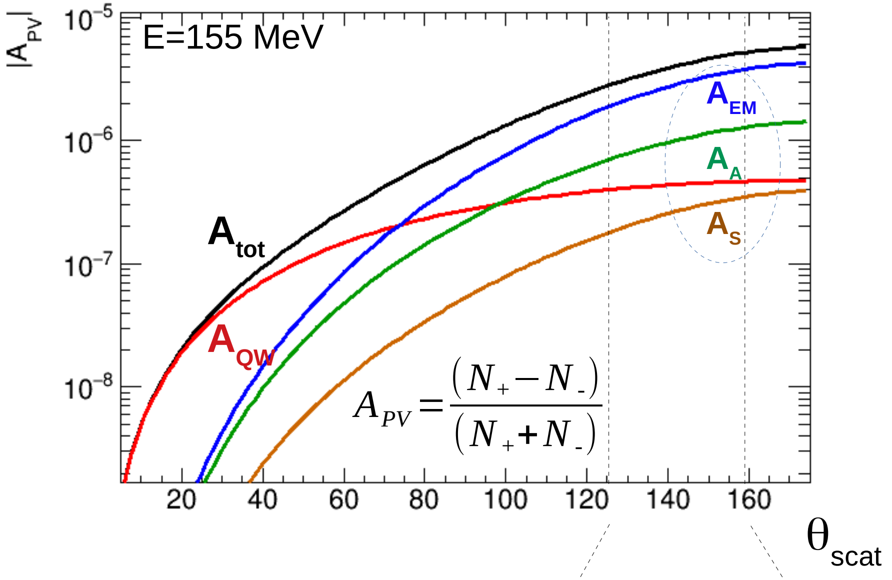


$120 < \theta < 160$ deg.
Total signal rate ~ 100 MHz
→ counting detectors possible, if sufficiently granular
→ ~1000 hours; 10^{14} electrons

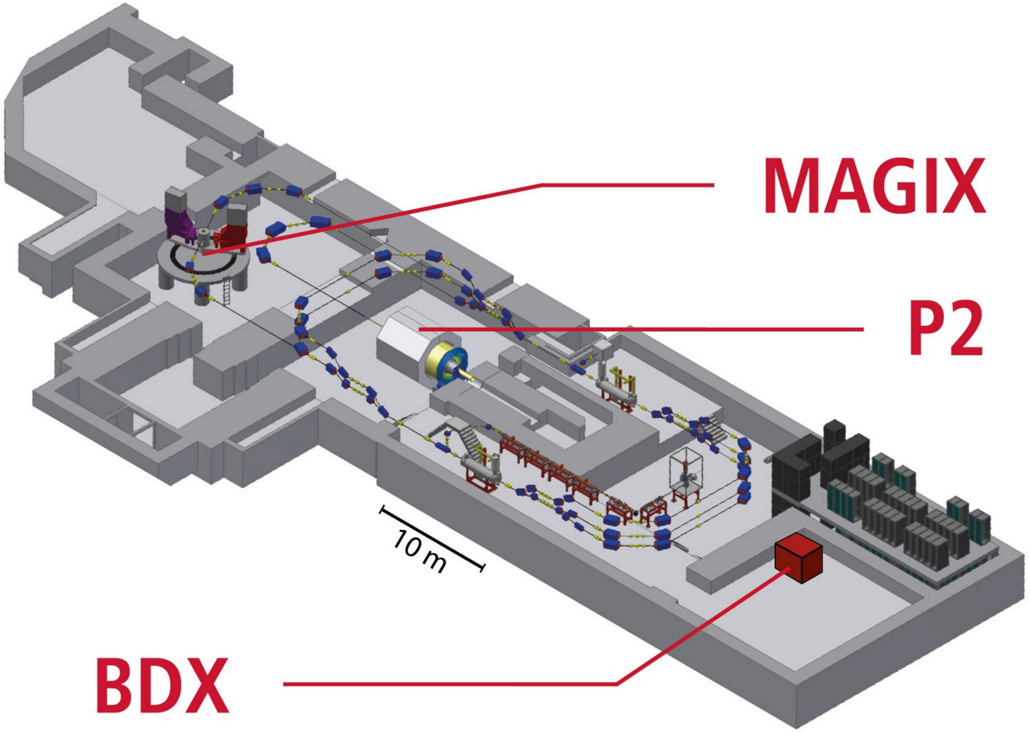
→ This proposal

MESA

- In construction; commissioning 2025 (55 MeV), 2026 (155 MeV)

  - 5 MeV (injection) + 3 x 50 MeV
  - ERL (Magix) or extracted beam (P2)
  - 5000 hours live time / year;
    4000 hours to experiments;
    ~2500 hours for P2

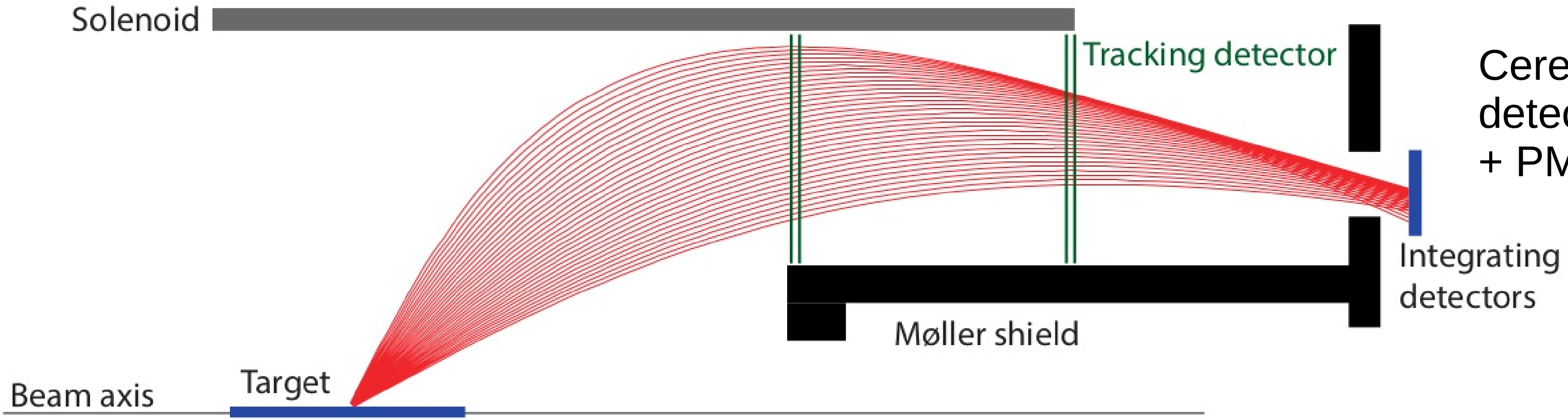
  - Polarized (85% +/- 0.5%);
    polarity flipped every 1 ms



P2

- Overview

Solenoidal field, 0.6-0.7 T



Cerenkov detectors + PMTs

LH_2, 60 cm
4 kW heat load

Detailed status per system in back up

Backward tracker project

- General considerations, assuming an overall signal rate of ~100 MHz
  - Physics opportunities
    - Hydrogen, Deuterium, Carbon , Lead targets
    - Very precise (<1%) determination of F_A (θ,Q^2)
    - **Required** to achieve the advertised precision in $\sin^2\theta_W$
    - Derived applications : atomic “neutron skin” and neutron stars; (coherent) neutrino scattering
  - Why a dedicated tracker technology?
    - Forward tracker optimised for high rates: small strips; large number of channels and data throughput; very partial azimuthal coverage → expensive solution (~1M // module)
    - Backward-angle measurements require full azimuthal coverage; pads of 1-2 cm^2 are sufficient to achieve ~20 kHz rates and adequate resolution

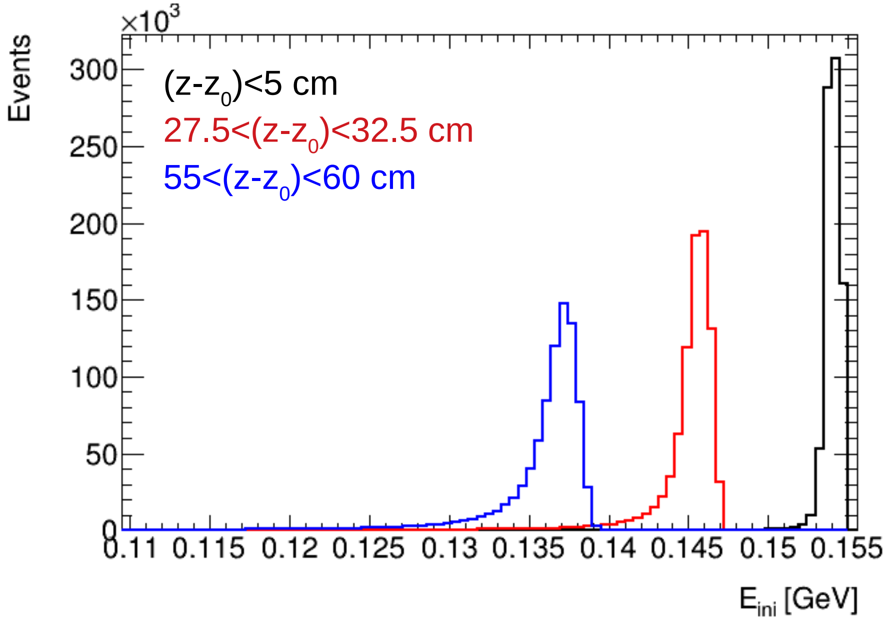
      → Micromegas known to function in such conditions

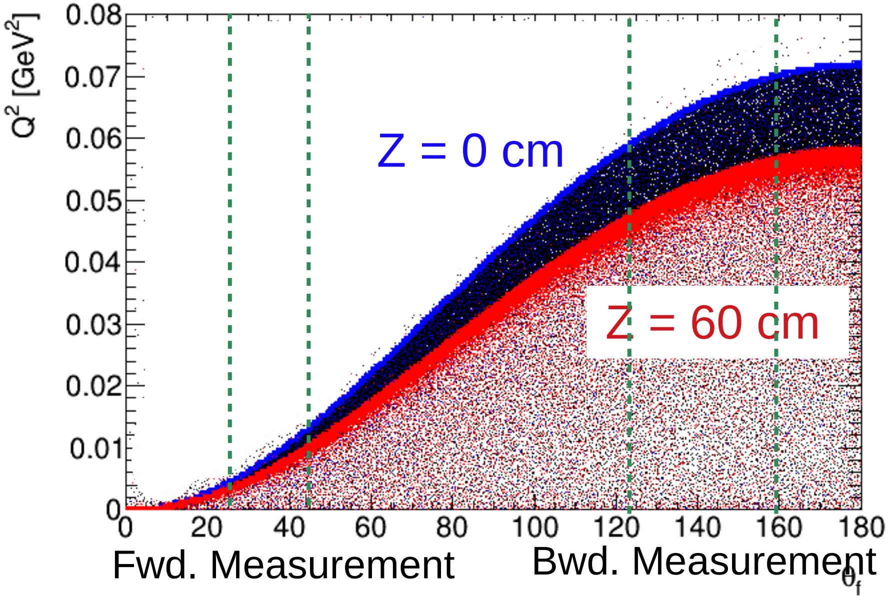
Backward tracker project

- General considerations, assuming an overall signal rate of ~100 MHz
  - Event-by-event track reconstruction possible, with many advantages
    - ($1/p$, θ, ϕ, z_0) vs integrated signal current
      - → Background control
      - → Monitor energy loss fluctuations in the target
    - A dynamical measurement : Form factors vs θ, Q^2
  - Track reconstruction requires sufficient Field integral, between target and detector.
    - Hardly any field seen in nominal target position
      - → target moved downstream, inside vacuum chamber
      - → optimised detector position
    - Low-energy electrons → thin detectors (<0.5% X_0)

Backward tracker project

- General considerations, assuming an overall signal rate of ~100 MHz
  - $A_{PV} \sim Q^2.Q_W^p$: accurate knowledge of momentum transfer needed, or we mis-interpret A_{PV} !





→ event/event reconstruction

Backward tracker project

- Overall geometry (sketch):

10<R<60 cm
Z = -200/-260/-320 cm

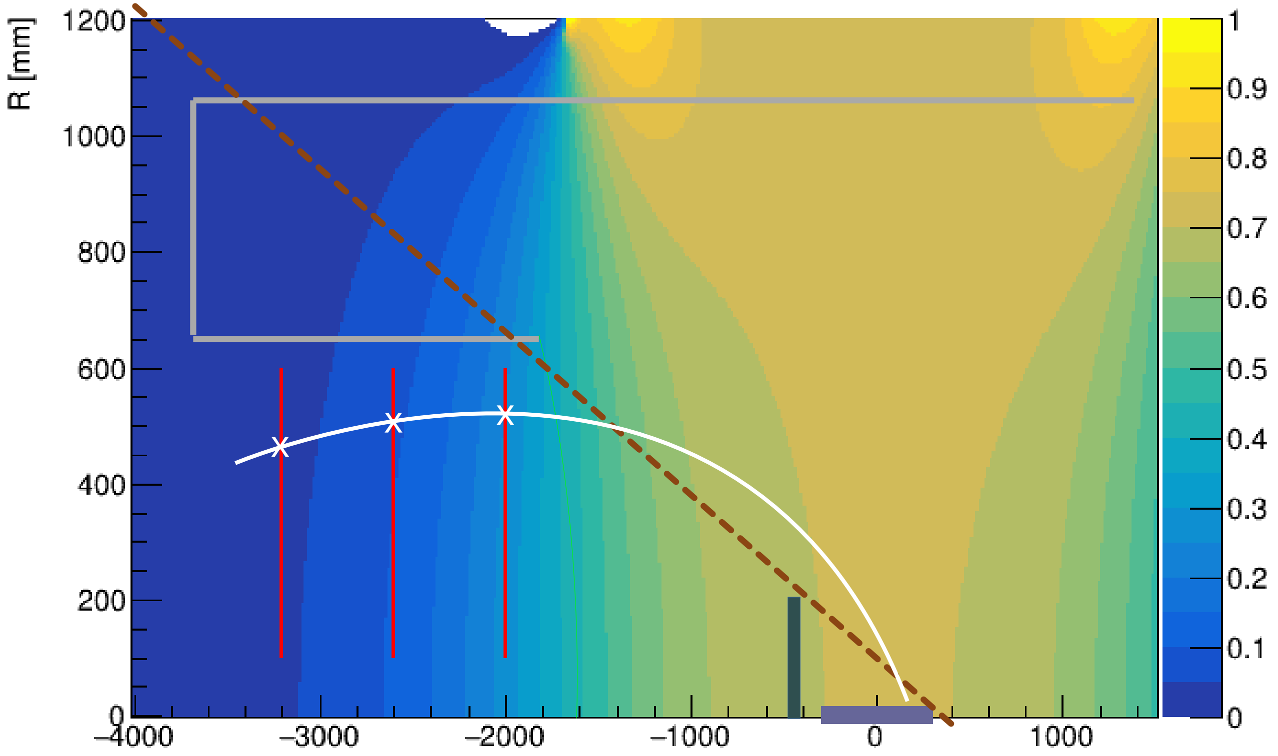
Carbon Fibre vacuum window

Shielding disk

Target

B Field

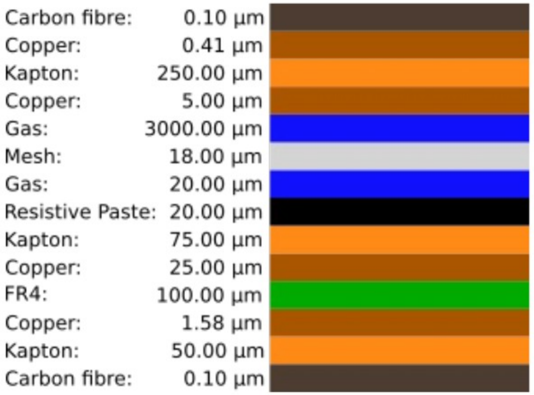
Line of sight

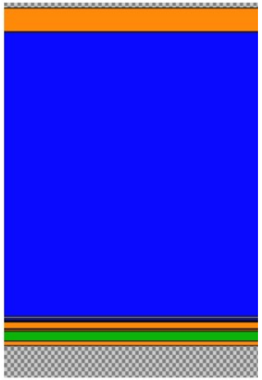


Backward tracker project

- Module design:
  - CLAS12 material budget & Geant4 implementation (credits F.Bossu):

		Matière	X0 (g/cm²)	Densité (g/cm3)	Epaisseur (µm)	Epaisseur (cm)	1-Transparence ("opacité")	X0 (cm)	x/X0
Dérive	Top	Cuivre	12.86	8.96	5	0.0005	0.1	1.435	3.48E-05
	PCB	Kapton	40.56	1.42	300	0.03	1	28.563	1.05E-03
	Bottom	Cuivre	12.86	8.96	5	0.0005	0.2	1.435	6.97E-05
Mesh	56/16	Inox	14	7.93	30	0.003	0.395	1.765	6.71E-04
Photoimageable		Pyralux			196	0.0196	0.005	35.700	2.75E-06
PCB détecteur	Pistes Resist	Carbone	42.7	2.0	35	0.0035	0.55	21.350	9.02E-05
		Epoxy			35	0.0035	0.45	32.5	4.85E-05
	Resist PCB	Epoxy			70	0.007	0.45	32.5	9.69E-05
		Fibre de verre	25.8	2.4	70	0.007	0.55	10.750	3.58E-04
	Top	Cuivre	12.86	8.96	12	0.0012	0.8	1.435	6.69E-04
	PCB	Epoxy			100	0.01	0.45	32.5	1.38E-04
		Fibre de verre	25.8	2.4	100	0.01	0.55	10.750	5.12E-04
	Bottom	Cuivre	12.86	8.96	12	0.0012	0.2	1.435	1.67E-04
	Coverlay	???			50	0.005	1	35.700	1.40E-04
								Total x/X0	4.05E-03

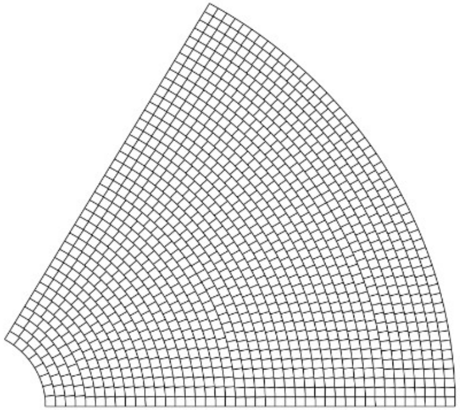


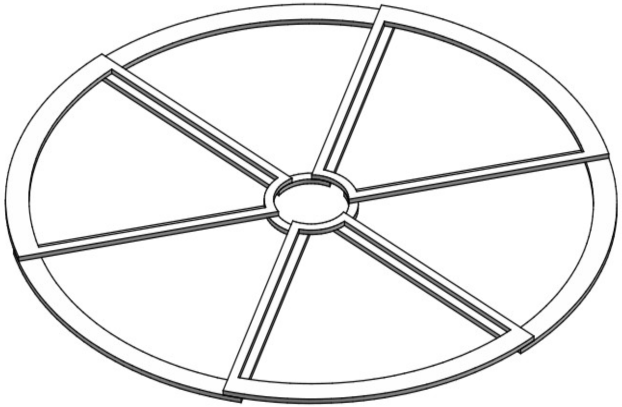


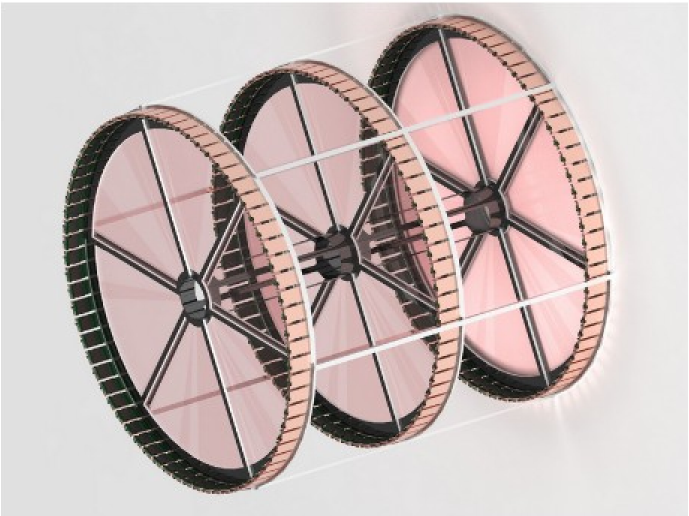
→ total of ~0.4% X_0 per plane.

Backward tracker project

- Module design and assembly:



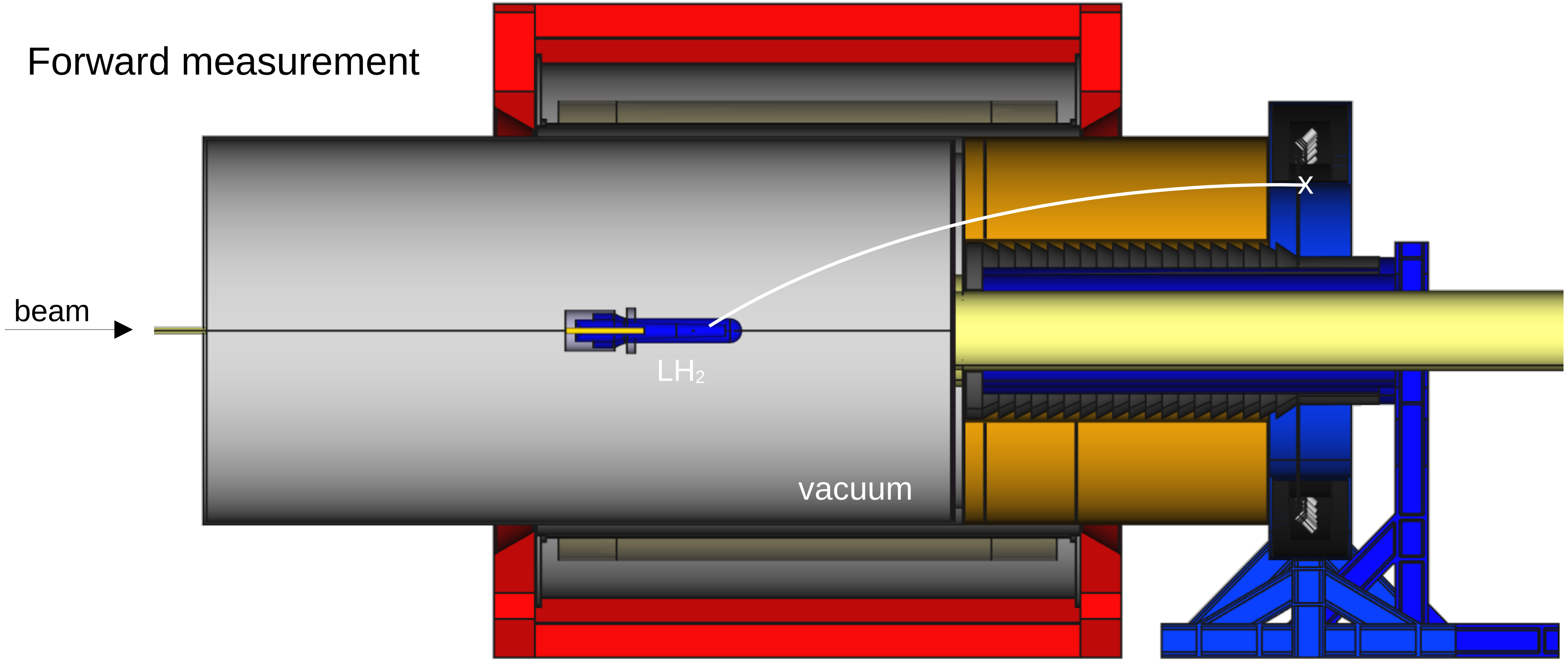




- Signal rates
  - Full acceptance ~ 100 MHz, Δt_{all} ~ 10 ns
    - signal ~85 MHz + 20% margin; beam current can be adjusted
  - Each pad sees ~14 kHz, Δt_{pad} ~ 70 μs
    - Time resolution ~20-30 ns important to reject background or accidental coincidences

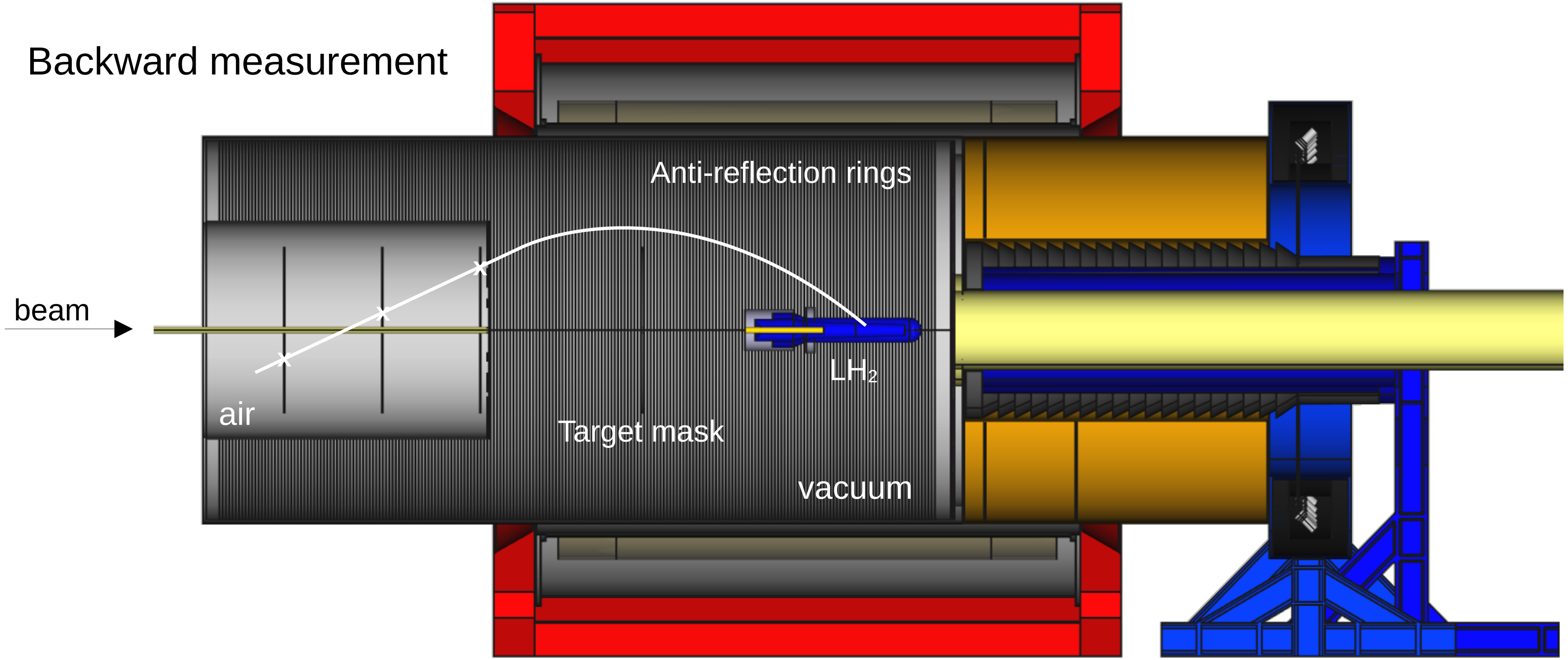
P2

Forward measurement



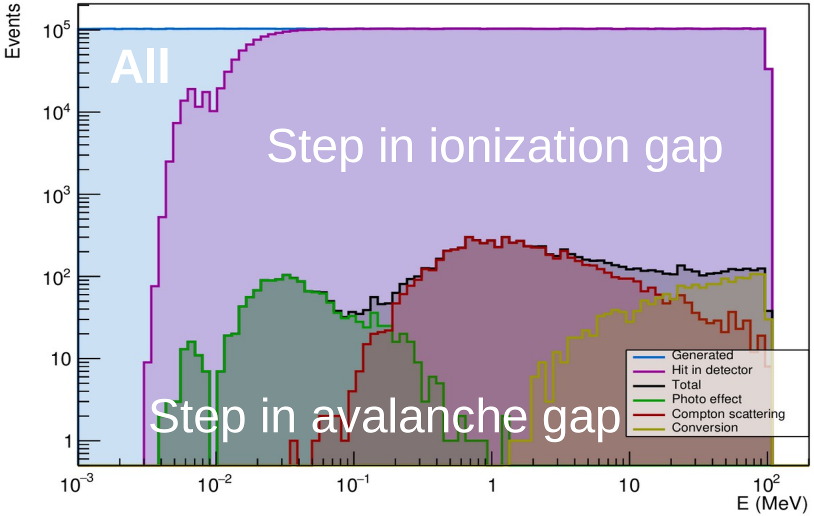
P2 + BASKET

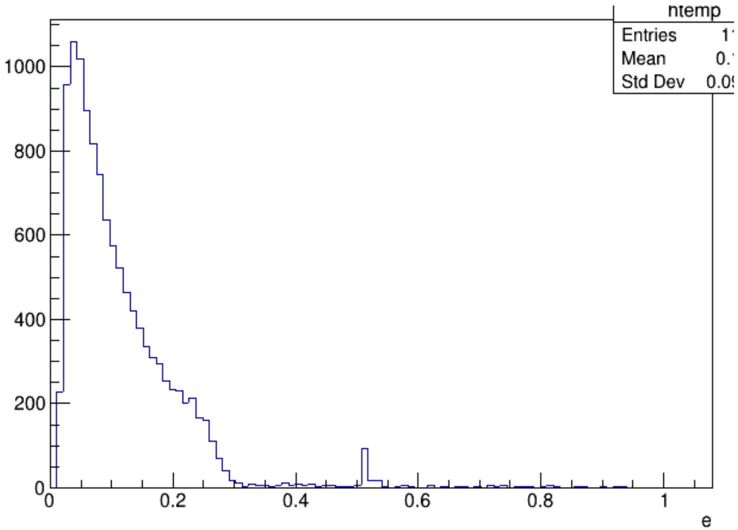
Backward measurement



Performance

- Background rates



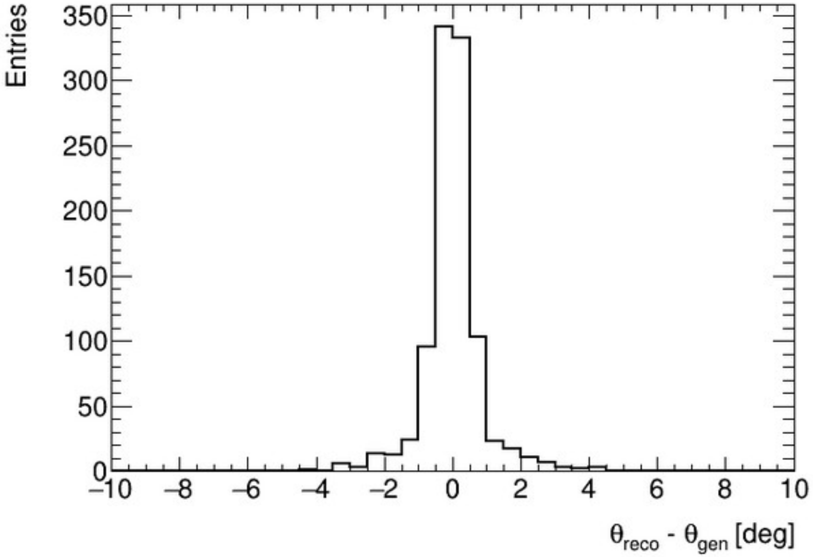


  - “raw” background-to-signal ratio (radiation from beam-target interactions) B/S ~ 10^5
  - Photon detection probability ~0.2% (G4 simulation) B/S ~ 200
  - Shielding B/S ~ 0.05

- Ongoing validation with sources : Fe-55 (6 keV), Am-241 (59 keV), Co-57 (122 keV)

Performance

- Resolution
  - Complete Geant4 simulation of the experiment
  - Track fits using software infrastructure by P-F Giraud ®™



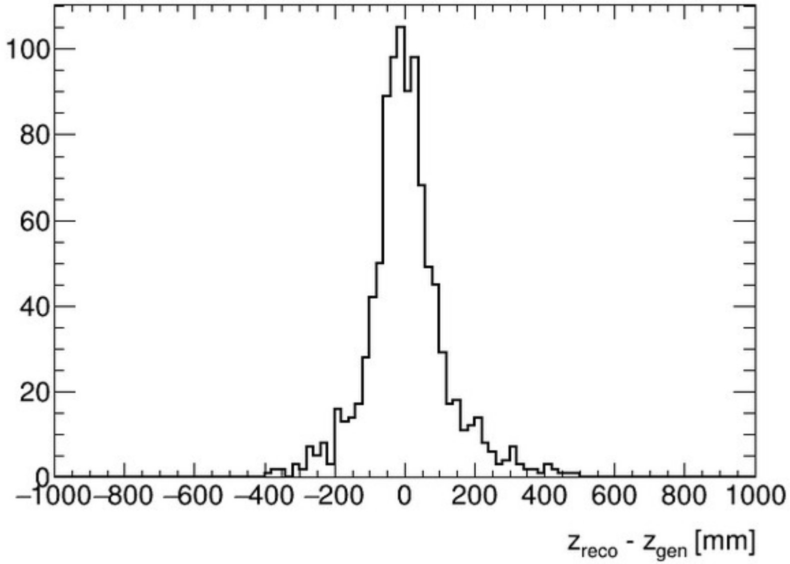
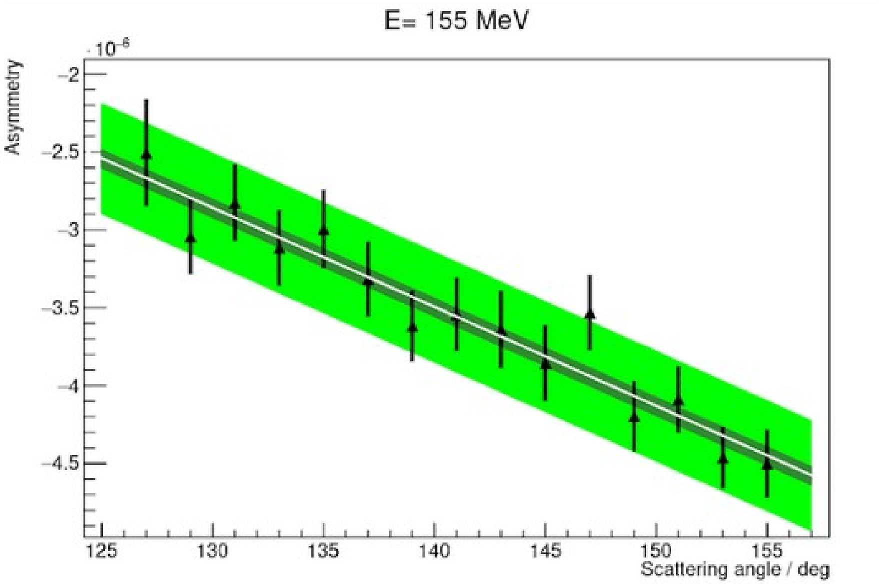


Figure 6 : Left : Scattering angle resolution, in degrees. Right : vertex position resolution, in mm.

Performance

- Physics – Hydrogen



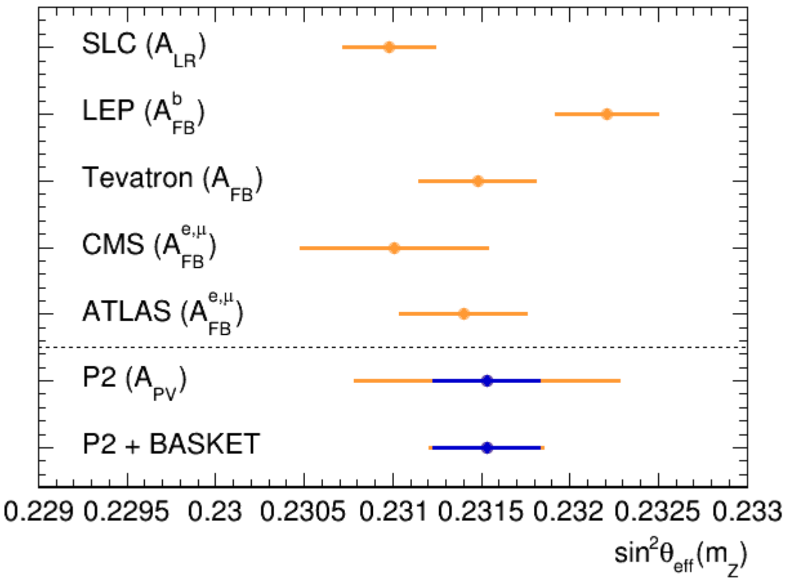
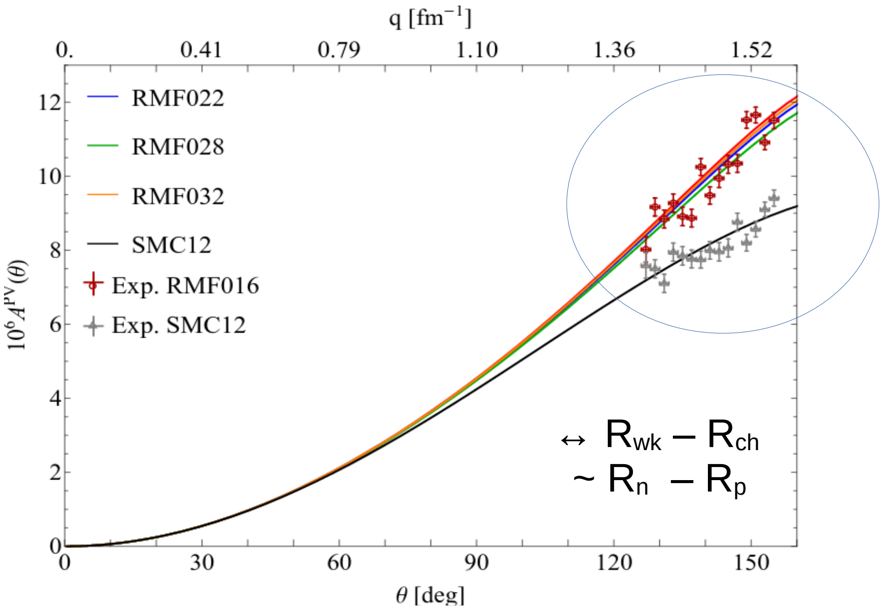
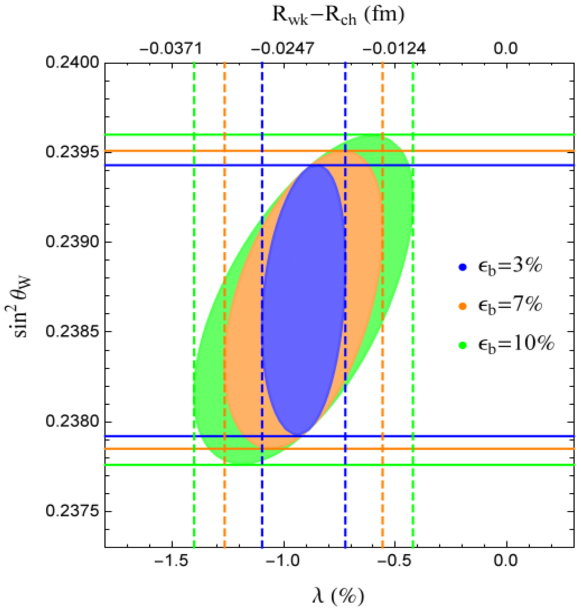


Figure 7 : Left : A_{PV} as a function of scattering angle. The line and outer envelope are the theoretical prediction and its present uncertainty. The points are simulated data. The inner band incorporates the measurement results. Right : achievable precision in $\sin^2\theta_W(m_Z)$, with and without BASKET.

Performance

- Physics – ^{12}C
  - Z=N=6; 0^+ : simple nucleus, parameterized in terms of a single form factor
  - $Q_W(^{12}C) = -24 \sin^2\theta_W$: large asymmetries!
  - $\sin^2\theta_W$ and the "neutron skin" – why don't neutron stars collapse into black holes?

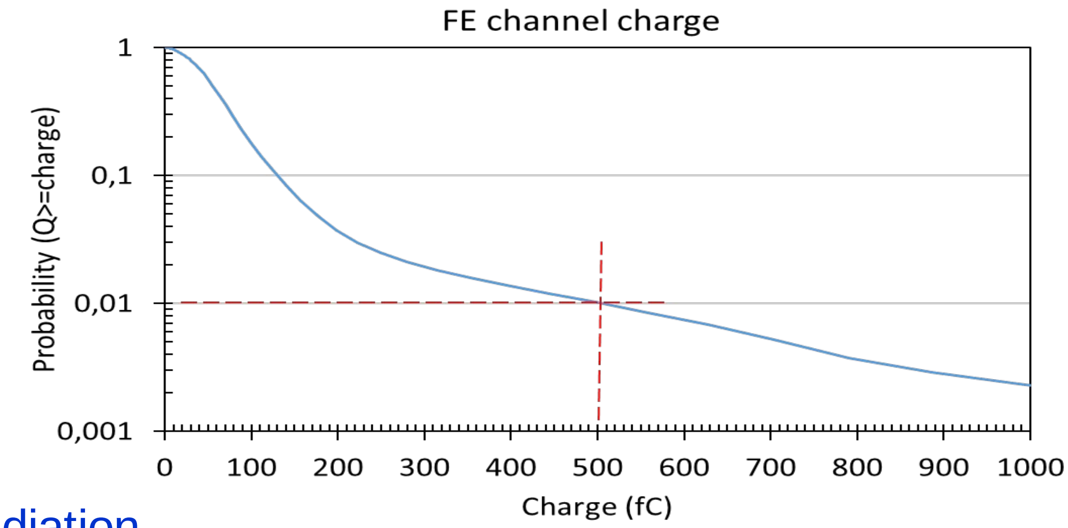




Readout : working hypotheses

- Physics: 100 MHz of tracks
- Tracker: 3 layers with total channel number of ~23k
  - → 7 680 pads per layer
  - → Particle rate per pad < 20 kHz; multiplicity close to 1
- Readout
  - → No trigger, streaming readout with time-amplitude extraction at frontend
  - → No events, data records formed by frontends are associated by timestamps
- Timing precision: ~20-30 ns

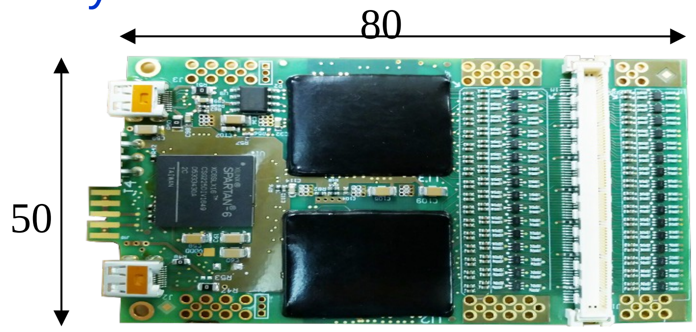
- Channel dynamic range: 10-bits
  - → Signal of ~20 fC
    - With modest detector gain of 5 000
    - With 80% charge collection efficiency
  - → Signal to noise ratio of 40
    - Effective noise charge: ~3 000 e^-
  - → Saturation to signal ratio of 25
    - 1% probability of signal > 500 fC



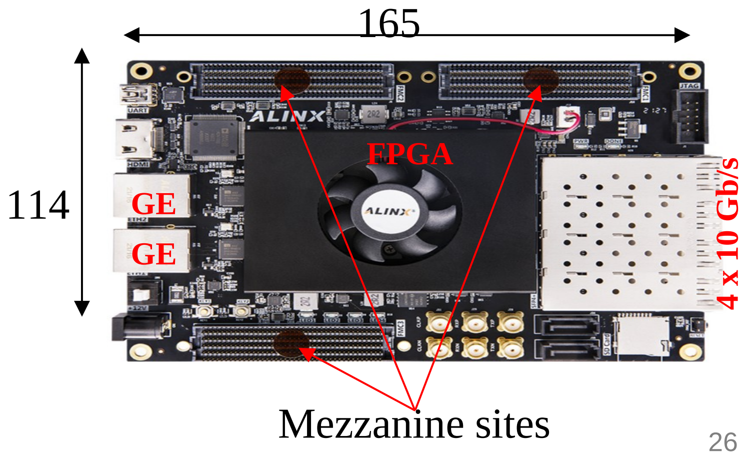
- Low residual magnetic field < 0.1 T ; no radiation

Pragmatic approach

- Build a readout based on the existing frontends and on the COTS components
  - → Stringent planning with first data taking already in 2025
  - → Tense situation with availability of electronics components
- Survey of performance, availability and cost within the community and on market
- Frontend: SRS 128-channel VMM-based hybrid
  - → Hosts two VMM3a ASICs (Atlas NSW)
    - Flexible very-frontend with large choice in gain and shaping
    - Streaming and triggered readout
    - 400 Mbit/s link per VMM chip
    - Promise of 2.5 ns timing resolution
  - → Production of 200 hybrids in 1.5 years by SRS Technology

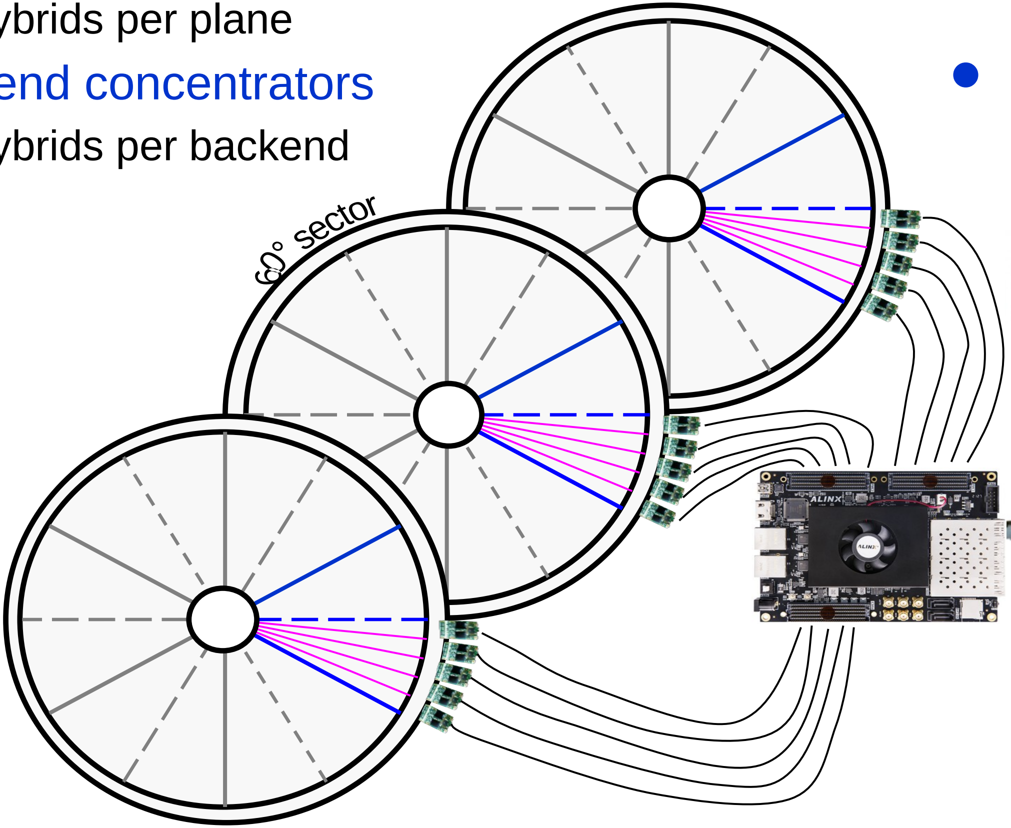


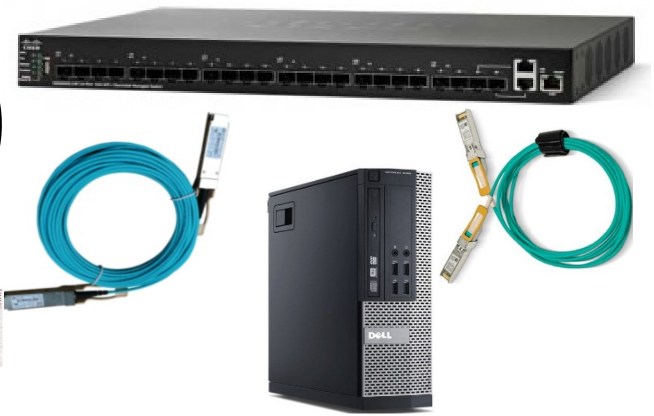
- Backend: AXKU040 development board
  - → Hosts Xilinx Kintex UltraScale FPGA - XCKU040
    - ~0.5M flip-flops; 21 Mbit RAM; 2k DSPs; ~500 IO
  - → 4 Gbyte DDR4 memory
  - → 10 Gbit/s and 1 GE interfaces
  - → 3 mezzanine connectors; can aggregate up to 16 frontends
  - → Offer from Alinx Electronic Technology for 15 units



System: the scale

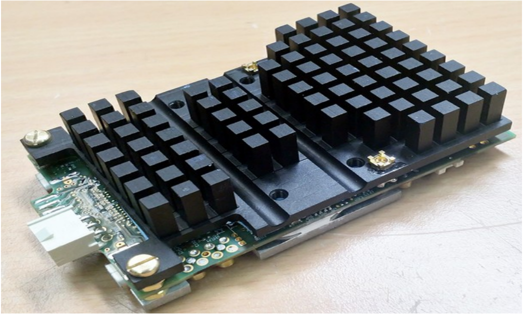
- 180 frontend hybrids
  - → 60 hybrids per plane
- 12 backend concentrators
  - → 15 hybrids per backend
- 16- or 32-port Ethernet switch
  - → 1 GE and/or 10 GE
- A farm of processors
  - → Scale as needed





- Full validation possible in a pilot run populating only one projective sector (1/6)

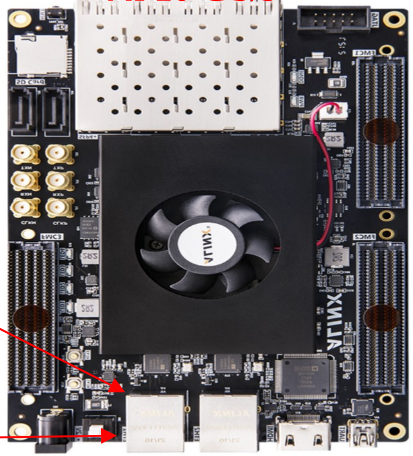
System: the data



- A frontend hybrid
  - → Raw data: ~120 Mbit/s
    - 20% of output link bandwidth
- Backend concentrator
  - → Raw data: ~1.5 Gbit/s
    - Requires one 10 Gbit/s Ethernet link: 20% load
    - Requires a high-end 16- or 24-port 10 GB Ethernet switch
    - Performant farm of 4-8 PCs
  - → On-line hardware tracking: 0.7 Mbit/s
    - Requires two 1 Gbit/s Ethernet links: ~50% load per link
    - Requires a 32-port middle-end mixed 1 GB / 10 GB Ethernet switch
    - A farm of 4-8 PCs with 10 GB Ethernet interfaces
  - → On-line histogram calculation in hardware: expected to be low
    - Single 1 Gbit/s Ethernet link
    - Requires 16-port Ethernet switch
- System
  - → Raw data: 2.4 Gbyte/s ; 8.5 Pbyte of cumulated data over 1 000 h of data taking

High level synthesis

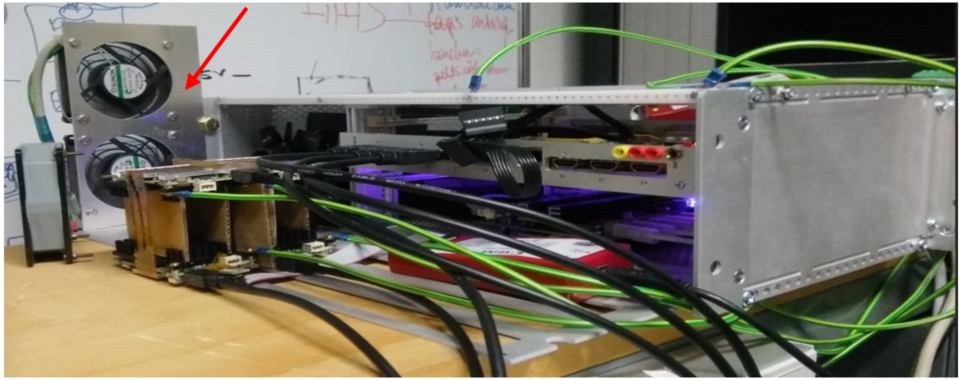
4 x 10 Gb/s

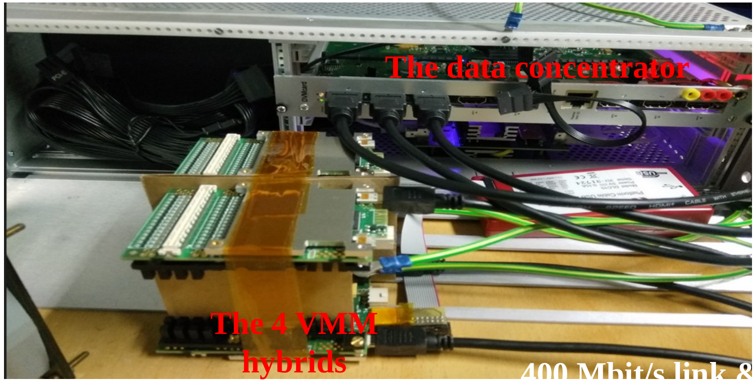


GE GE

On-going validation

- A small SRS system acquired with 4 128-channel VMM-based hybrids
  - → Deployment of data acquisition software on-going
  - → "A cool system-D" arrangement while waiting for beam-test "Pro" mechanics





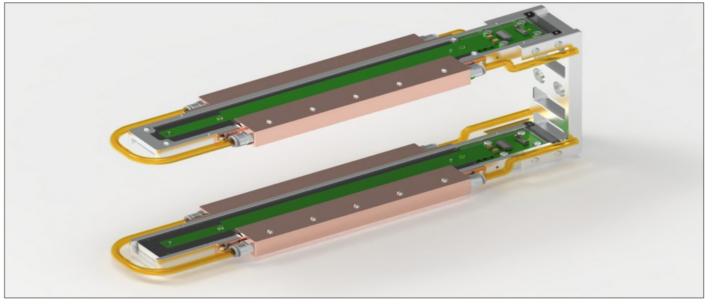
- Performance tests
  - → Synchronous generation of signal pulses exceeding threshold
    - Internal pulsing at ~20 kHz / channel rate
  - → Sustained rate of ~2.7 Mhits/s per hybrid observed
    - ~130 Mbit/s throughput towards the acquisition PC (~48 bits / hit / channel including SRS data collection protocol)
  - → Data quality under study
  - → Encouraging, but high rate operation with poissonian hit arrivals needs to be validated

P2 / EIC Test Beam à MAMI 6-12 Juin 2023

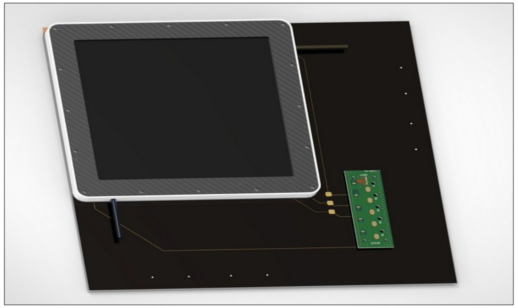
- Prototype “RD4” avec readout modulaire pour tester le motif de lecture pixel P2 et strips 2D pour EIC
- Minimal material budget : “sail tracker” à la P2. R&D for resistive layer ongoing

  → tests multiplicity; position resolution
- Tests et comparaison de VMM, SAMPA, DREAM en test beams

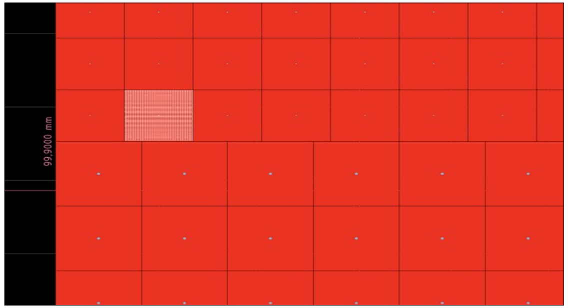
  → Physics rates up to ~1MHz in P2-like conditions (“continuous beam”)



Precision tracker



RD4 detector



P2 pixel readout

Timelines

- MESA & P2

Time / Experiment	2023		2024		2025		2026	
	S1	S2	S1	S2	S1	S2	S1	S2
MESA			Injector E=5 MeV	Main accel.	55 MeV Comm.	Data	155 MeV Comm.	Data
P2 – Main		Solenoid delivered	Nominal vacuum chamber	Target; Cerenkov; Readout	Comm.	Pilot run (55 MeV)	Comm.	Main run (155 MeV)
P2 - Basket		Design	<- Construction -> Commissioning			Exploitation		

  - 155 MeV, backward measurement : T4, 2026
  - 155 MeV, forward measurement : 2027++

Timelines

- BASKET

Time / Experiment	2023 S1	2023 S2	2024 S1	2024 S2	2025 S1	2025 S2	2026 S1	2026 S2
P2 Infra-structure				Modified endcap Shielding				
Detector								
Mechanics	Design & procurement		Assembly					
Micromegas	Design Prototypes Tests		Layer 1 ready	Layer 2 ready	Layer 3 ready Commis-sioning	Exploitation		
Readout						55 MeV Pilot run		155 MeV Physics
Frontend	ASIC/FE Validation	ASIC procurement	FE board procurement		Tests	Exploitation		
Back-end	Choice & Validation	procurement	Hw/Fw/Sw adapt		Tests			
Services		Cooling / cabling / grounding			In situ			

up to 2+2 FTE during this period

Budget (all costs updated recently; includes spares)

- **Detector : 291 kE**
  - 156 kEur for micromegas detector modules (6 sextants in three planes, plus 4 prototypes and 4 spares, for a cost of 6 kEur each);
  - 70 kEur for the design and construction of the mechanical support;
  - 40 kEur for the gas system (mixing, distribution, safety);
  - 25 kEur for the high voltage supply (crates, cables, modules).
- **Readout : 275 kE**
  - 25 kEur for 500 VMM read-out ASICs;
  - 140 kEur for 200 packaged front-end cards (2 ASICs or 128 channels each);
  - 30 kEur for 15 back-end cards and their adapters;
  - 20 kEur for detector, front-end and back-end cables;
  - 30 kEur for ethernet switches and DAQ PCs;
  - 30 kEur for power supply, cooling and mechanics.
- **P2 Environment (modified end flange, shielding) : 75 + 20 kE**

Conclusions

- P2 is a cutting-edge project with longstanding expected results and many implications :
  - Precision electroweak tests (Weak mixing angle landscape);
  - indirect searches for new physics;
  - Impact on coherent neutrino scattering (F_A) and astrophysics (neutron skin)
- BASKET is a chance for IRFU to have a very strong impact in this leading experiment

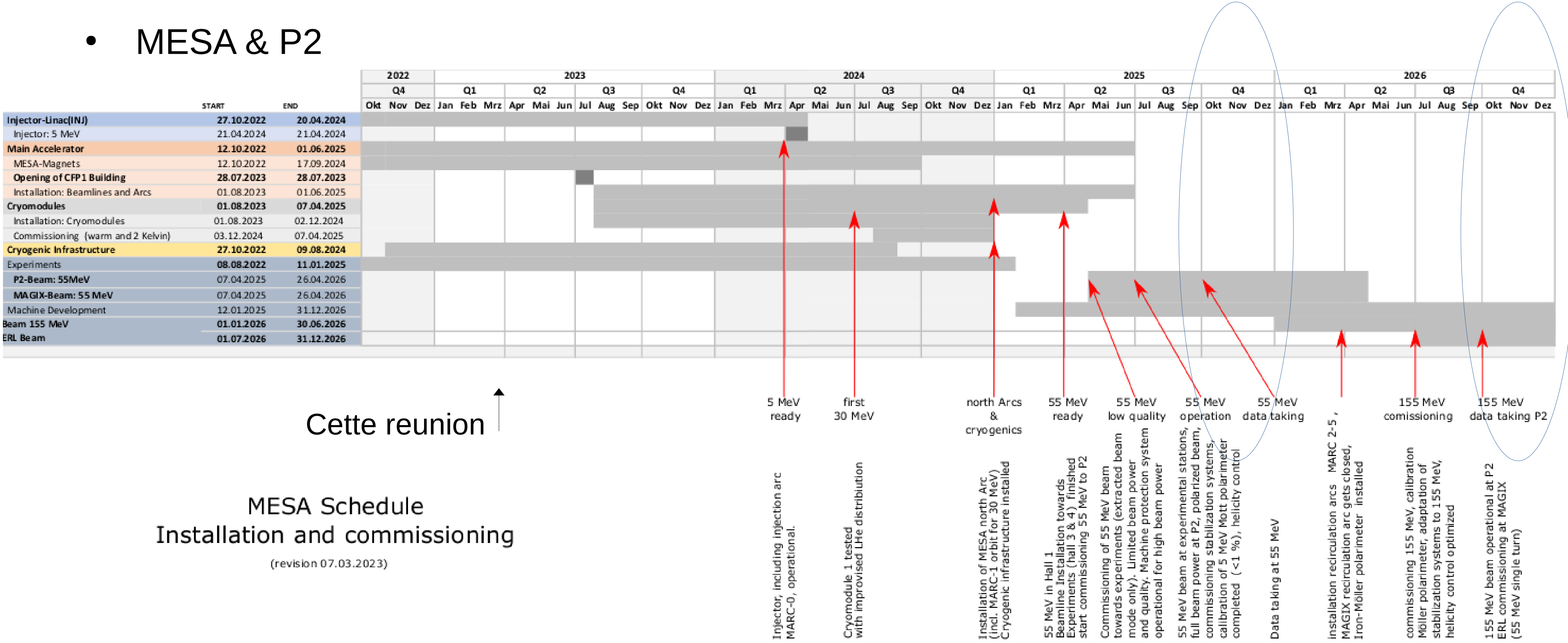
  Interest : detector and readout design for 100 MHz tracking; hardware-based tracking algorithms

- Detector design pre-final; clear readout strategy; validation of several important aspects is ongoing (readout test bench; cosmics; sources; test beam)
- Time is pressing – given advancement this project can be built in 2.5-3 years, but concrete decisions need to made now.

Back-up

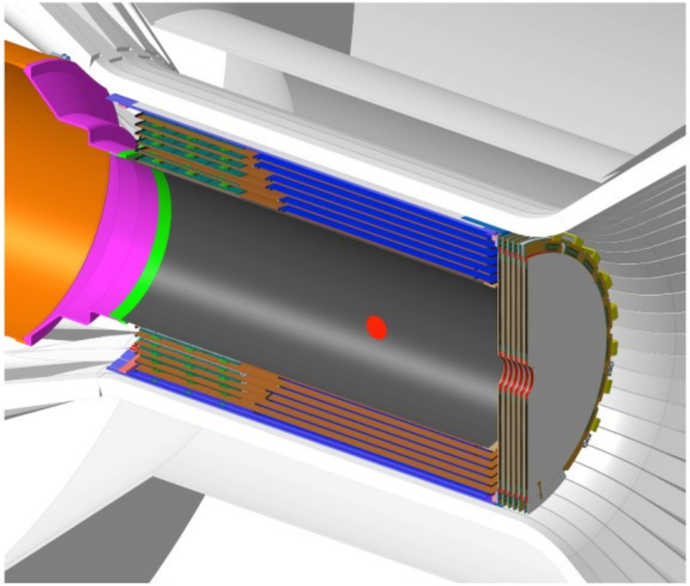
Timelines

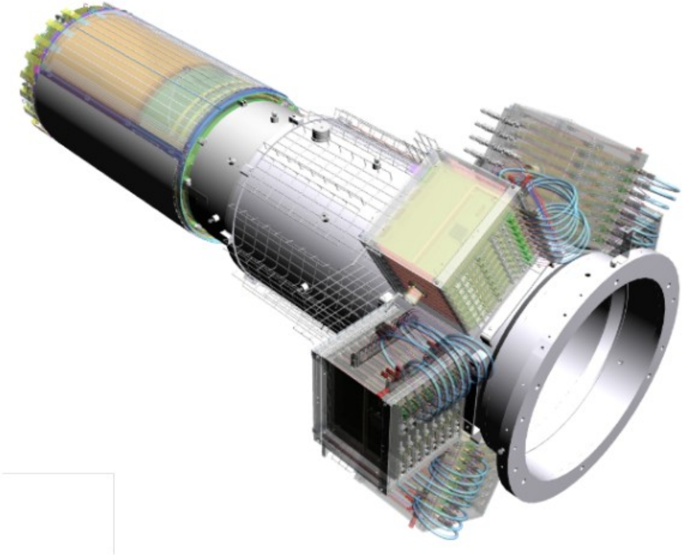
- MESA & P2



Backward tracker project

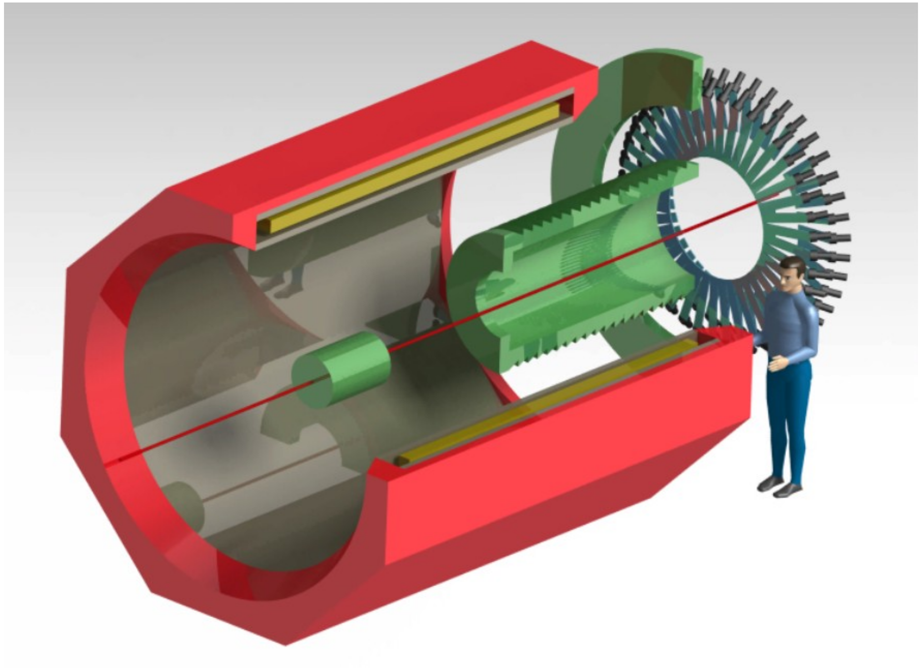
- Further study based on resistive Micromegas detectors.
- Module design
  - Inspired by CLAS12 :

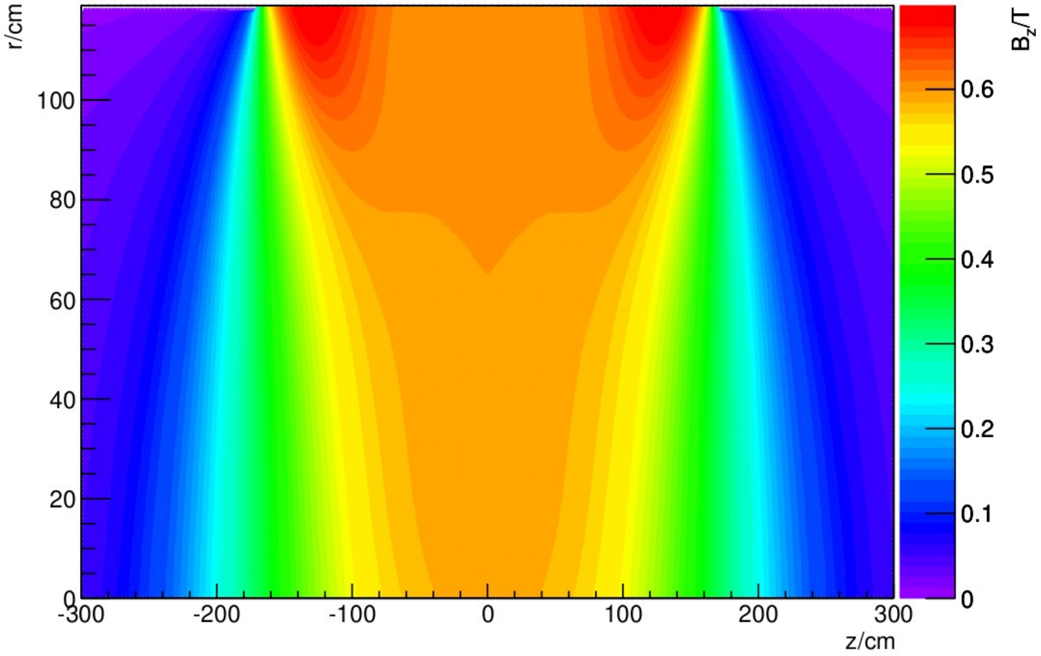




P2

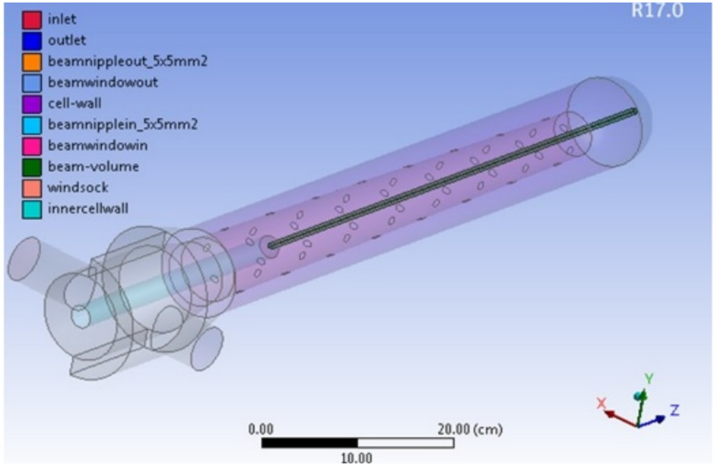
- Superconducting solenoid : in construction, delivered 2023





P2

- Target : designed; construction about to start
  - Extensive experience in Mainz with targets for past experiments (G0, A4)
  - collaboration with Q_{weak}



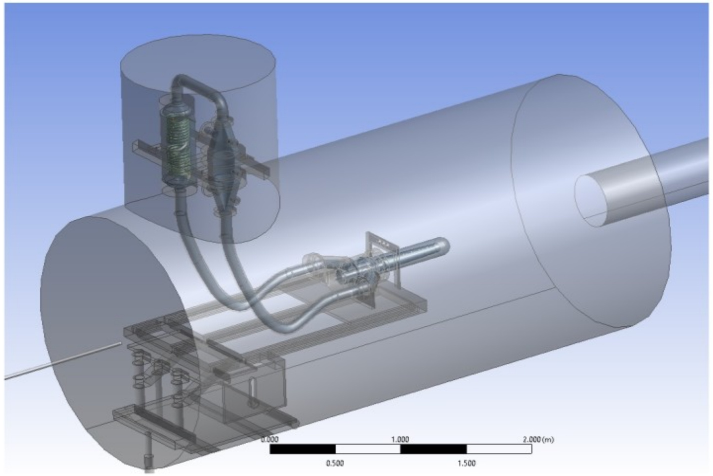


Table 9. P2 target design parameters

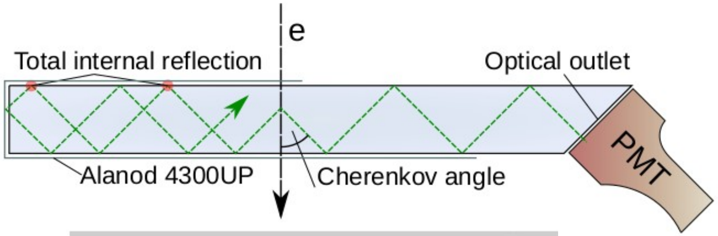
Pressure/temperature	2.4 bar / 20 K
Cell length	60 cm
$\dot{m}$	< 2 kg/s
ℓH_2 pump head	< 0.1 bar
Beam area on target	25 mm^2
HX cooling power	4 kW
Target thickness	4.3 g/cm^2
ℓH_2 $(\Delta\rho/\rho)$	< 2 %
ℓH_2 $(\delta\rho/\rho)$ at 1 kHz	< 10 ppm

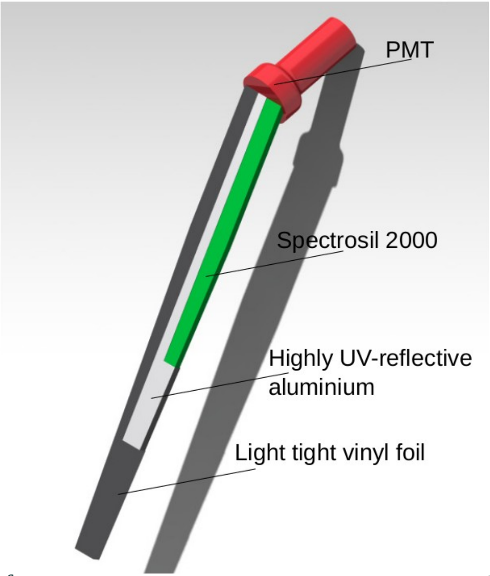
Table 10. P2 target heat load

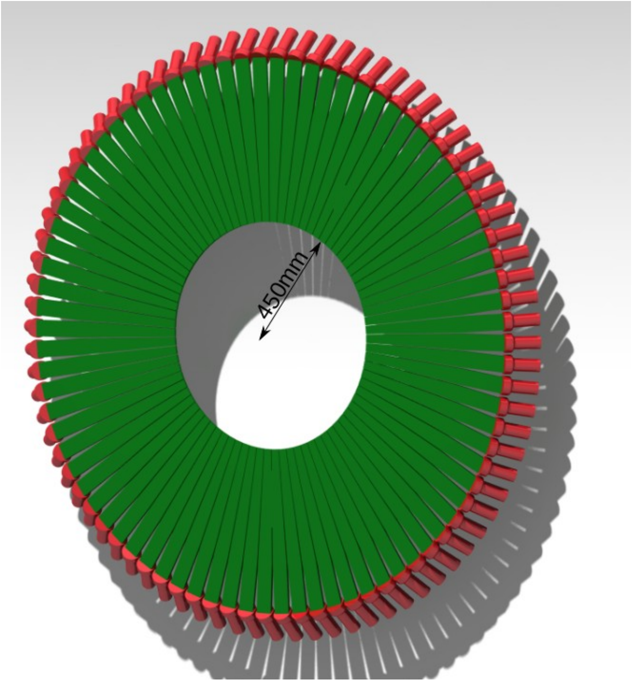
Source	Value (W)
Beam power in ℓH_2	3100
Beam power in cell windows	35
Viscous heating	275
Radiative losses	200
Pump motor	150
Reserve heater power	240
Total heat load	4000

P2

- Main integrating detectors : Cerenkov counters + PMT (delivered)
  - Performance fully under control from extensive test-beam studies

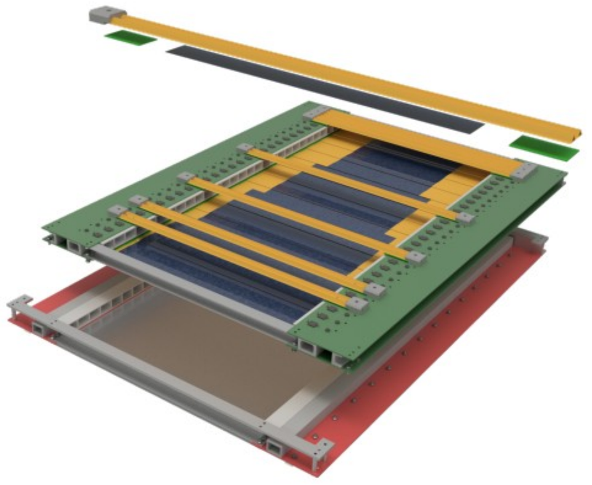


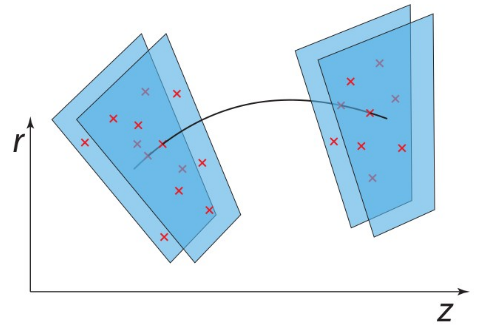


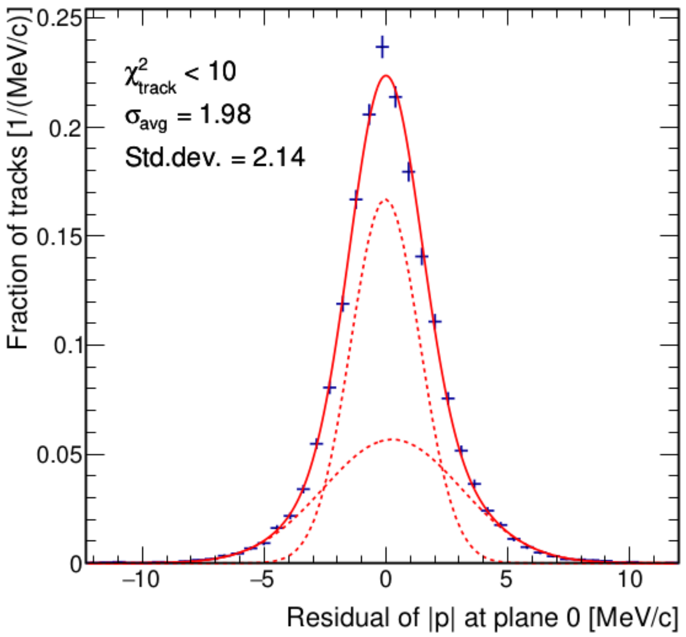


P2

- Forward tracker, for the determination of <Q²>

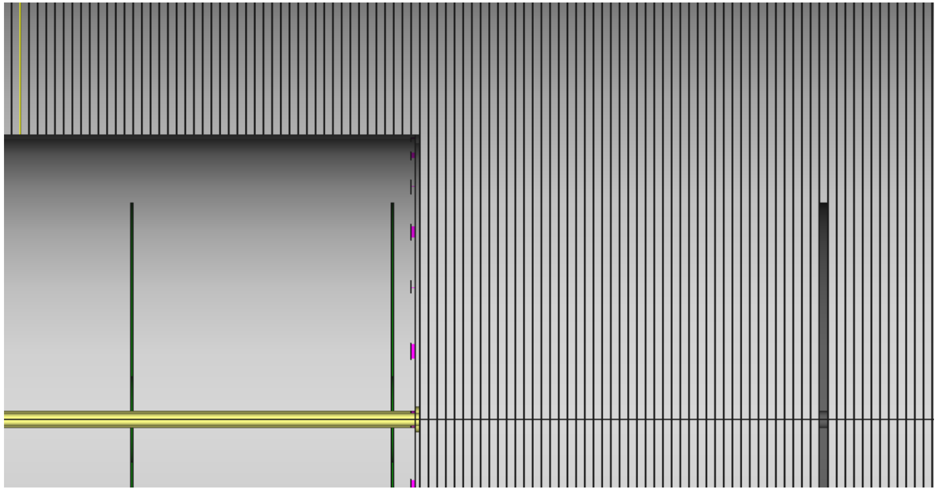


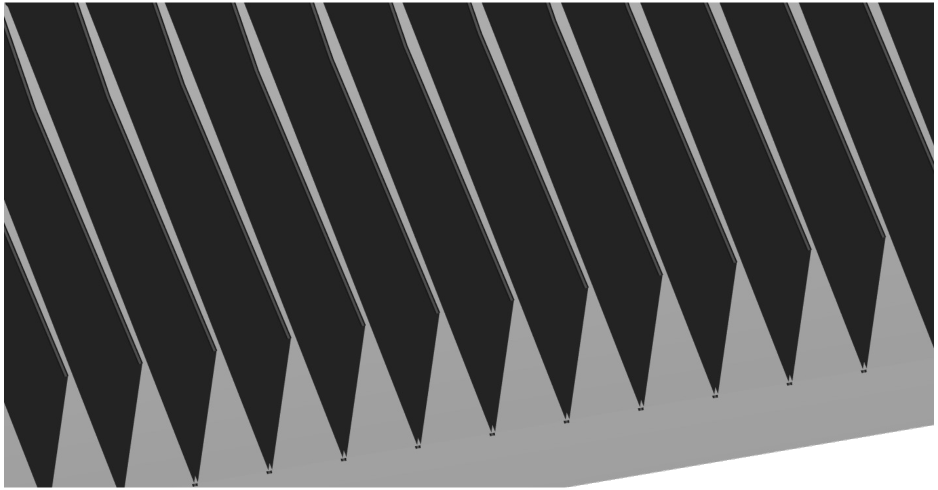




HVMAPS, ~0.2% X_0
632 sensors / module; point resolution ~1 mm
Partial azimuthal coverage

Shielding



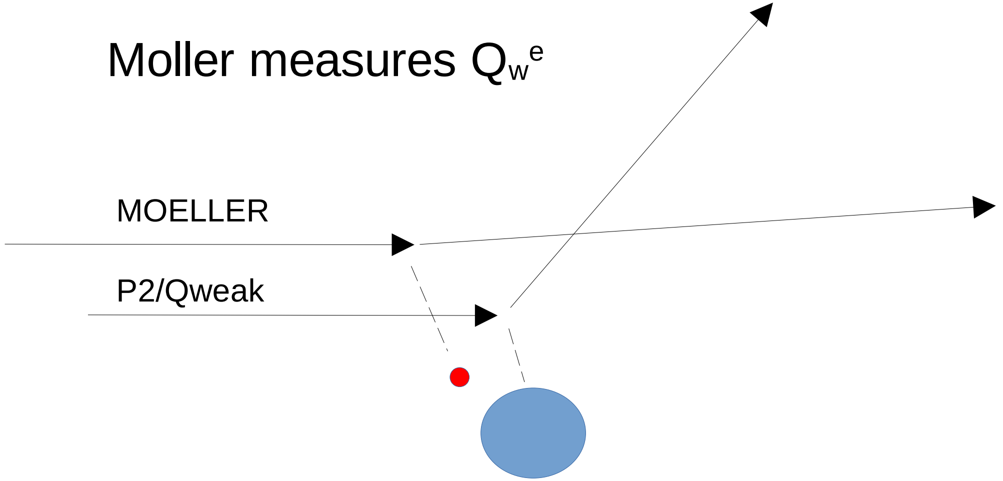


Rates

P2, Qweak vs Moller

- P2, Qweak measure Q_w^p ;

  Moller measures Q_w^e

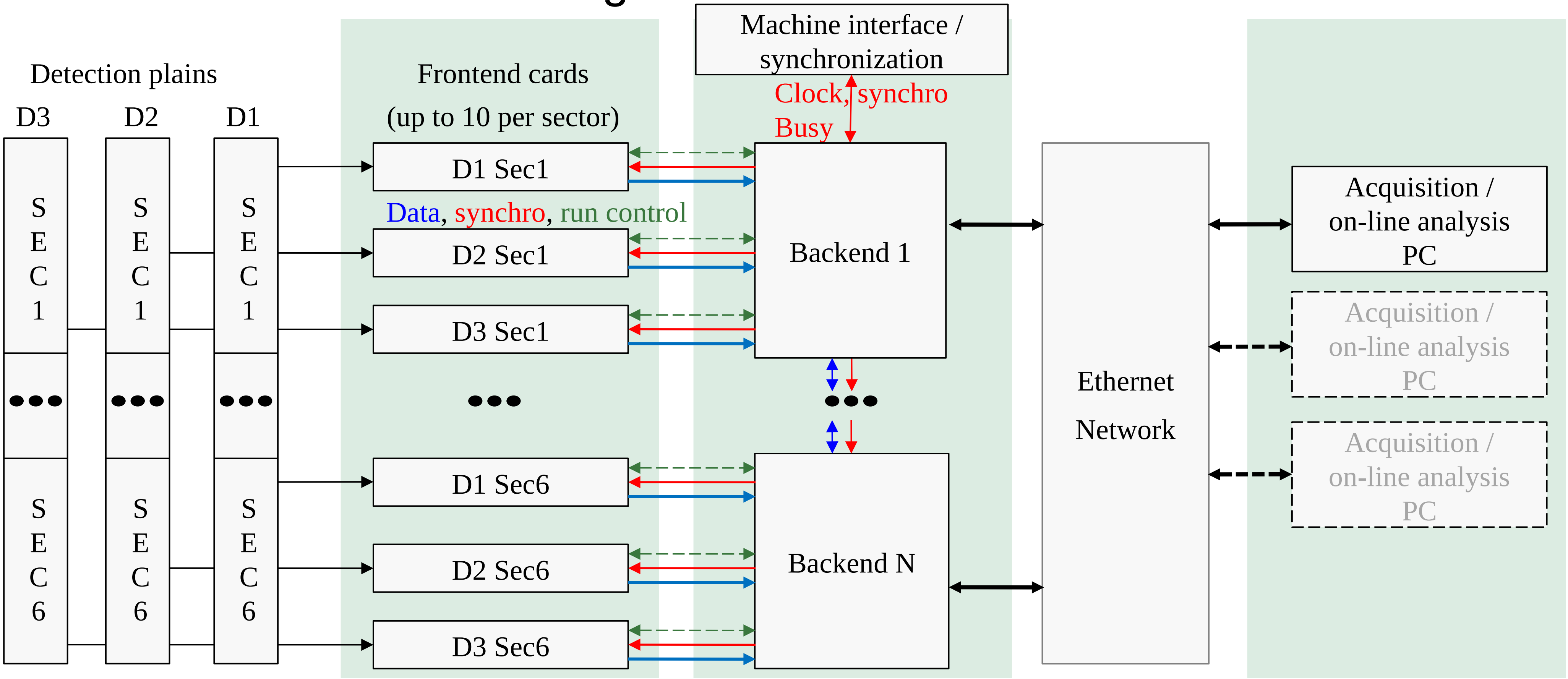


Exp^t	E_{beam}	θ	Q^2	Status
Qweak	1.16 GeV	~9 deg.	~0.025	published
P2	155 MeV	~35 deg.	~0.007	~2026+
Moeller	11 GeV	5-17 mrad	~0.007	~2026+

P2 vs Qweak

	Q_{WEAK}	P2
Energy	1.16 GeV	155 MeV
Scattering angle	~10 degrees	~35 degrees
Q^2	0.025 GeV^2	0.007 GeV^2
A_{PV} (δA_{PV})	226.5 10^{-9} (4.1%)	40 10^{-9} (1.4%)
Target length	34 cm	60 cm
Target heat load	3 kW	4 kW
Luminosity	1.7 10^{39} $cm^{-2}s^{-1}$	2.4 10^{39} $cm^{-2}s^{-1}$

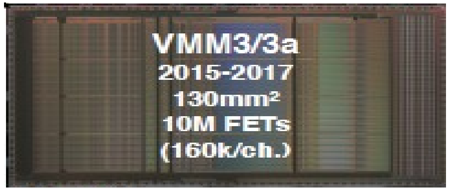
A 3-stage readout architecture



- Potential to perform on-line tracking in hardware
  - → A backend treats projective parts of all detectors and transfers only track candidates
  - → If needed, scale PCs to sustain on-line analysis

Approach

- Two frontend ASICs in the community adapted for the high rate operation
  - → 32-channel SAMPA developed in particulate for ALICE TPC
    - Basket needs: ~800 ASICs
  - → 64-channel VMM3a developed in particular for Atlas NSW
    - Basket needs: ~400 ASICs



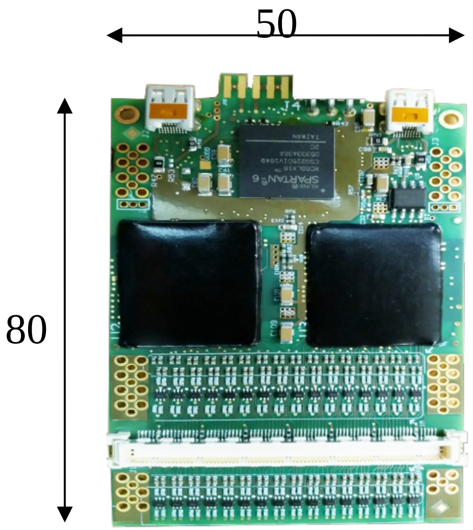
- Starting a brand new development for the large scale acquisition – too risky
  - → Stringent planning with first data taking already in 2025
  - → Tense situation with availability of electronics components

- Reproducing existing readout systems – heavy or not possible any more
  - → LHC acquisitions too specific for particular use
    - Detector specific, clock / control distribution LHC bunch structure oriented
  - → sPhenix (BNL) TPC acquisition based on Sampa – attractive but excluded
    - Some components already obsolete, dynamic range of the Sampa version too small – 100 fC only
  - → CERN RD51 SRS (scalable readout system) – not an optimal solution
    - Results to a costly combination of bulky frontend and bulky backend: ~18€ / channel
    - Some parts under upgrade
- Build a readout based on the existing frontends and on the COTS components
  - → Use the 128-channel VMM-based SRS hybrids
  - → Adapt commercial FPGA kit as backend

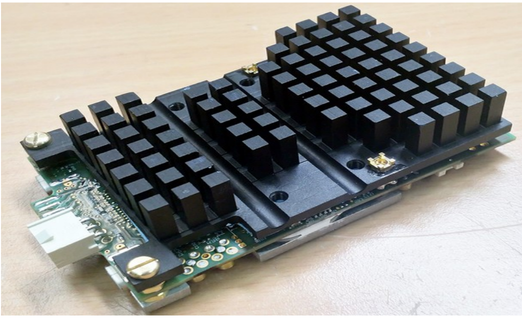
Frontend: 128-channel VMM-based SRS hybrid

- Very front end
  - → Maximum charge: up to 2pC in linear range, fast recovery from 50 pC
    - 8 adjustable dynamic ranges including 333 fC and 1 pC
  - → 4 adjustable peaking times: 25, 50, 100 and 200 ns
  - → Input capacitance: from sub-pF to several nF
  - → Can operate in continuous readout mode
    - A channel above threshold produces a 38-bit word

	1	2	3–8	9–18	19–26	27–38
hit data	F	N	Chan# (6)	ADC (10)	TDC (8)	BCID (12)

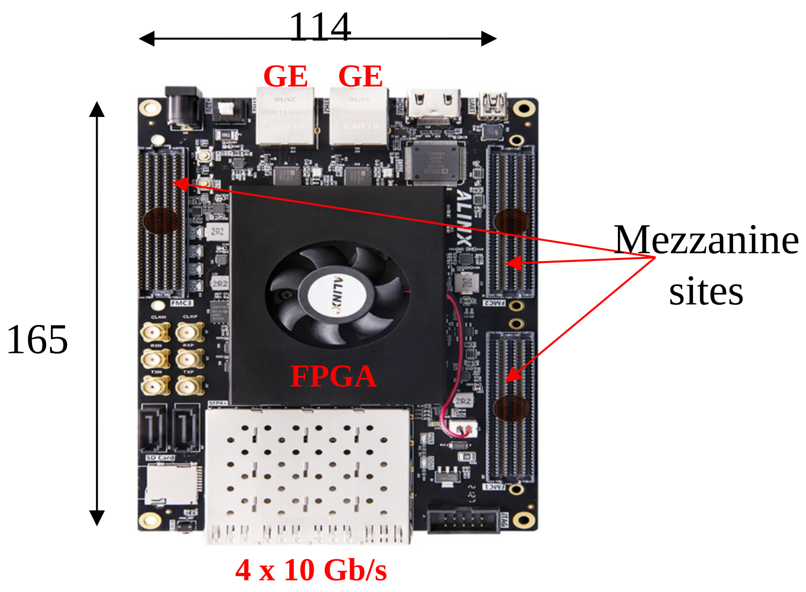


  - → ~400 Mbit/s link per VMM ASIC
  - → Amplitude resolution 1.3 fC (8.1 ke-) @ 333°fC range
    - About twice than noise expected from the detector capacitance
  - → Timing resolution ~2.5 ns
- Production of 200 hybrids requires 1.5 years
  - → Includes spares and test bench boards
  - → Irfu provides 500 ASICs including expected yield
  - → Production and testing performed by SRS Technology



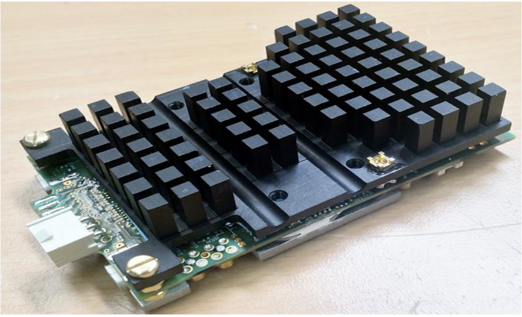
Backend

- Backend candidate: AXKU040 from Alinx Electronic Technology
  - → Xilinx Kintex UltraScale FPGA - XCKU040-2FFVA1156I
    - ~0.5M flip-flops; 21 Mbit memory; 2000 DSPs; ~500 IO; 20 16 Gb/s transceivers
  - → 4 Gbyte DDR4 memory
  - → 4 10 Gbit/s (optical) interfaces
  - → 2 1 Gbit/s Ethernet interfaces
  - → 3 mezzanine connectors
    - Possibility to aggregate up to 16 frontends
    - Passive interface boards to be developed



- Offer received for 15 units
  - → Includes spares and test bench boards
  - → Available right away

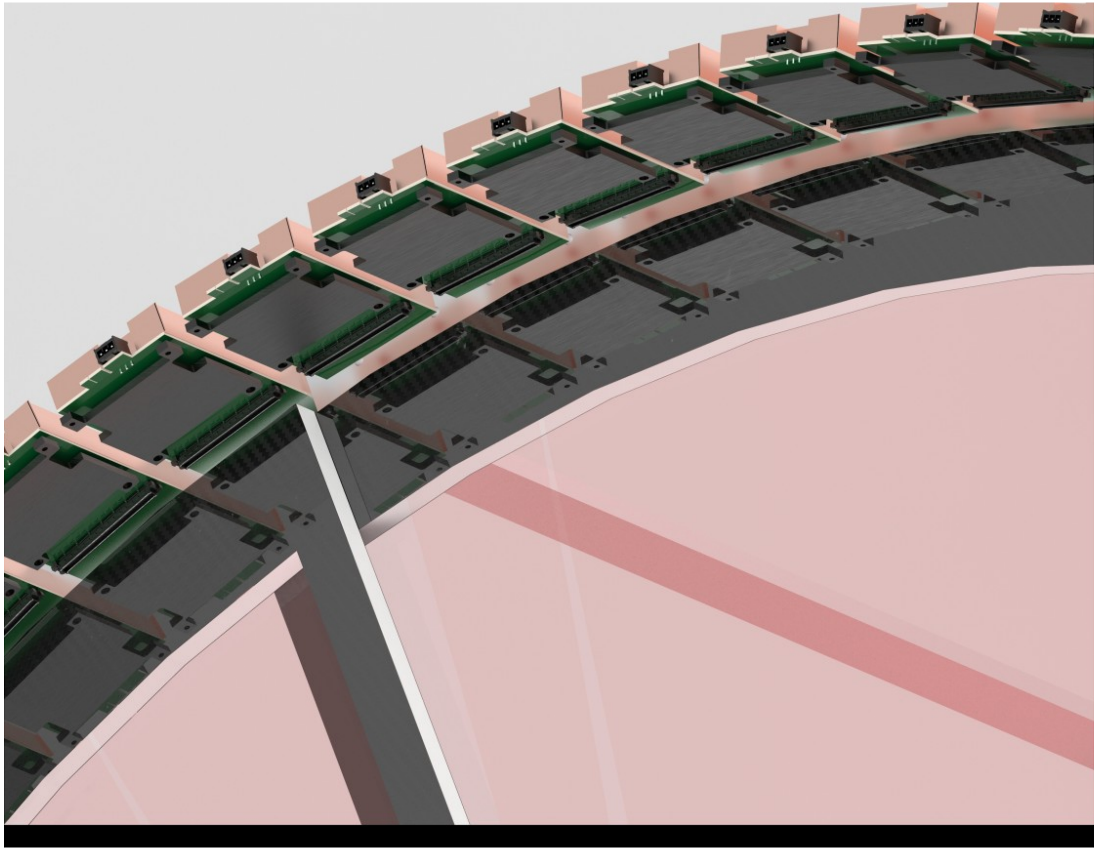
System: the data



- A frontend hybrid
  - → Raw data: ~120 Mbit/s
    - 20% of output link bandwidth
- Backend concentrator
  - → Raw data: ~1.5 Gbit/s
    - Requires one 10 Gbit/s Ethernet link: 20% load
    - Requires a high-end 16- or 24-port 10 GB Ethernet switch
    - Performant farm of 4-8 PCs
  - → On-line hardware tracking: 0.7 Mbit/s
    - Requires two 1 Gbit/s Ethernet links: ~50% load per link
    - Requires a 32-port middle-end mixed 1 GB / 10 GB Ethernet switch
    - A farm of 4-8 PCs with 10 GB Ethernet interfaces
  - → On-line histogram calculation in hardware: expected to be low
    - Single 1 Gbit/s Ethernet link
    - Requires 16-port Ethernet switch
- System
  - → Raw data: 2.4 Gbyte/s; 8.5 Pbyte of cumulated data over 1 000 h of data taking

High level synthesis

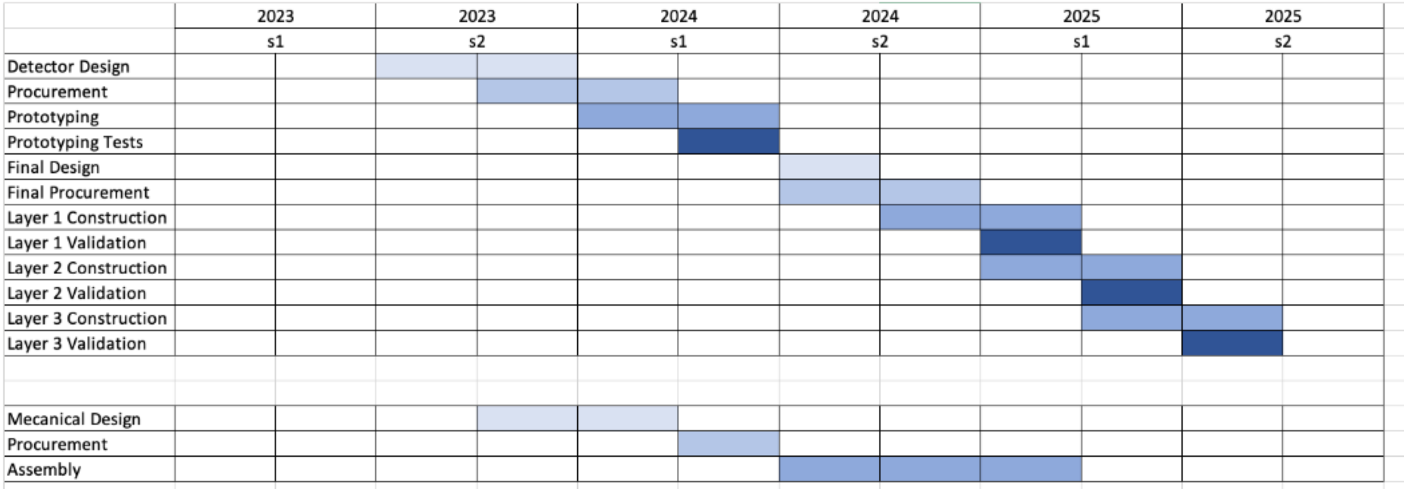
Readout



Resources

- Personpower – detector

		2023		2023		2024		2024		2025		2025	
		s1		s2		s1		s2		s1		s2	
D	A1 Chef de projet	10%	20%	20%	30%	40%	50%	50%	50%	50%	50%	20%	10%
E	A1 Labo Bulk												
D	A2 CAO	10%	10%	30%	30%	30%	20%	20%	10%	10%	10%		
I	A2 Labo Bulk					10%	10%	30%	30%	30%	30%	30%	10%
P	A2 Serigraphie					10%	10%	10%	10%				
DPhP	A1 Hardware	20%	20%	20%	50%	50%	50%	100%	100%	100%	50%	50%	50%
DIS	A1 CAO			30%	30%	30%	30%	30%	30%	20%	10%		



Resources

- Personpower – readout

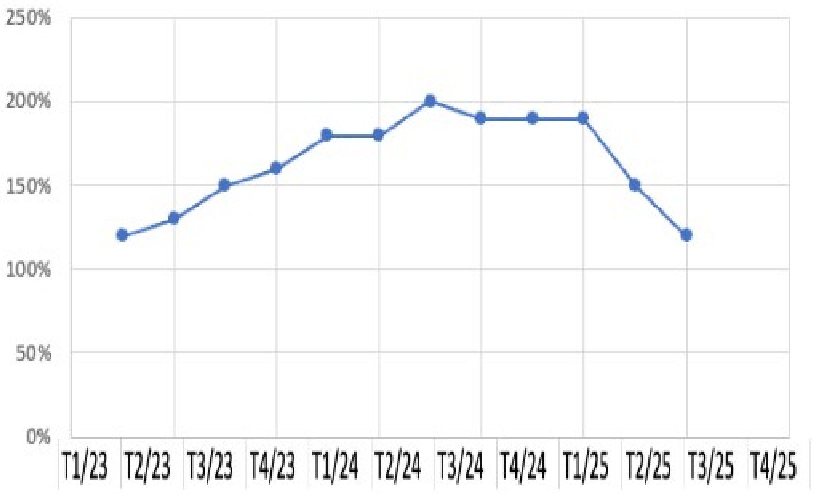
  Competences :

Expertise		FTE (total)
Management		0.5
Electronics		1.5
Software		1.0
Physicists		0.5
Mechanics		0.5
Technician		0.5
CAD		0.1
Engineering		**4.0**
Technical		**0.6**

Resources

- Person power – time profile

Detector



Readout