ELBNF-logo.jpg

How to get involved in the CERN WA105 programme

André Rubbia (ETH Zürich)

ELBNF proto-collaboration meeting, January 2015

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

v1

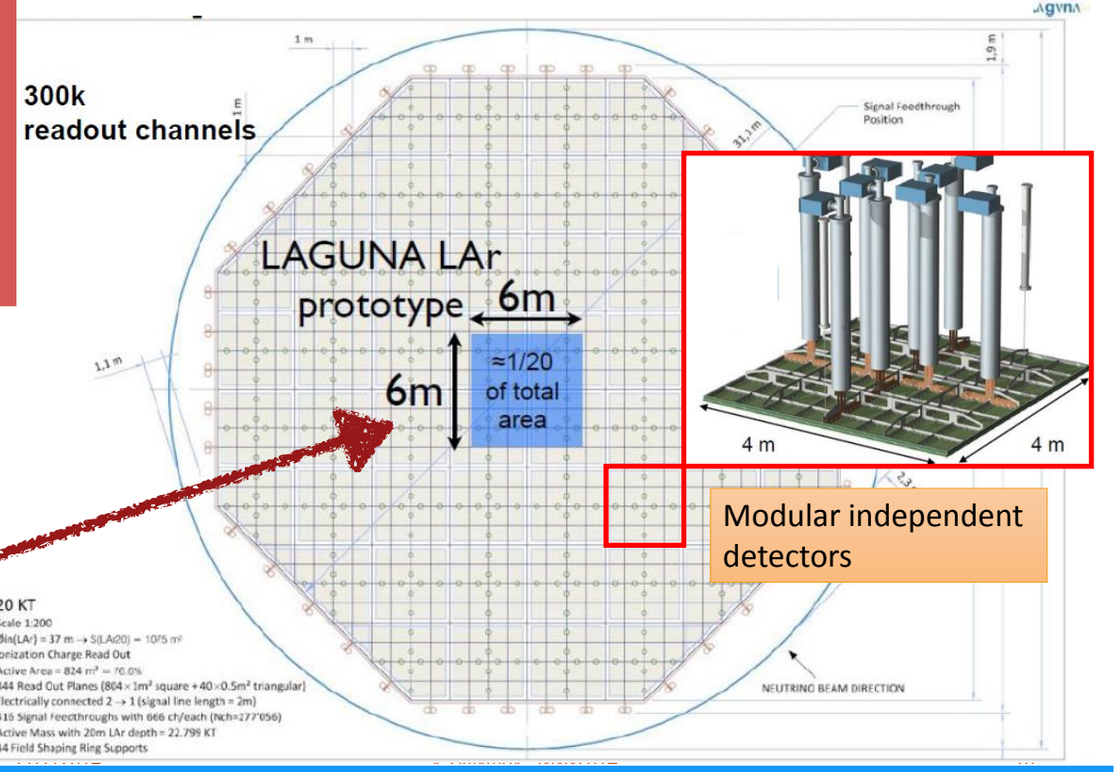
WA105 in a nutshell...

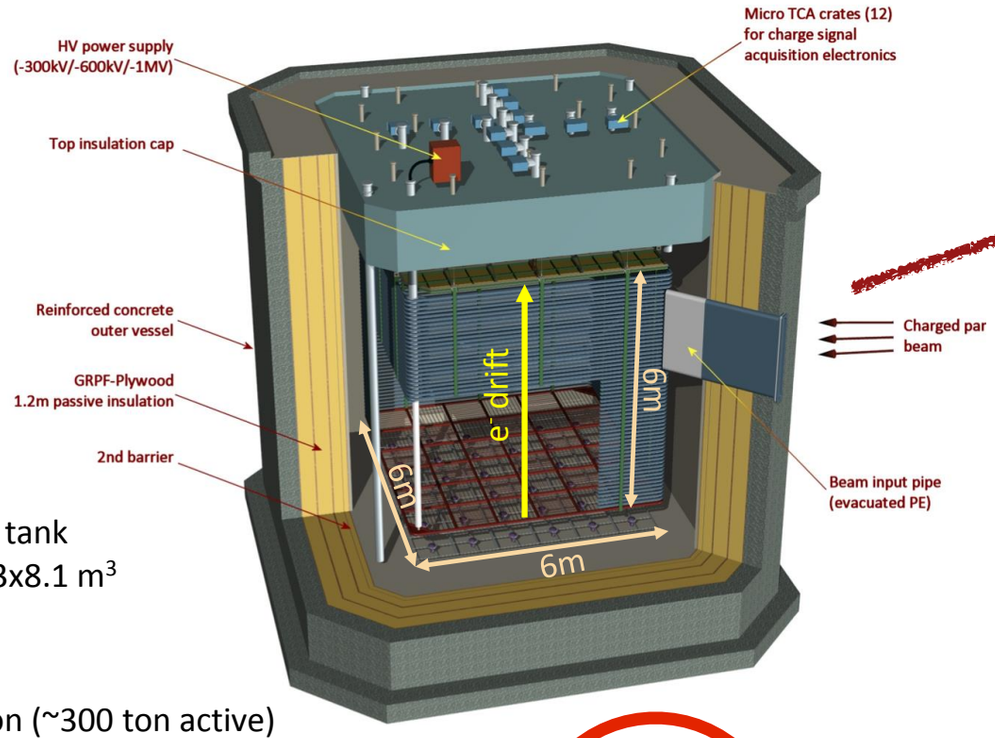
Build and operate a large scale prototype to demonstrate the feasibility and performance of the DLAr TPC design for O(10) kton detectors

CERN-SPSC-2014-013 ; SPSC-TDR-004 (April 2014)

- SPSC Technical Design Report submitted in April 2014
- Approved in June 2014
- 6x6x6m3 demonstrator in the CERN North Area (2016)
- Exposed to charged particle beam (2018)
- Now: construction/operation of 3x1x1m3 proto (2015)

Compared to LAGUNA/LBNO 20 kton DLAr

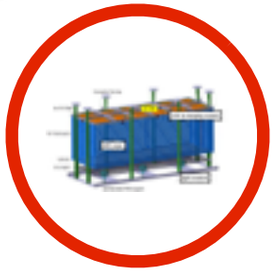




6x6x6 m3

Some detector parameters:

- Insulated membrane tank
  → inner volume 8.3x8.3x8.1 m^3
- Active area 36 m^2
- Drift length 6 m
- Total LAr mass 705 ton (~300 ton active)
- Hanging field cage & readout plane
- # of signal channels: 7680 in 12 signal FT
- # of PMTs: 36



3x1x1 m3
25 ton LAr
to scale

- A 1:20-scale "demonstrator" & industrial solutions
- Technical proof-of-principle:
  - Purity in non-evacuated tank
  - Large hanging field cage structure
  - Very high voltage generation
  - Large area charge readout
  - Accessible cold front-end electronics
  - Long term stability of UV scintillation light readout

The groups presently involved

WA105

22 institutes, 130 physicists

University of Oulu

UCL

Sofia University St. Kliment Ohridski Bulgaria

CERN

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

University of Jyväskylä

ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ РОССИЙСКОЙ АКАДЕМИИ НАУК INSTITUTE FOR NUCLEAR RESEARCH OF RUSSIAN ACADEMY OF SCIENCES

KEK High Energy Accelerator Research Organization

Institut de Física d'Altes Energies IFAE

LPNHE Paris

IAPP

University of Glasgow

Université de Genève

cea Saclay

IPNL

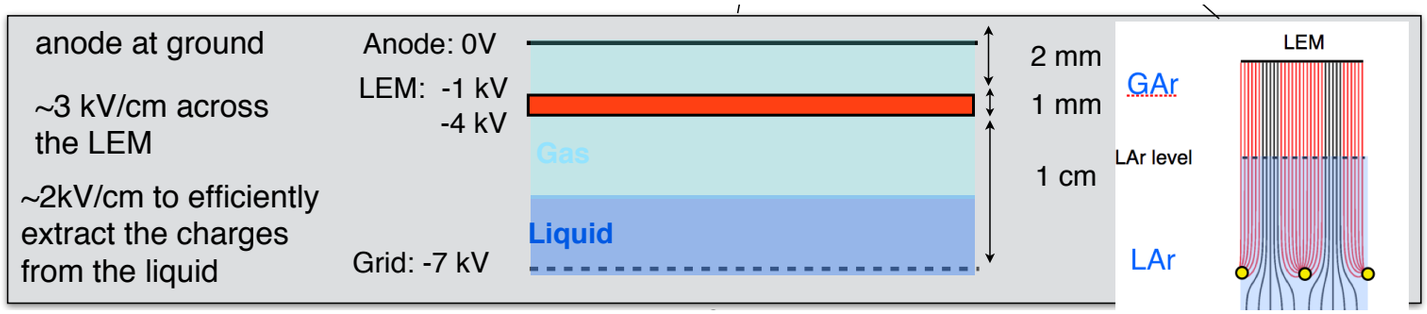
IN2P3 Institut National de Physique Nucléaire et de Physique des Particules

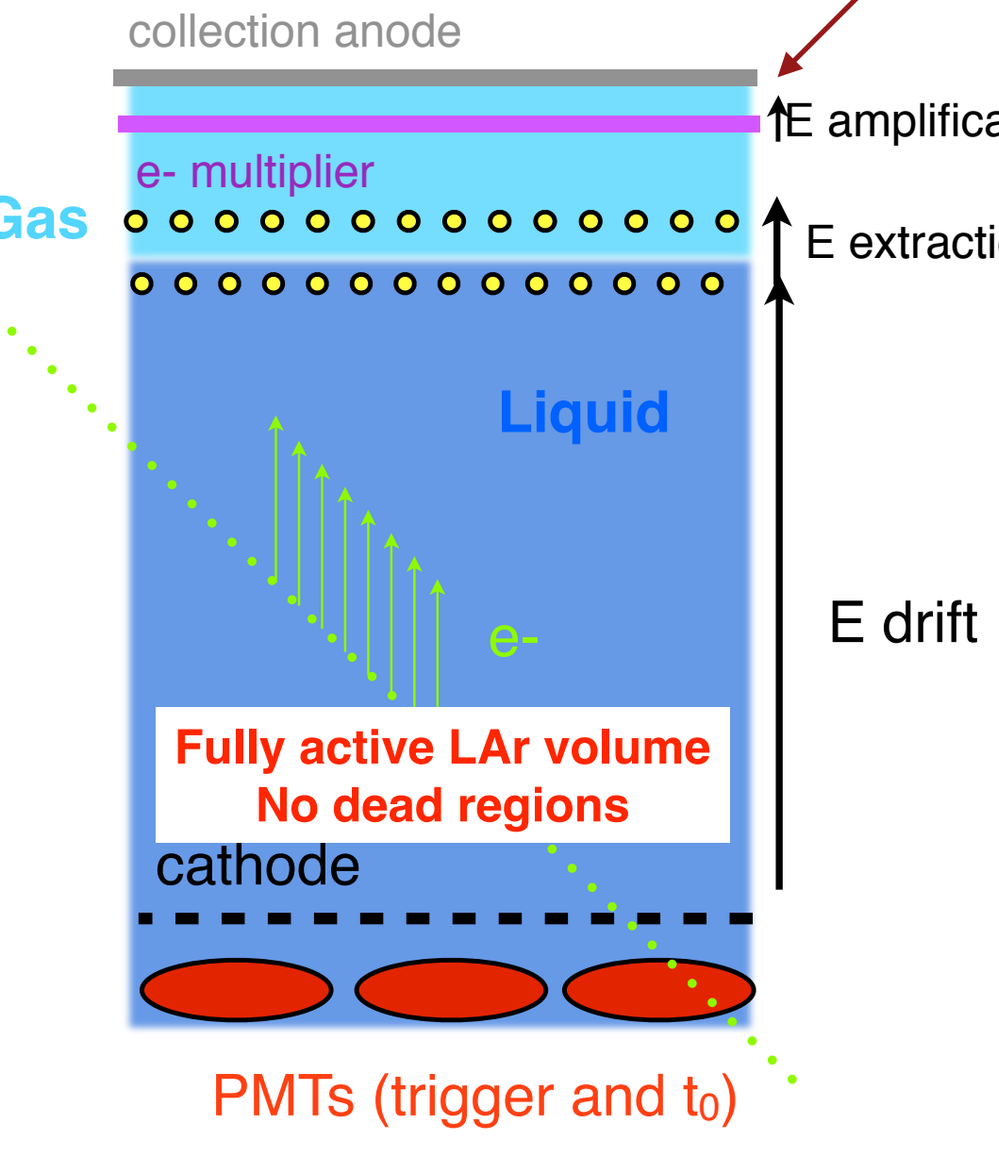
Double Phase LAr LEM TPC

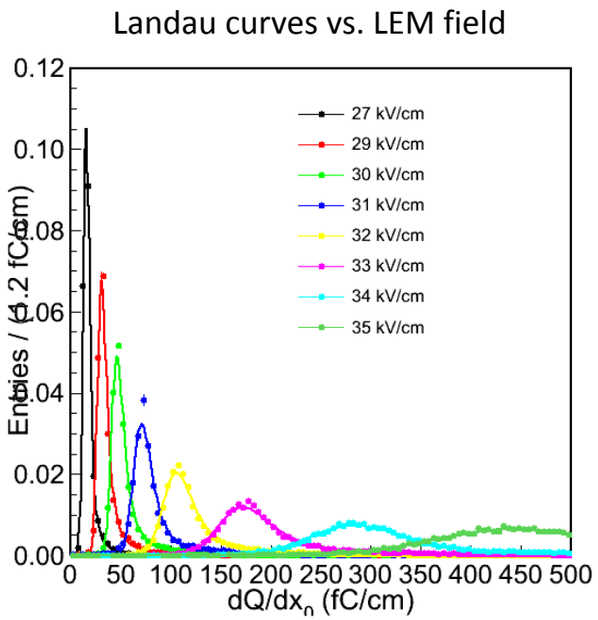
Overview

Double Phase LEM TPC

*LEM or ThickGEM







- Fully active, fully homogeneous
- Tuneable charge amplification
- Threshold < 100 keV on single channel
- S/N>100 for m.i.p.
- Symmetric collection views
- Diffusion tolerant (→long drift)
- No microphonic noise

For MIPs:
- 10 fC/cm — ~10 k e^- for each strip (3 mm pitch,2 views) — SNR of 10 (noise of 1000 e^-)
- SNR of 100 — gain of 20 is needed

➢ **2003: the GLACIER concept**
- A. Rubbia, Experiments for CP-violation: A giant liquid argon scintillation, Cherenkov and Charge imaging experiment? arXiv:hep-ph/0402110

➢ **Proof of principle with 10x10 cm² double phase LAr LEM-TPC prototype:**
- A. Badertscher et al., "Operation of a double-phase pure argon Large Electron Multiplier Time Projection Chamber: Comparison of single and double phase operation "NIM A617 (2010) p.188-192
- A. Badertscher et al., "First operation of a double phase LAr Large Electron Multiplier Time Projection Chamber with a two-dimensional projective readout anode" NIM A641 (2011) p.48-57

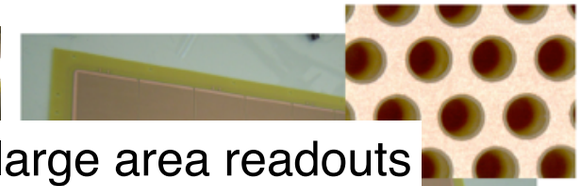
➢ **First successful operation of a 40x76 cm² device in November 2011:**
- A. Badertscher et al., "First operation and drift field performance of a large area double phase LAr Electron Multiplier Time Projection Chamber with an immersed Greinacher high-voltage multiplier " JINST 7 (2012) P08026
- A. Badertscher et al., "First operation and performance of a 200 lt double phase LAr LEM-TPC with a 40x76 cm² readout", JINST 8 (2013)P04012

➢ **10x10 cm² double phase LAr LEM-TPC prototype: further R&D towards final, simplified charge readout for GLACIER:**
- Long-term operation of a double phase LAr LEM Time Projection Chamber with a simplified anode and extraction-grid design, JINST 9 P03017
- Performance study of the effective gain of Large Electron Multipliers in LAr-LEM TPCs, paper arXiv:1412.4402, JINST

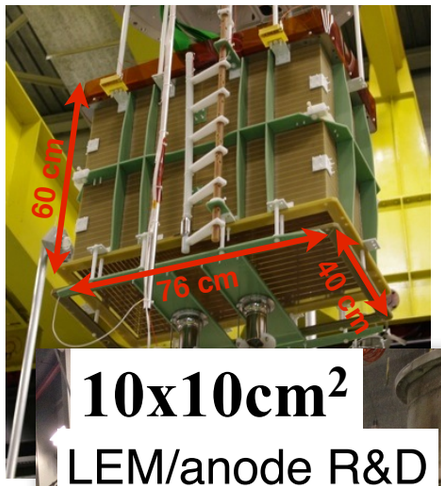
Outcome of many years of R&D

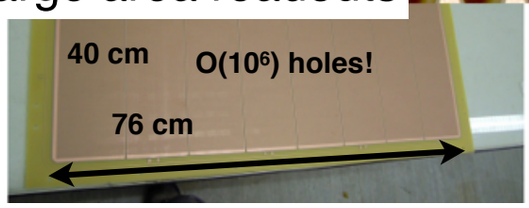
Continuation of the supporting R&D activities on smaller prototypes

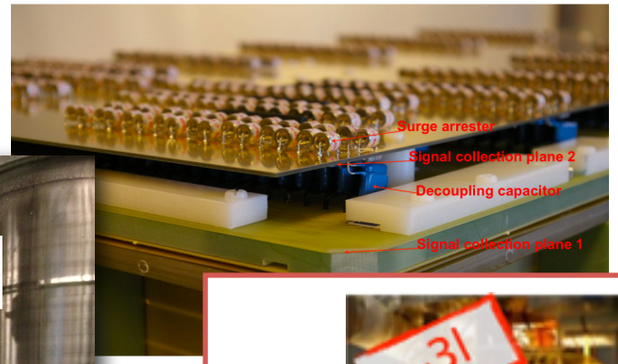
40x80cm²



stable operation of large area readouts

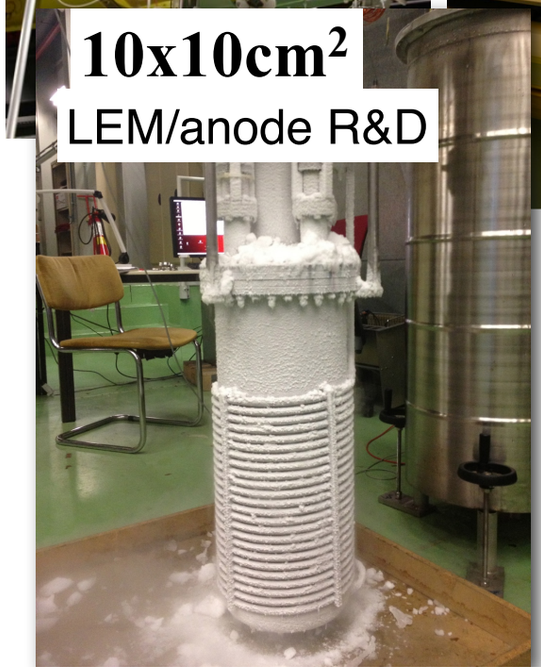


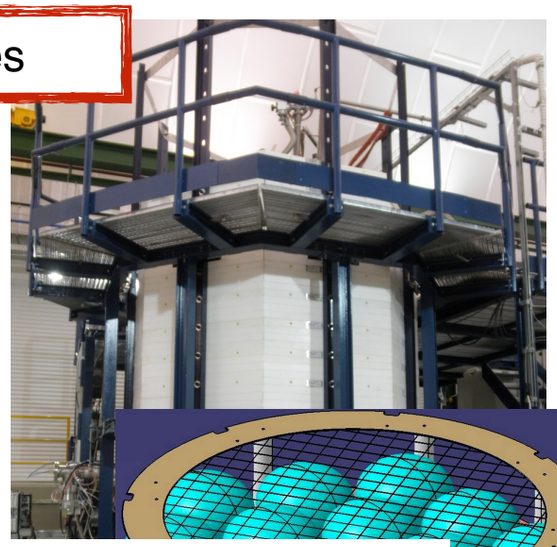




10x10cm²

LEM/anode R&D

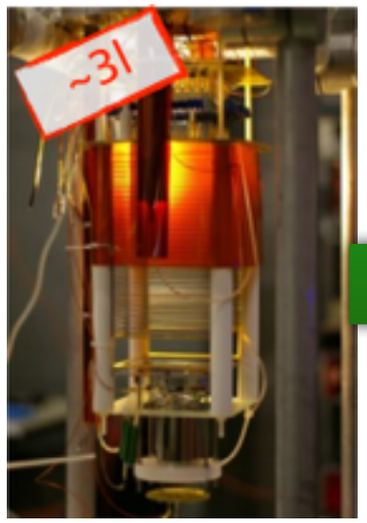




ArDM 1ton

-light readout

-**Operating underground**

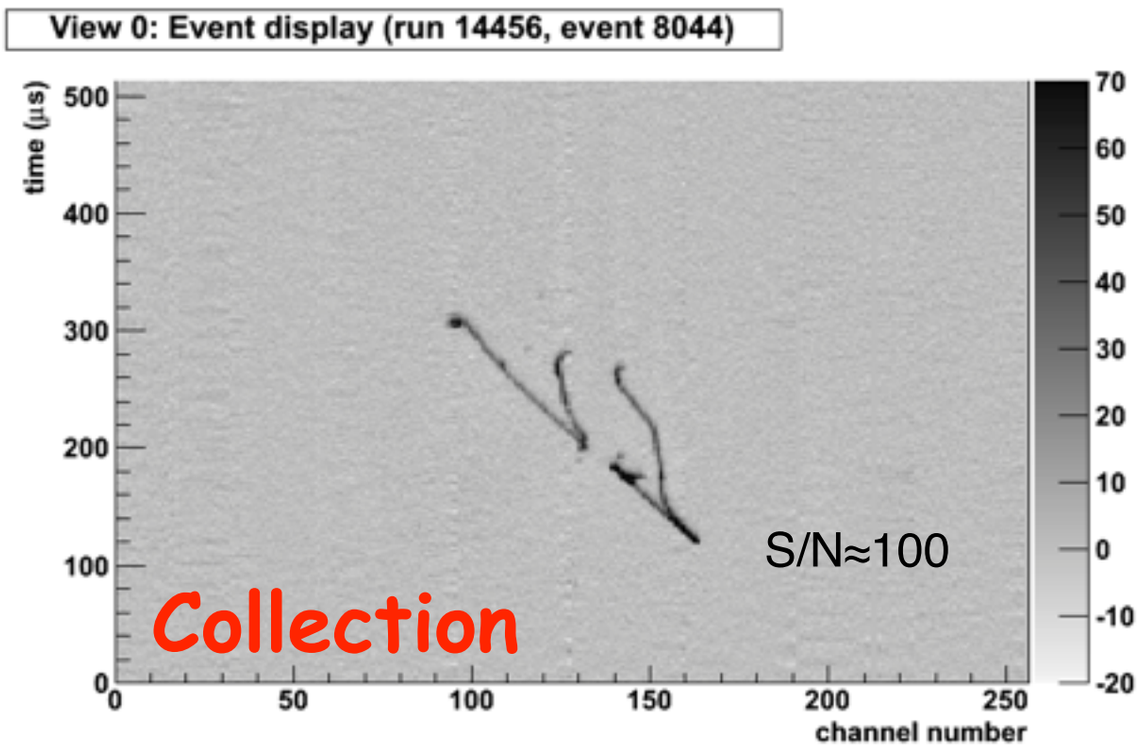


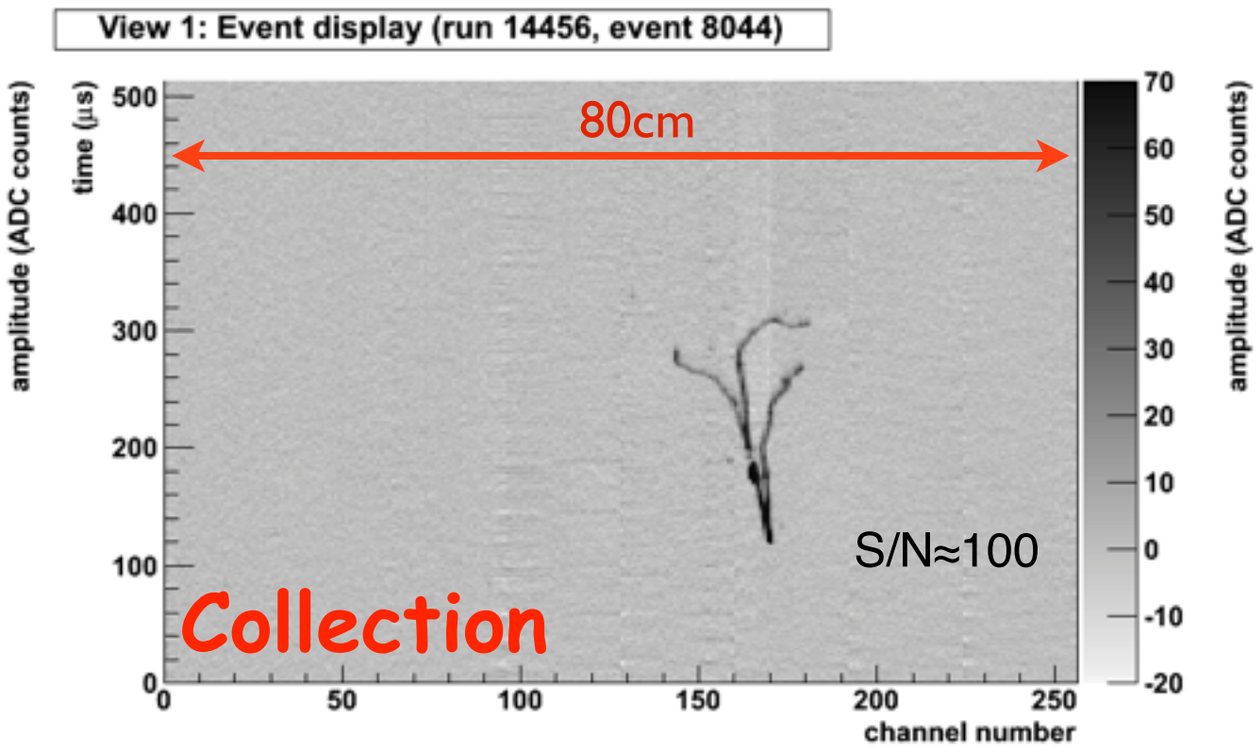
Long term operation in 3 lt setup: >15 millions cosmic events collected very stable conditions

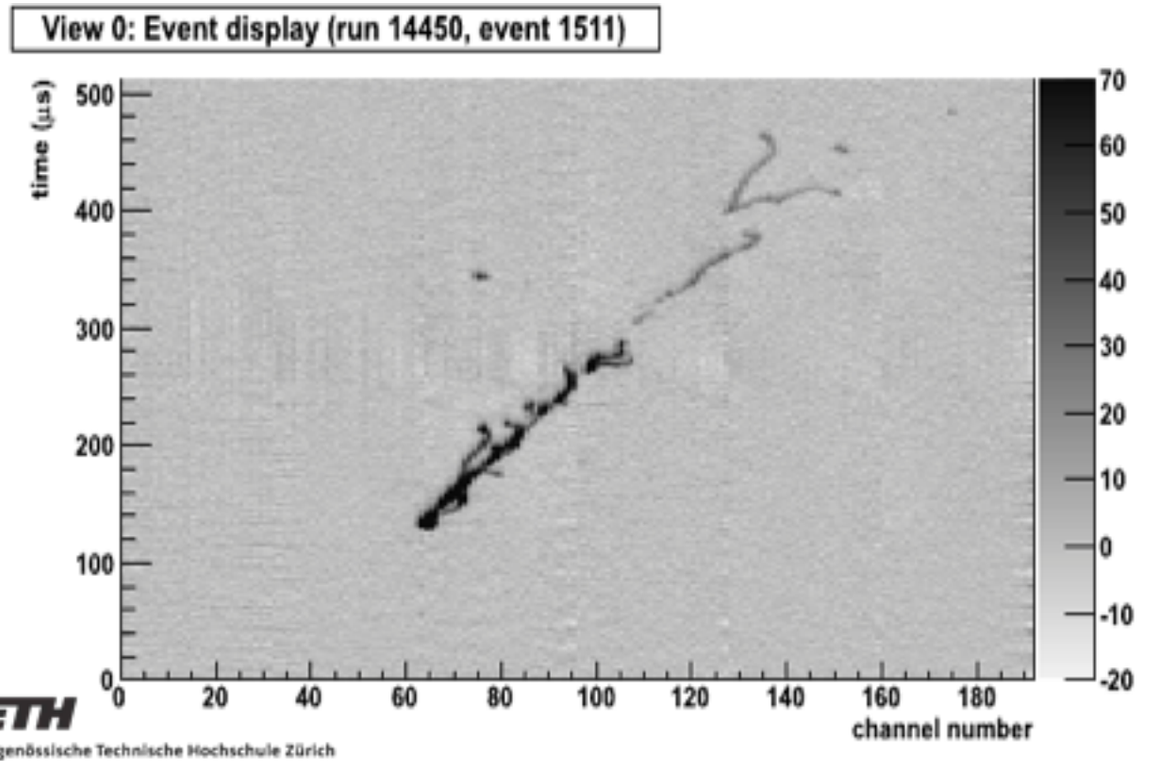
	data taking period			number of triggers	number of discharges
	start	stop	days running		
anode A	11-Apr	16-May	20	7.5 M	6
anode B	16-July	29-July	12	4.2 M	2
anode C	27-Aug	02-Sept	7	1.4 M	0
anode D	15-Oct	21-Oct	7	1.5 M	0

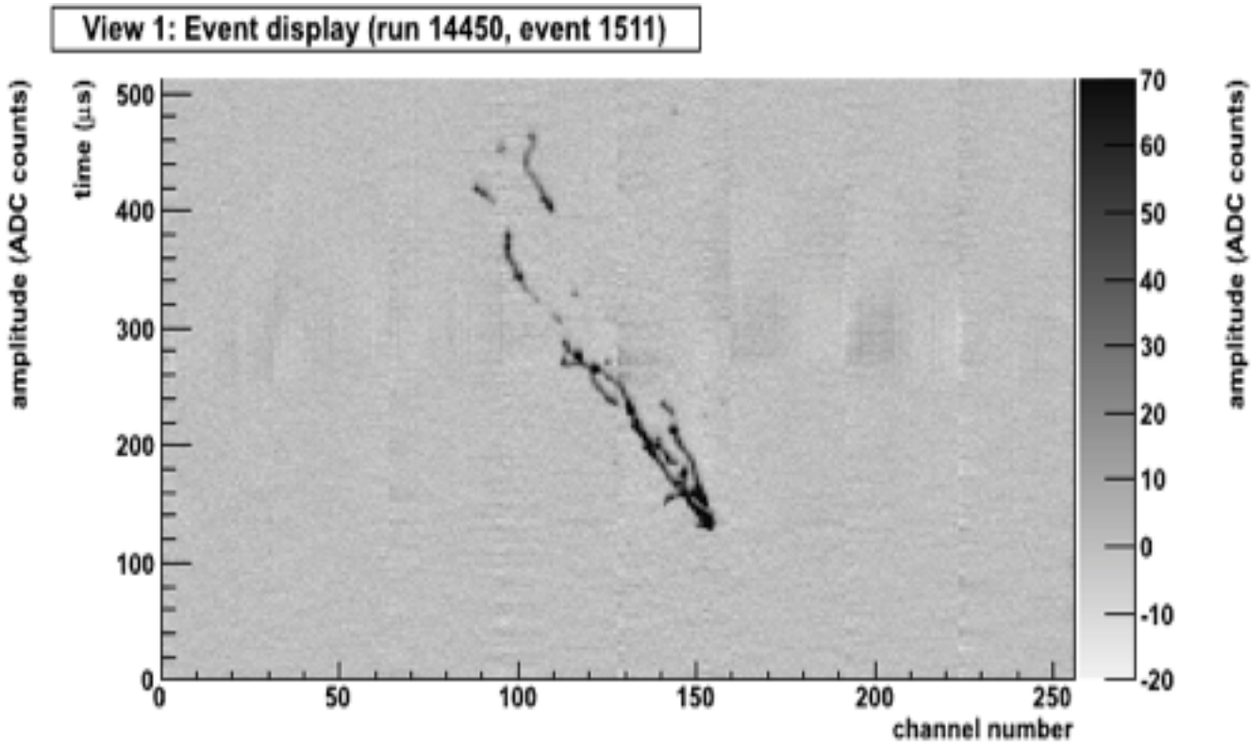
Double phase: event gallery

With "nominal" gain ≈ 15 —> S/N >≈ 100 for m.i.p !









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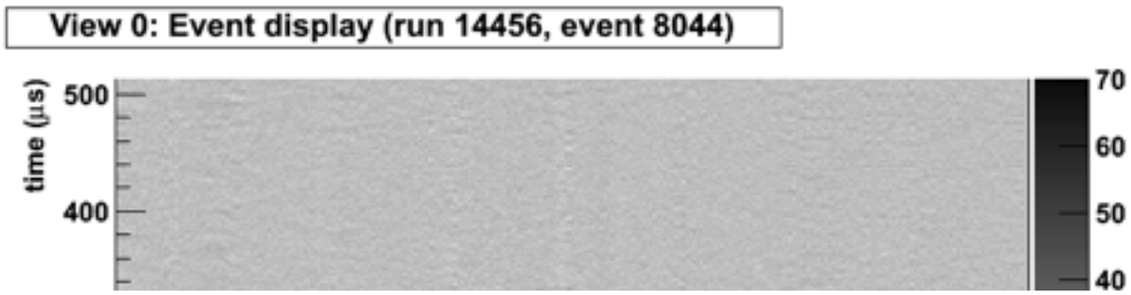
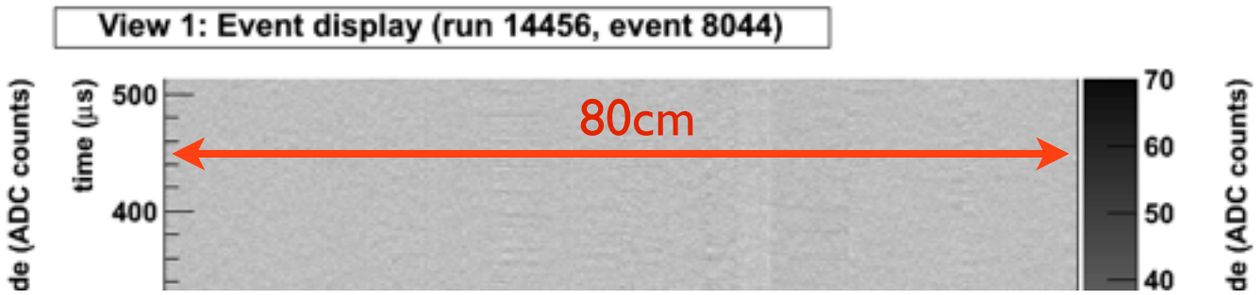
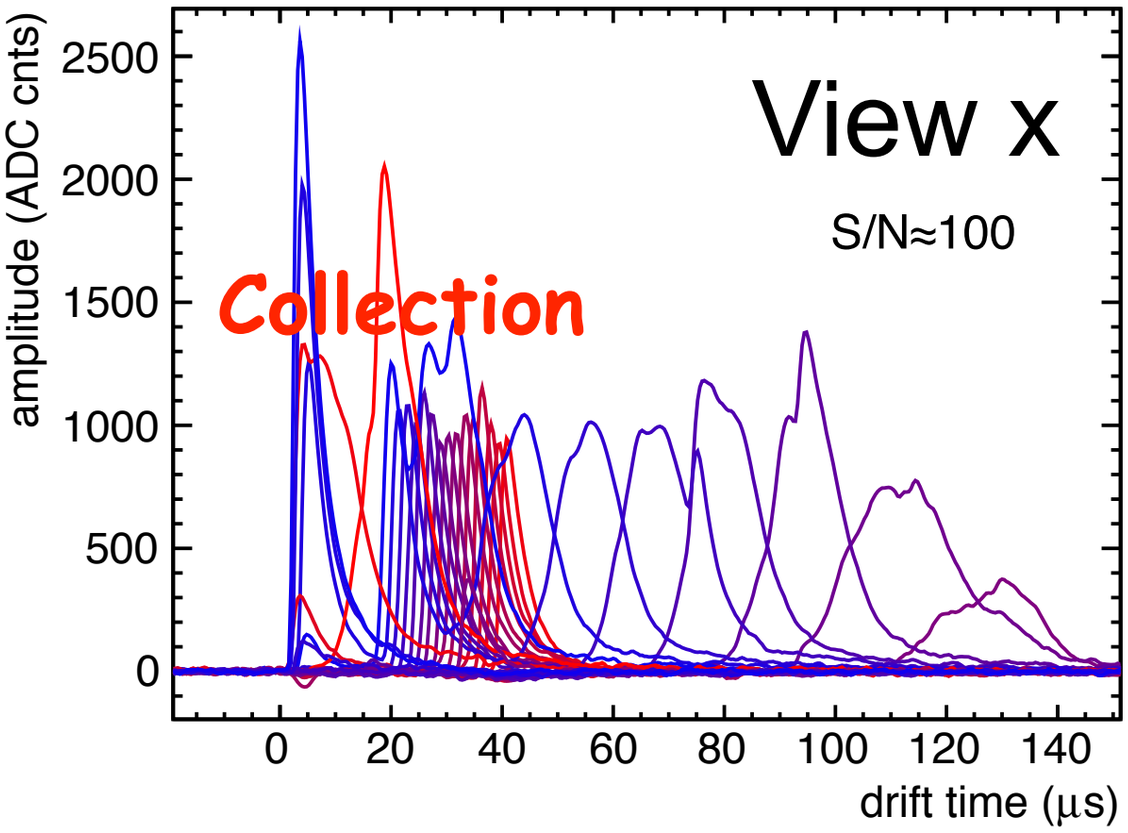
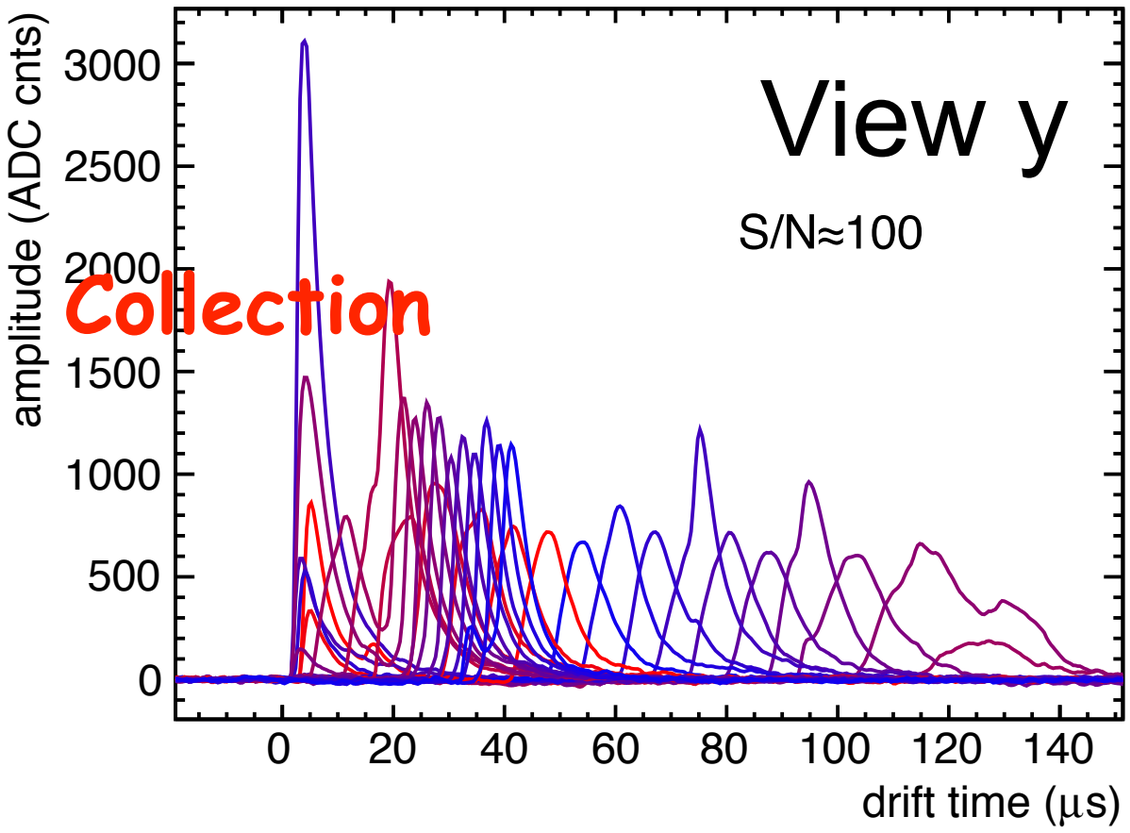
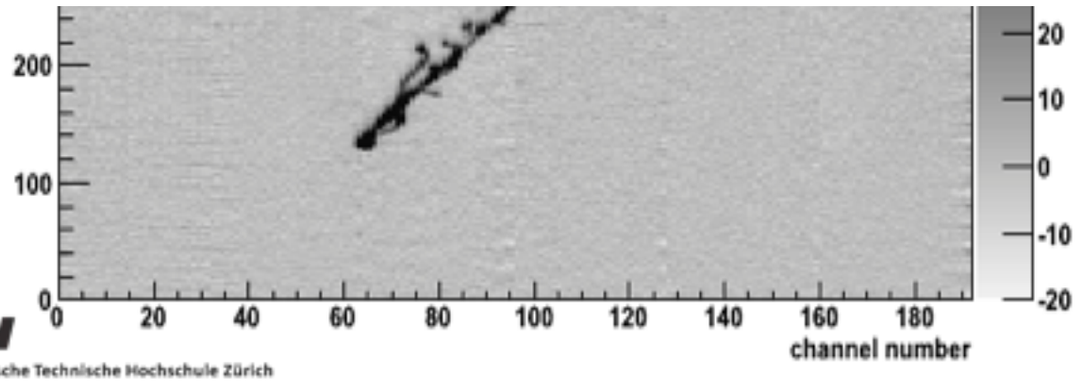
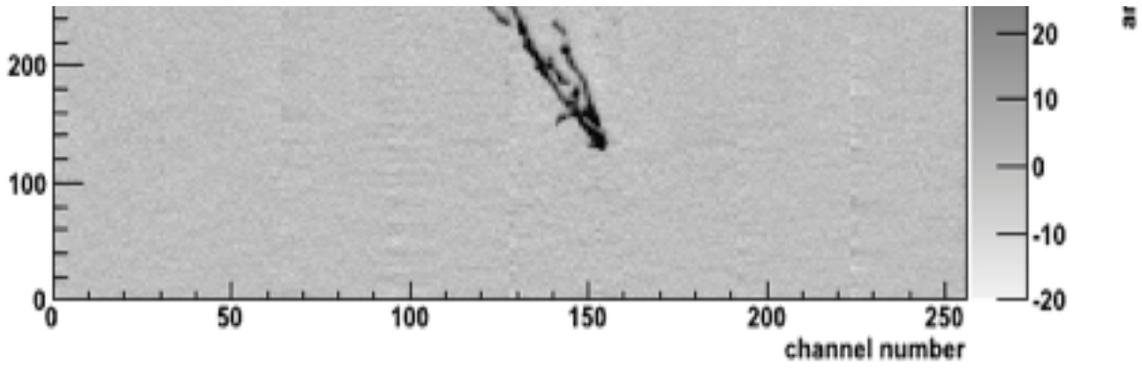






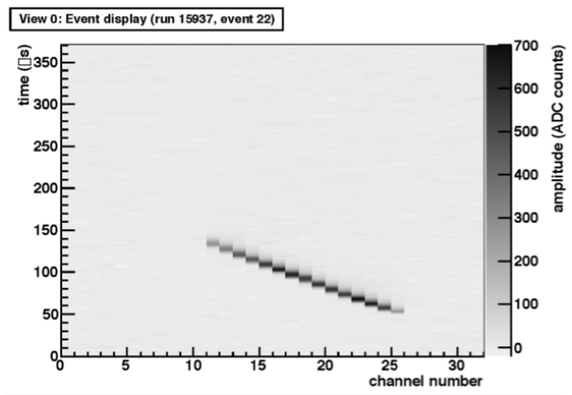


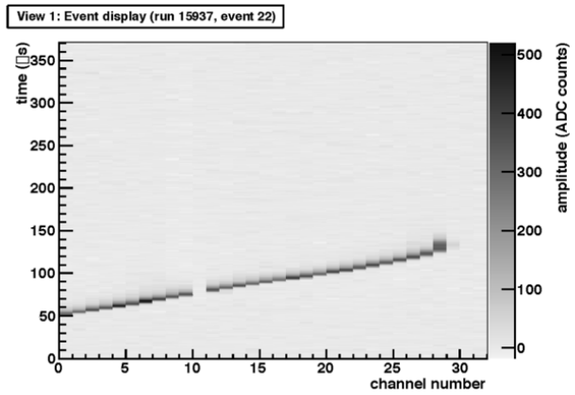


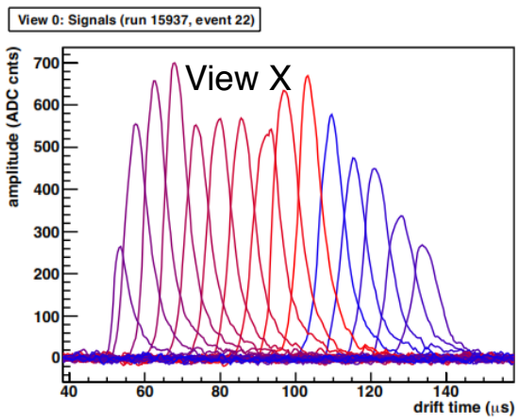


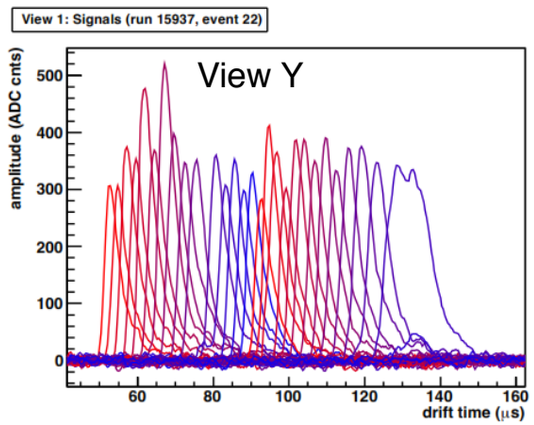
Adjustable gain

"Nominal" gain ≈ 20 (x10 per view)



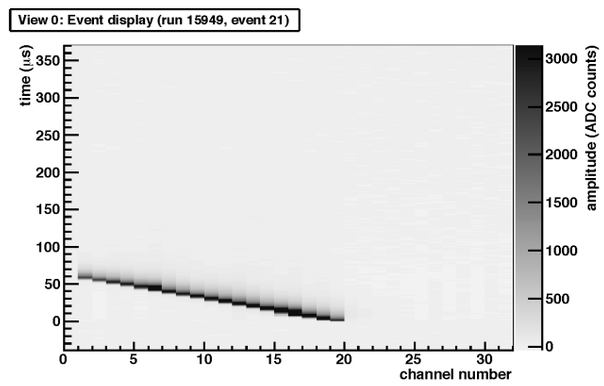


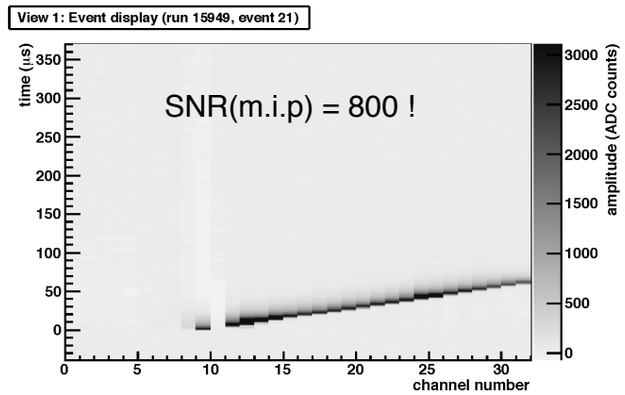


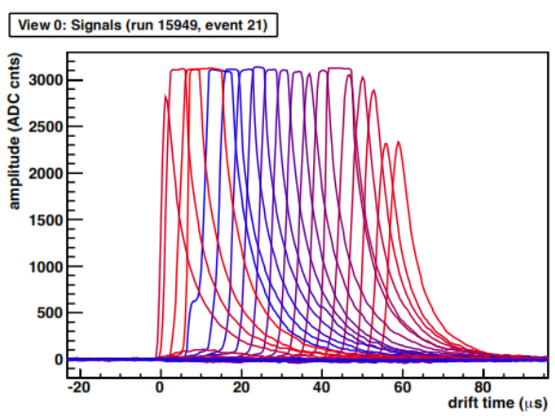


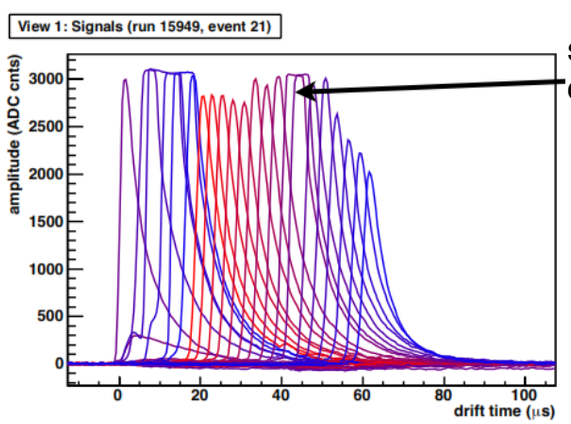
Gain brings enough ionisation charge to "share" it among views collecting identical waveforms
(for two views: 50%-50%).

Max gain reached ≈ 180 !!!









saturation of the pre

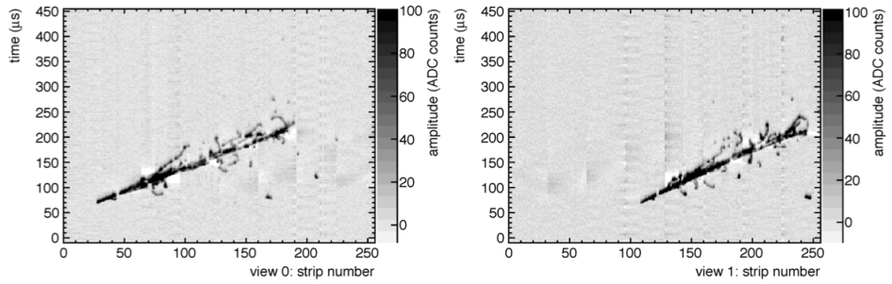
Opens possibilities:

- very low energy threshold in the 10's keV range
- very small pitch < 3mm
- very long drift path (compensates for diffusion and charge attenuation)
- only charge collection, no induction
- …

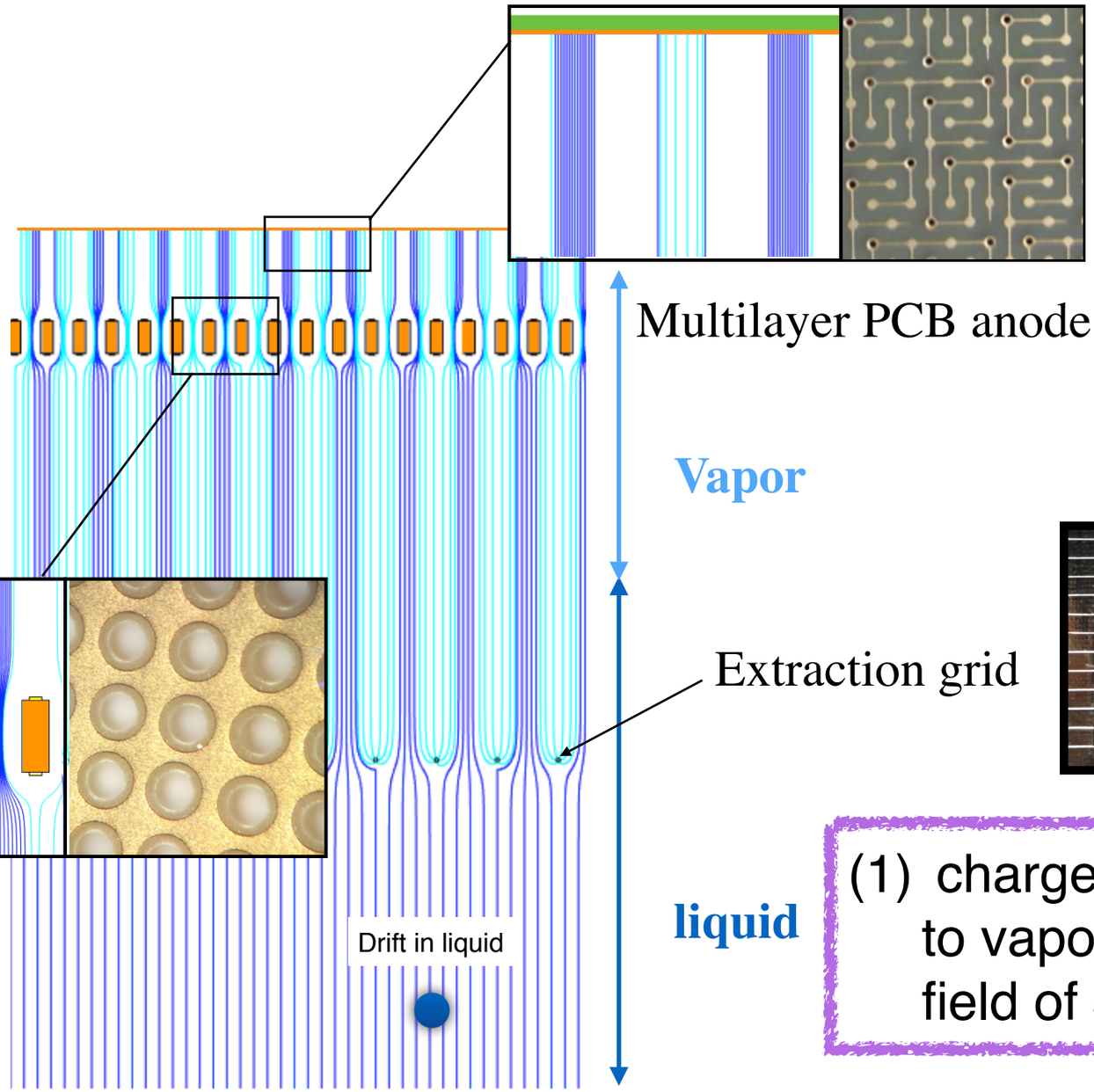
Double phase readout: detail

data collected on a 40x80 cm^2 DLAr TPC at CERN

(3) charges **collected** on specially designed two view anode. Both views see the same amount of charge and have **identical signals**



(2) charges **amplified** in Large Electron Multiplier E field of ~30 kV/cm



(1) charges **extracted** to vapor phase E field of ~2 kV/cm

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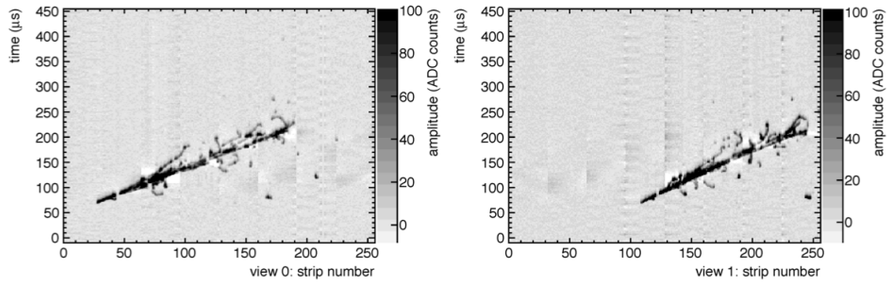

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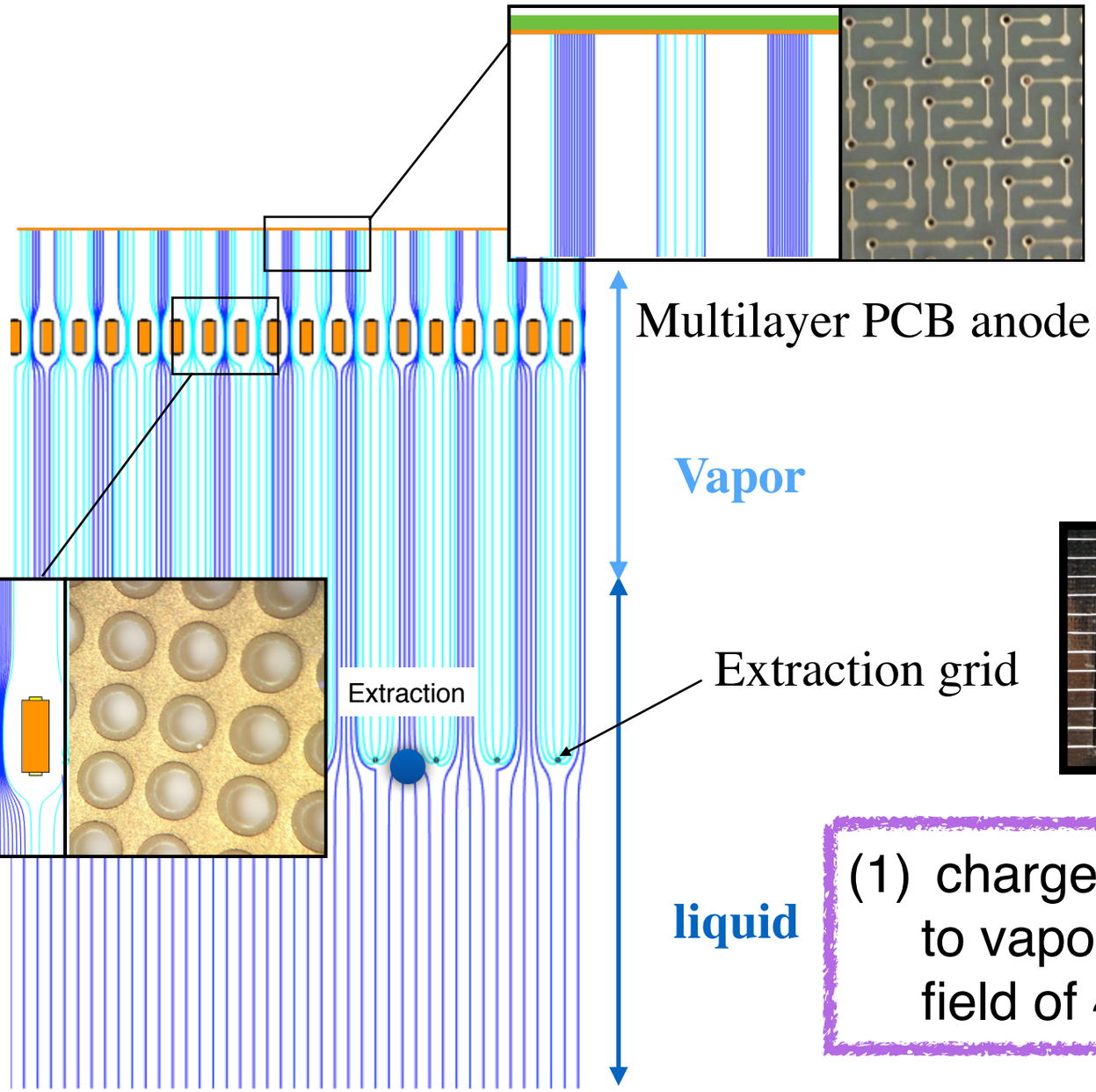

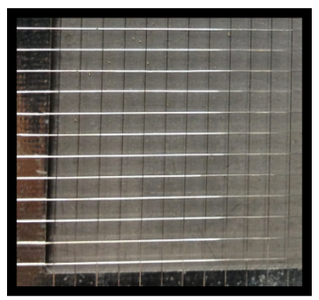

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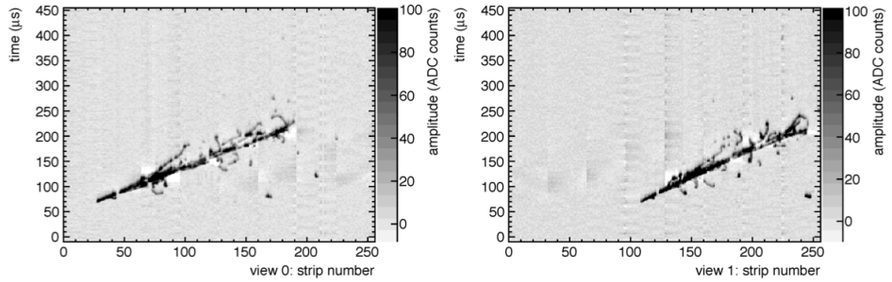

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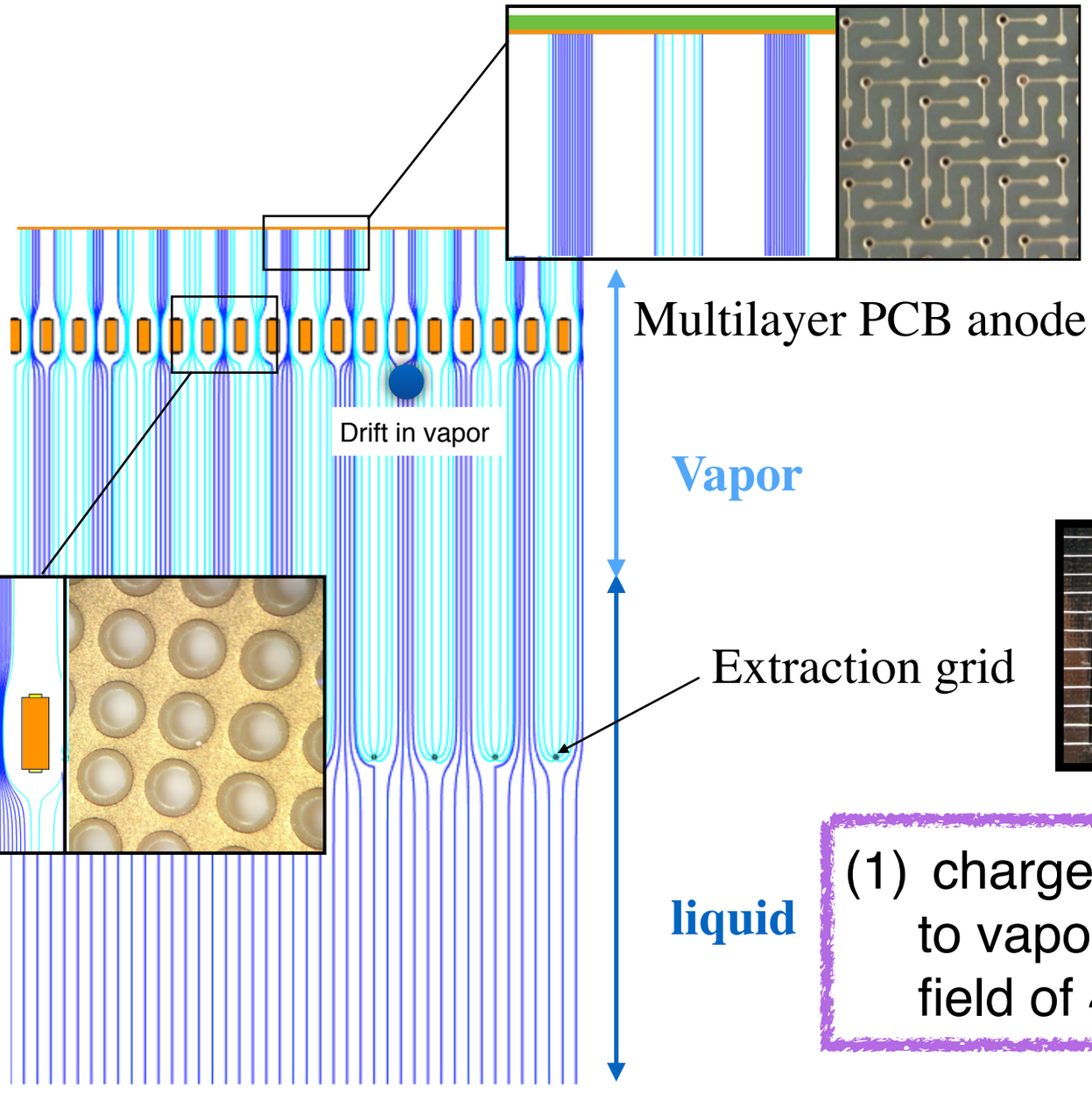

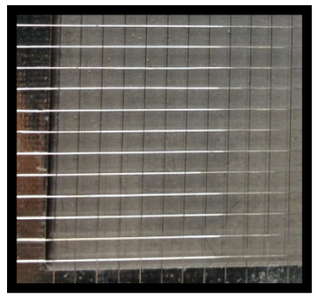

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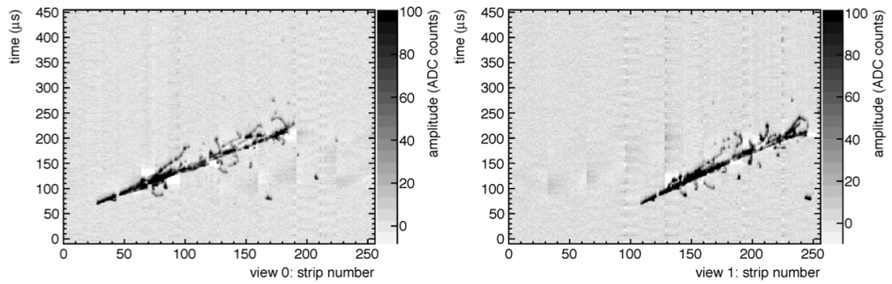

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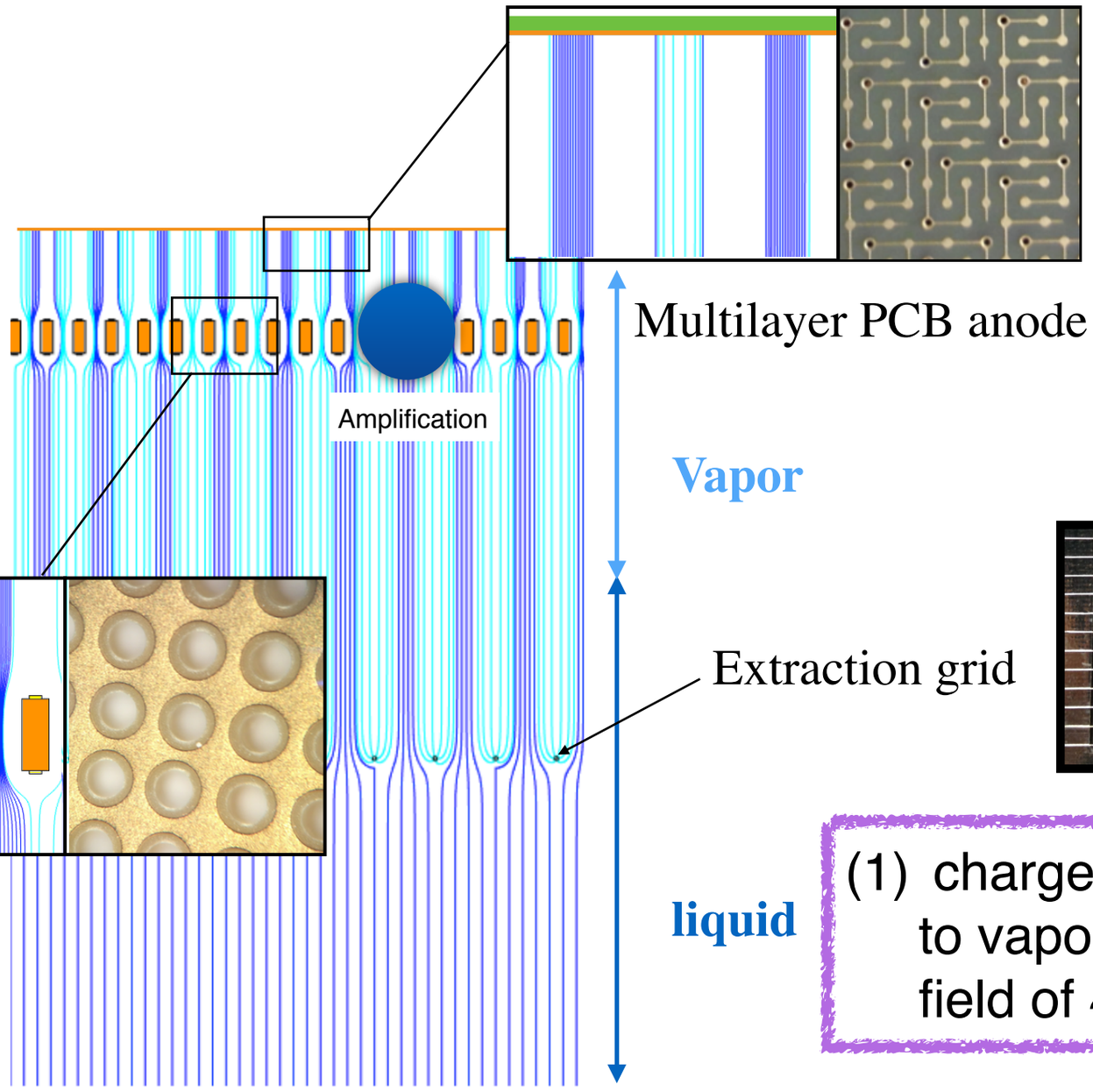

(1) charges **extracted** to vapor phase E field of ~2 kV/cm

Double phase readout: detail

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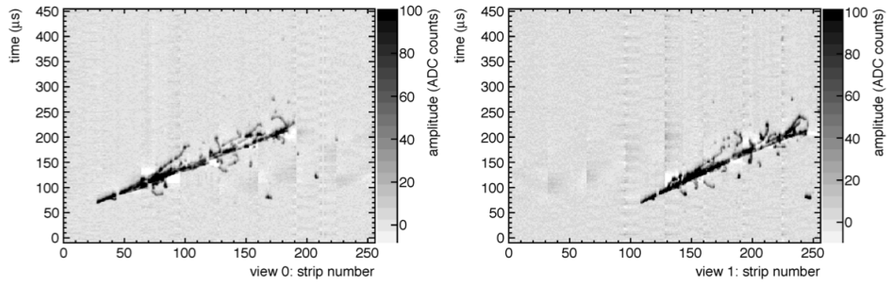

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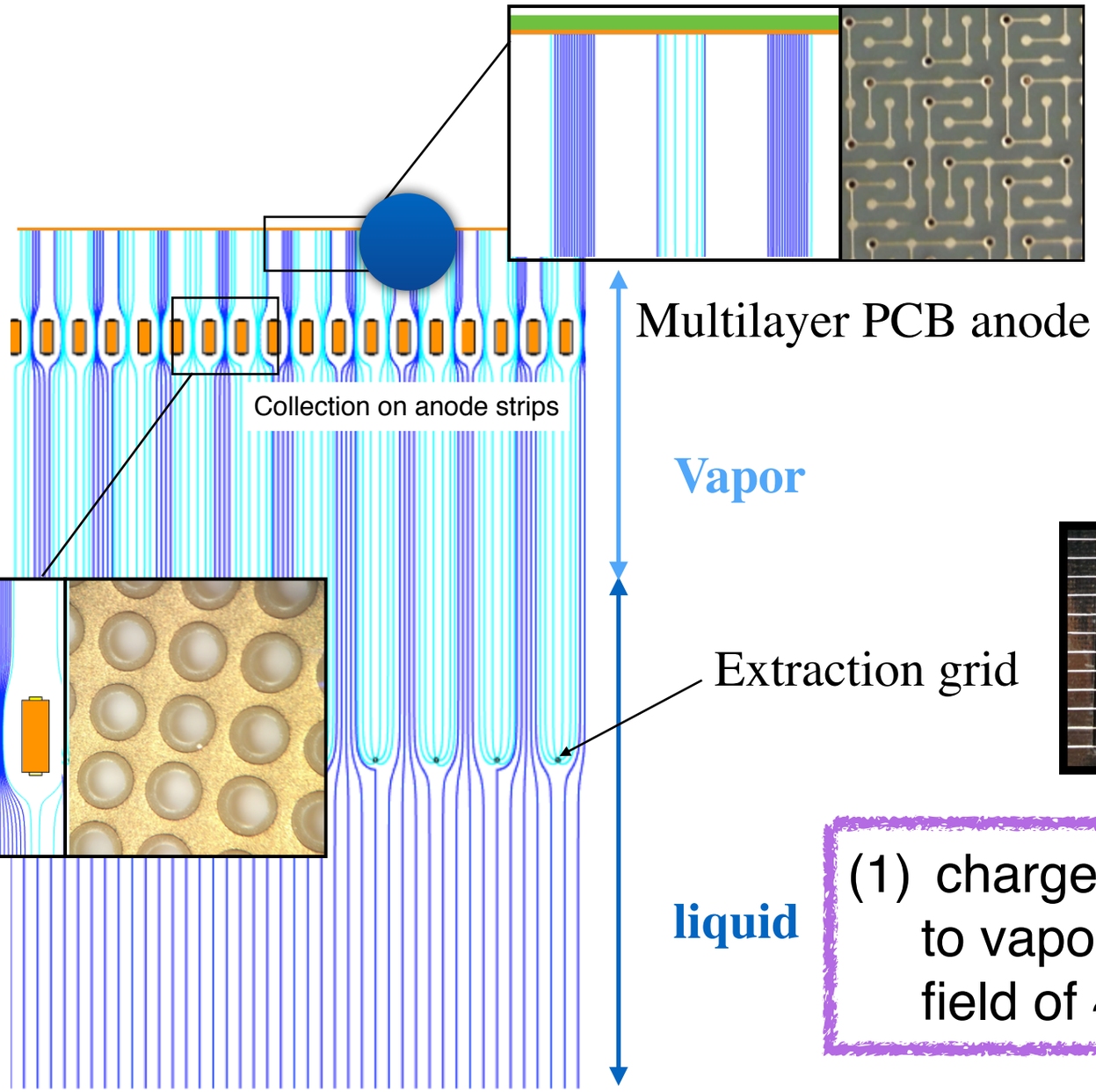


(1) charges **extracted** to vapor phase E field of ~2 kV/cm

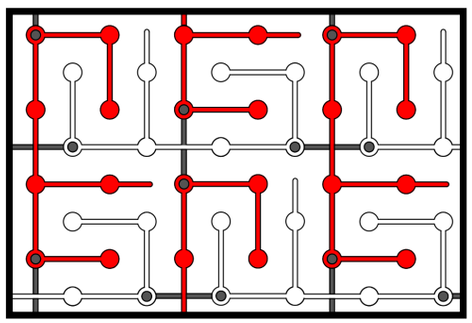
Optimisation of anode

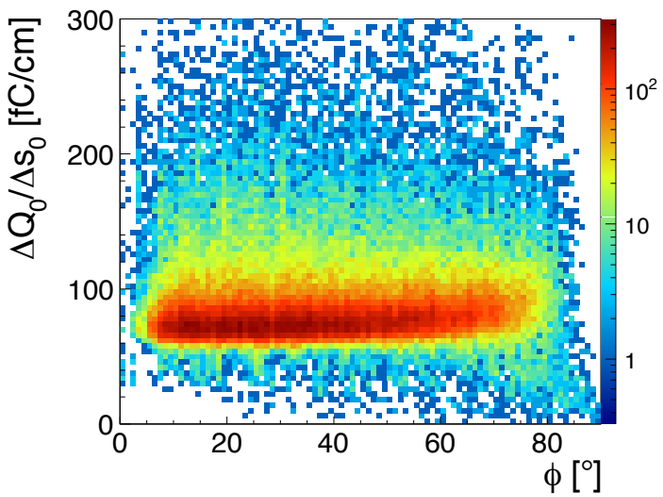
arXiv:1412.4402

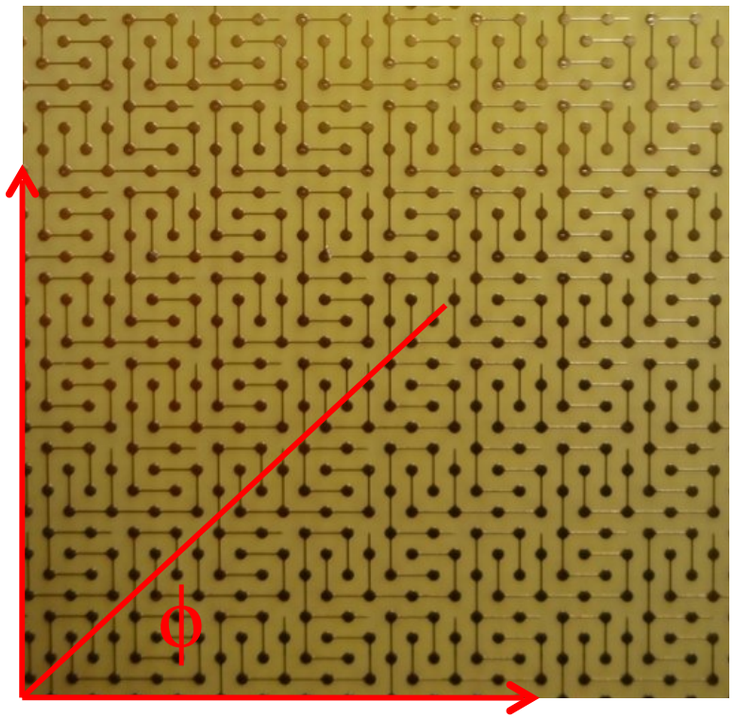
Optimise the layout of the strips

anode: compromise between resolution on charge measurement and capacitance

dC/dl ~ 150 pF/m

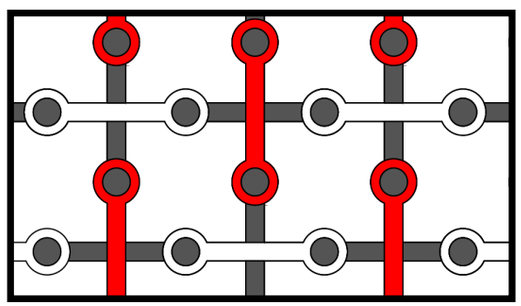


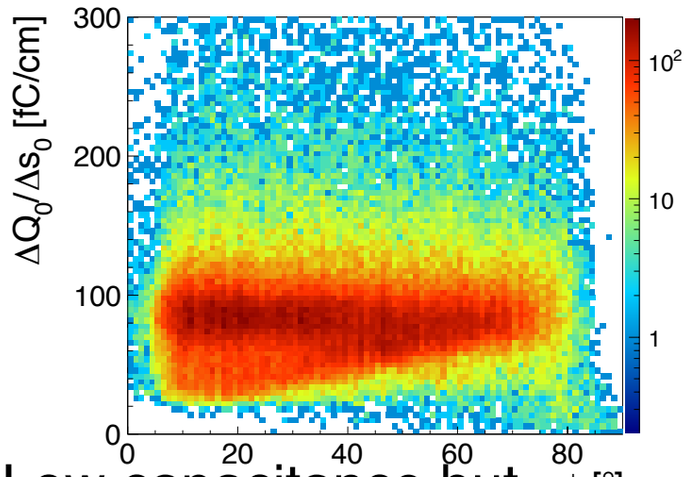




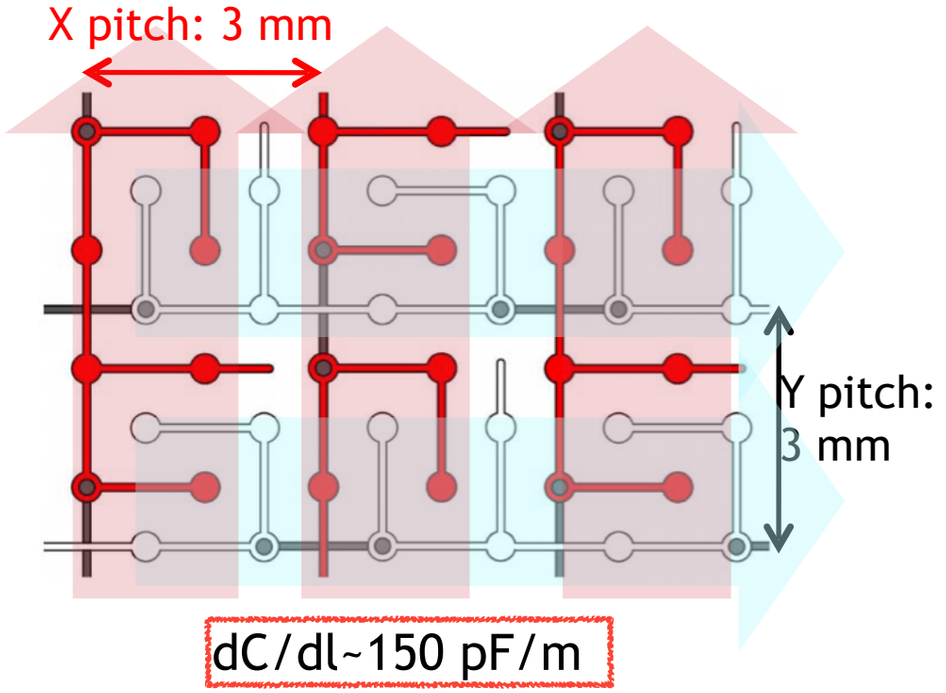
C Cantini et al 2014 JINST 9 P03017

dC/dl ~ 100 pF/m





anode pattern too corse. Low capacitance but charge collection not uniform



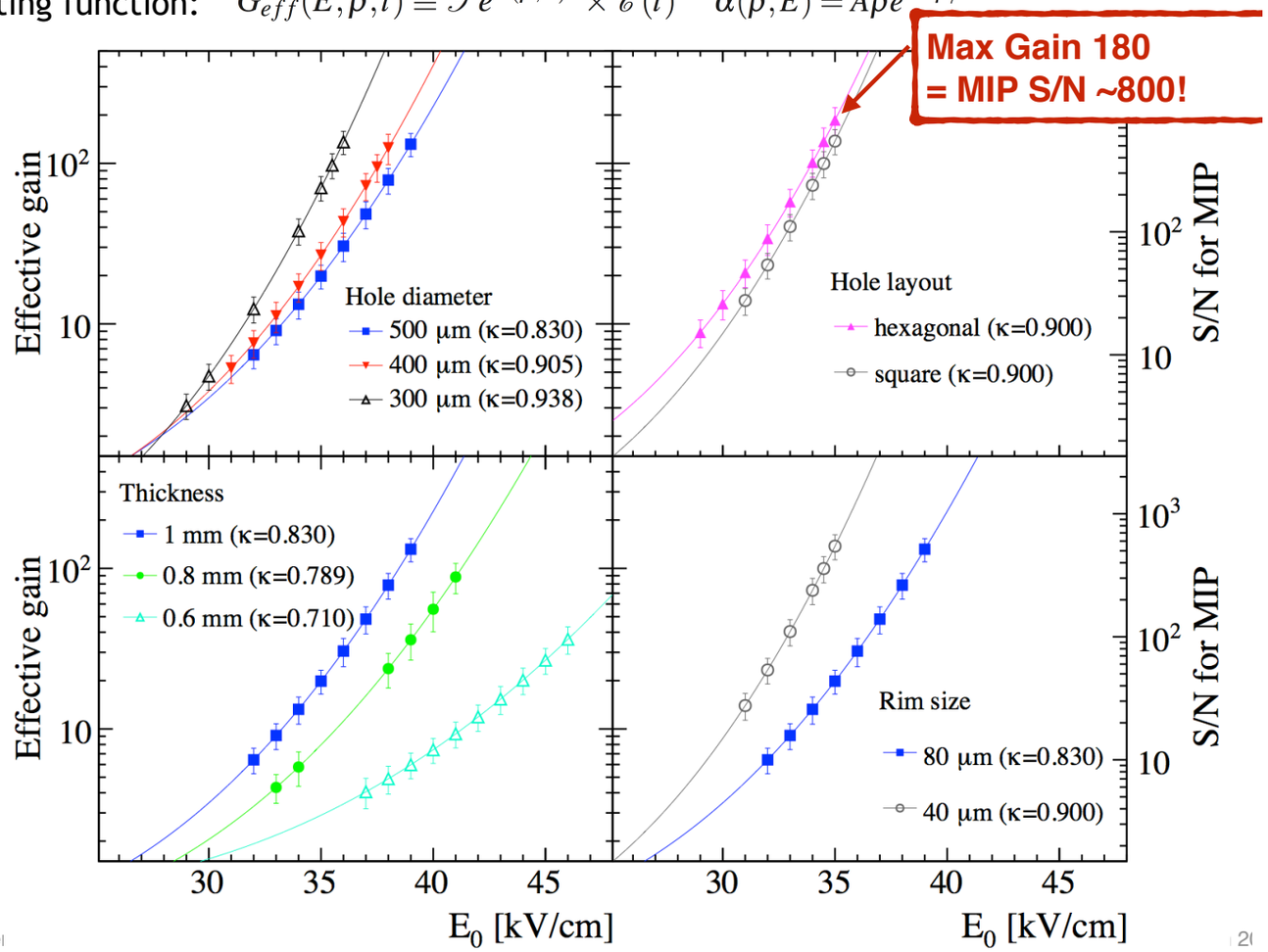
dC/dl~150 pF/m

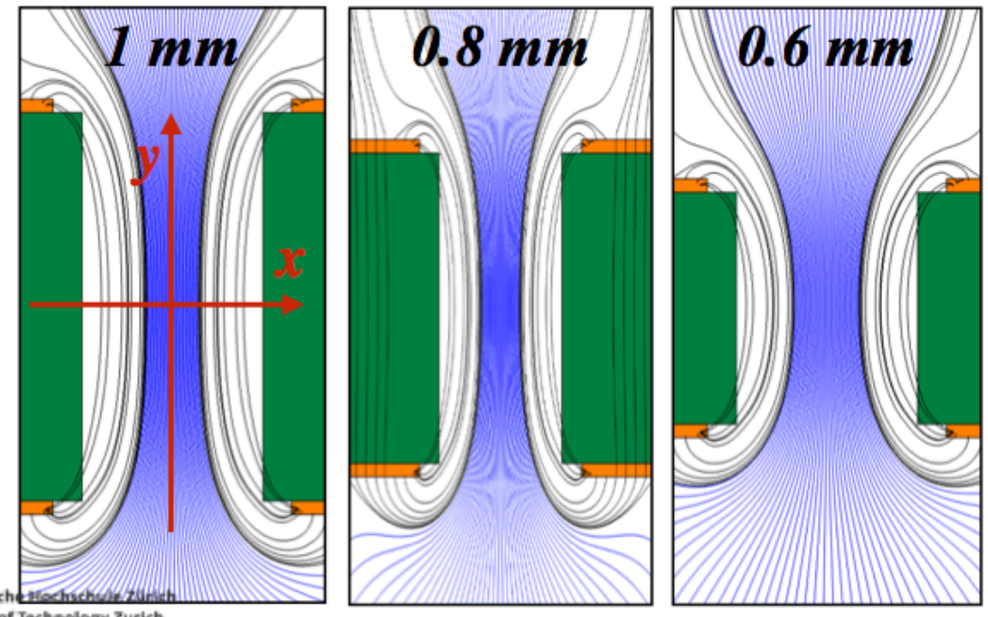
Best solution to optimize capacitance and resolution

Optimisation of LEM

arXiv:1412.4402

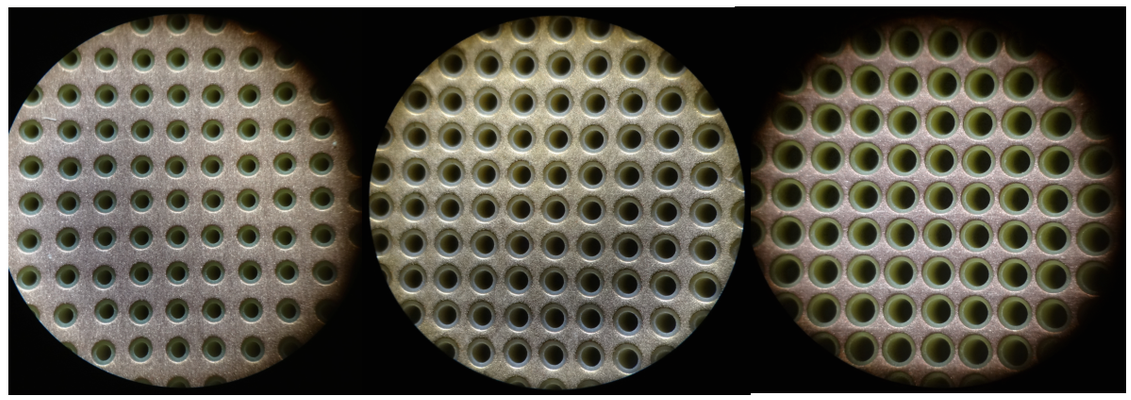
Fitting function: $G_{eff}(E,\rho,t) \equiv \mathscr{T} e^{\alpha(\rho,E)x} \times \mathscr{C}(t) \quad \alpha(\rho,E) = A\rho e^{-B\rho/E}$

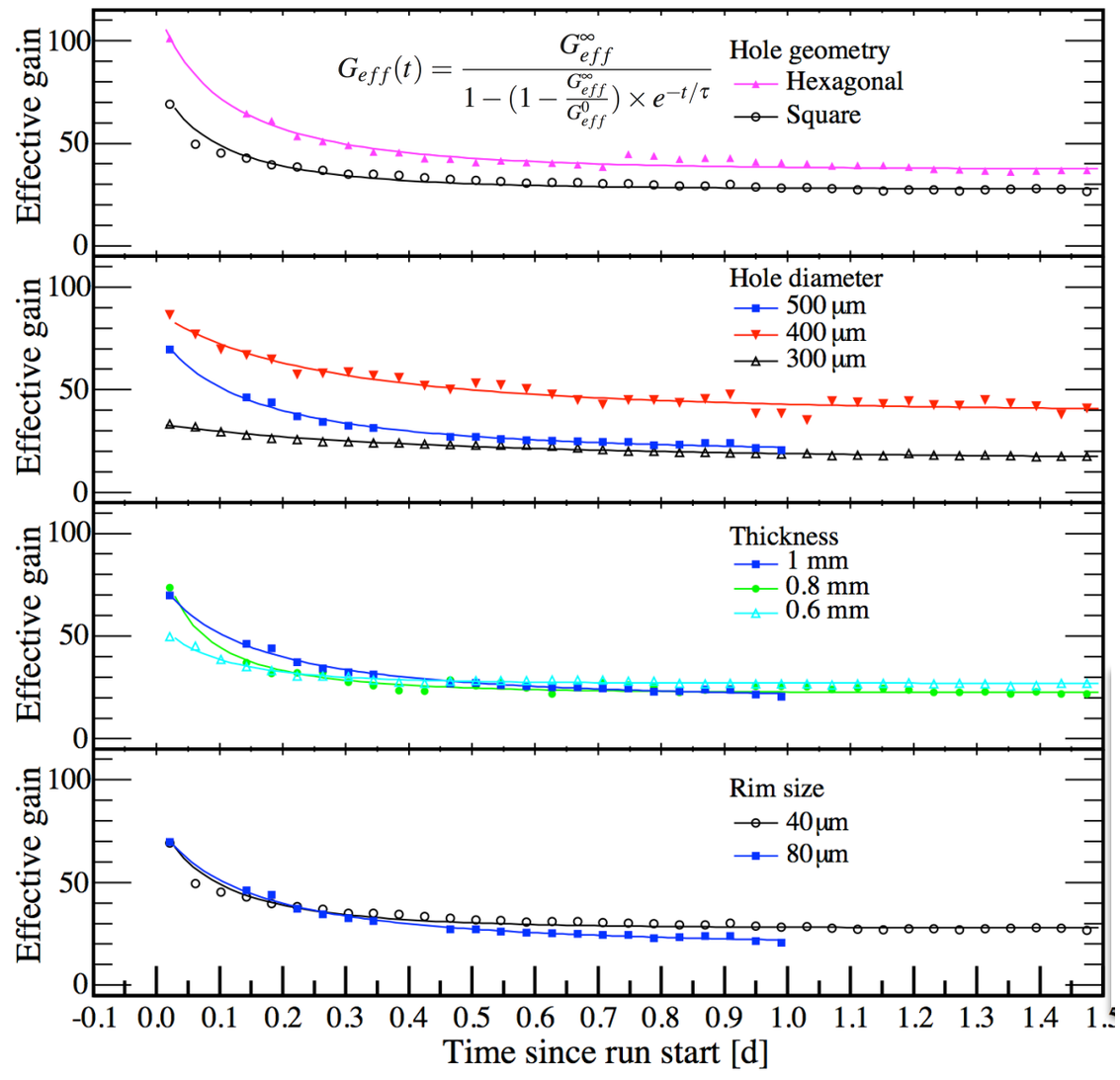




Hole diameter:

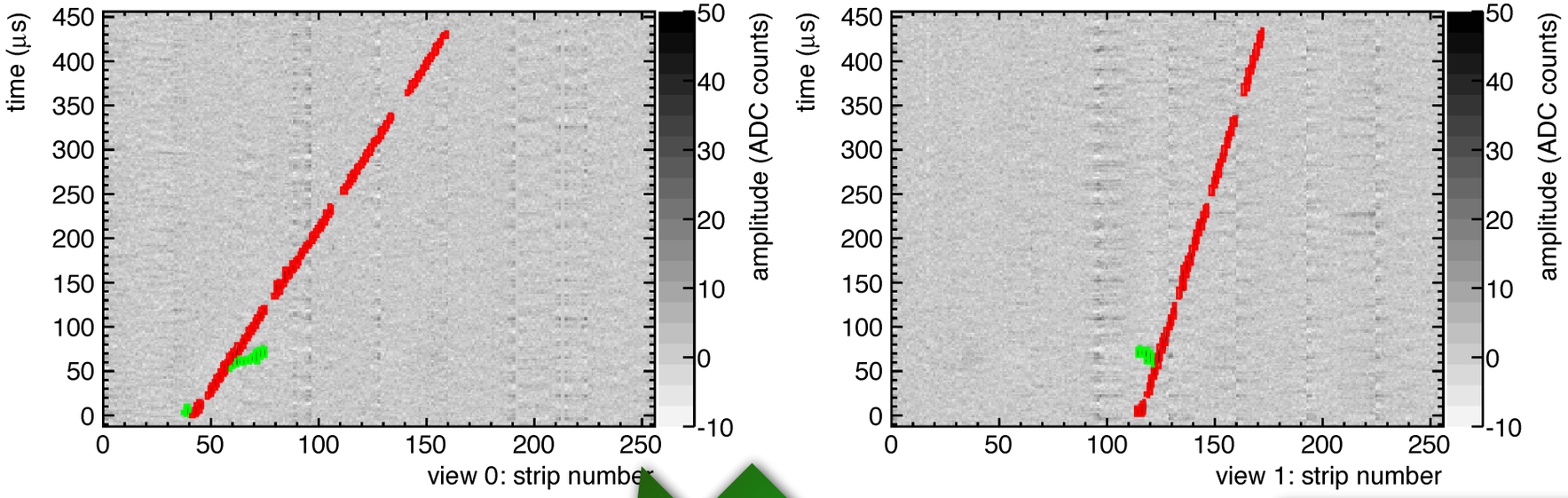
300 µm 400 µm 500 µm





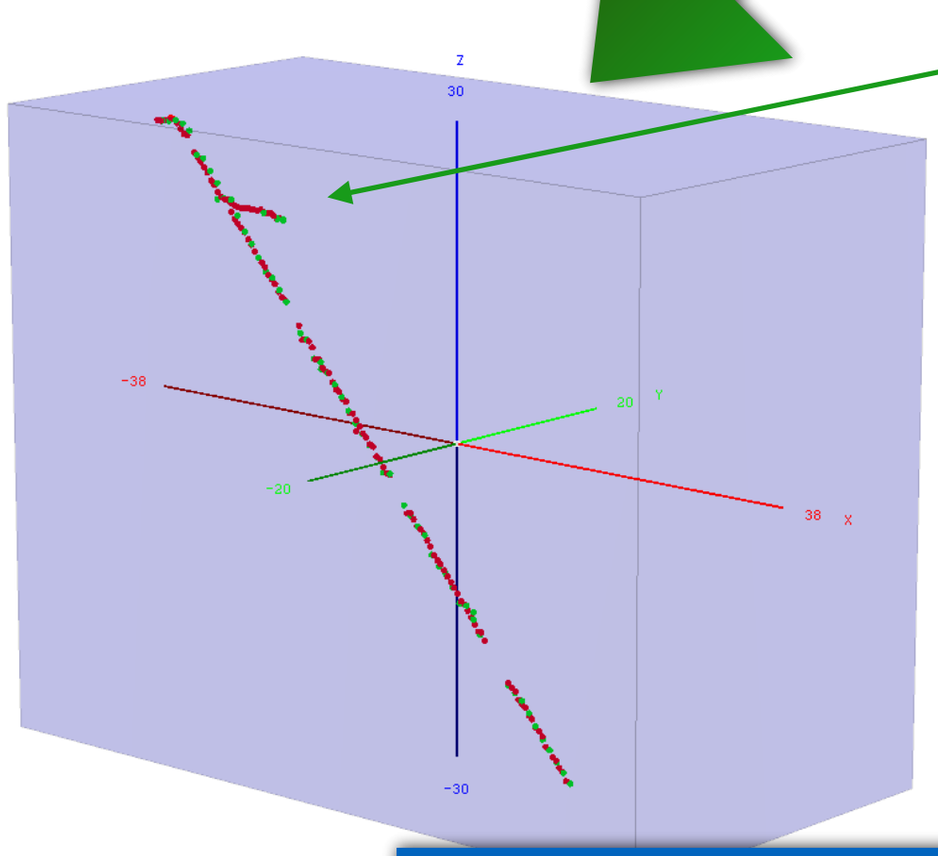
Gain stability & charge up

Delta-rays 250 lt DLAr prototype



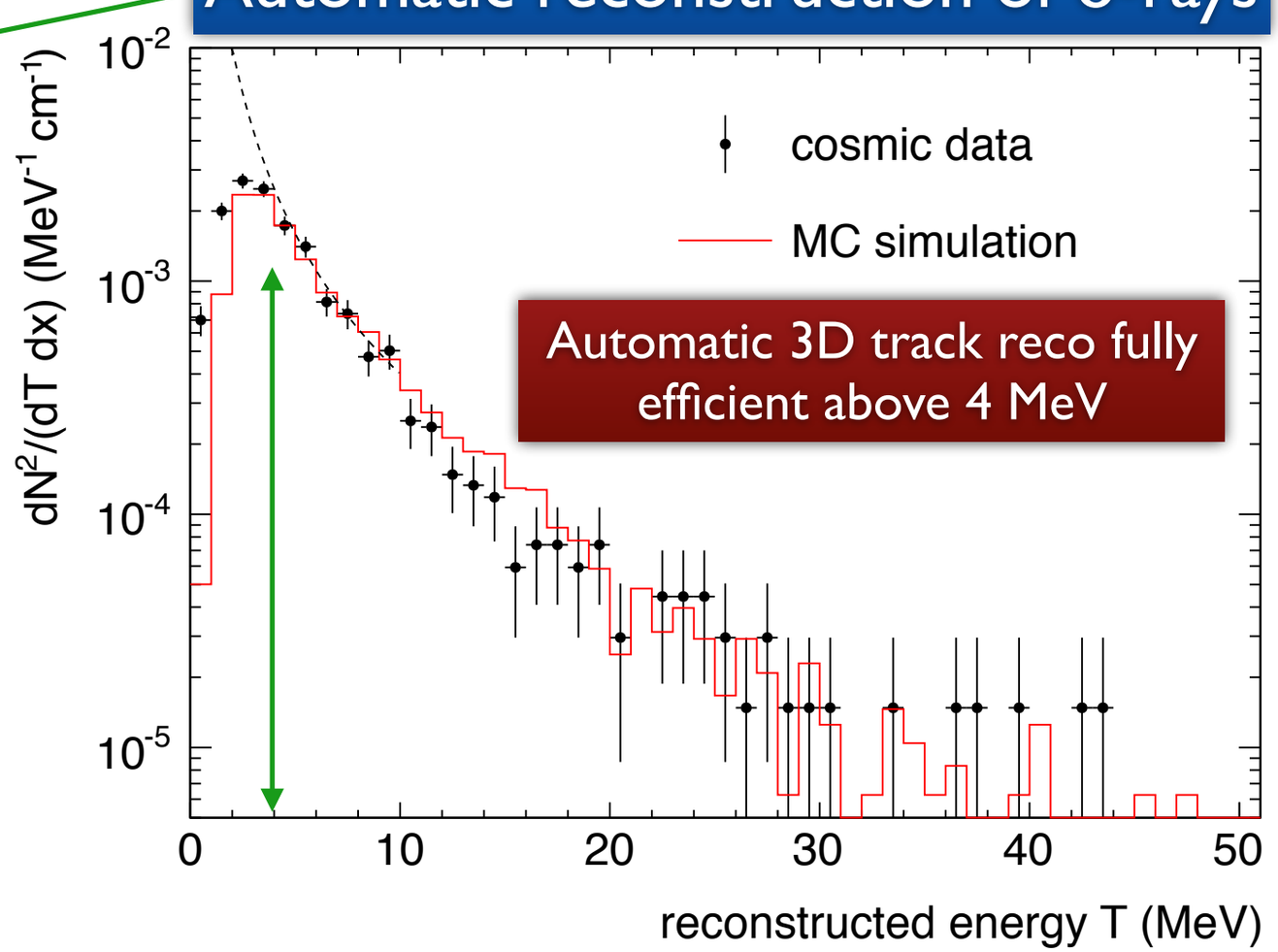
JINST 8 (2013) P04012

Event recorded in 200 lt. double phase chamber exposed to cosmic rays



3D reconstruction

Automatic reconstruction of δ-rays

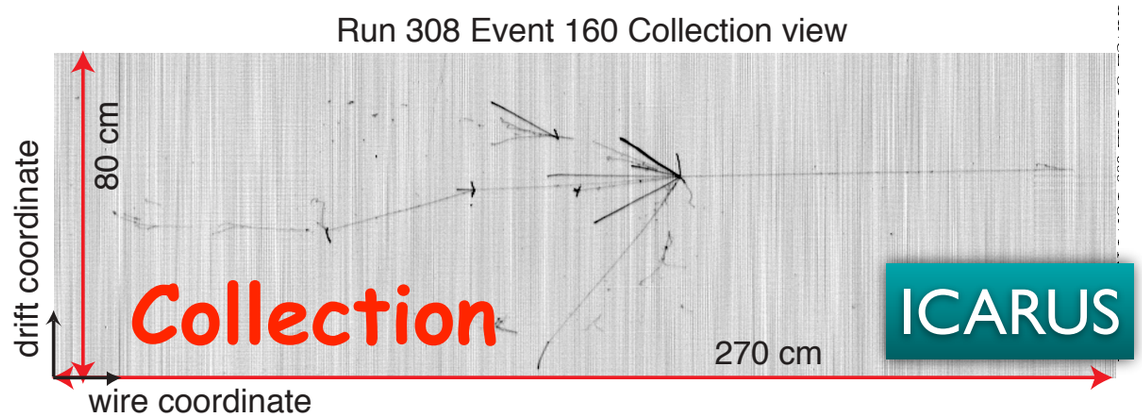


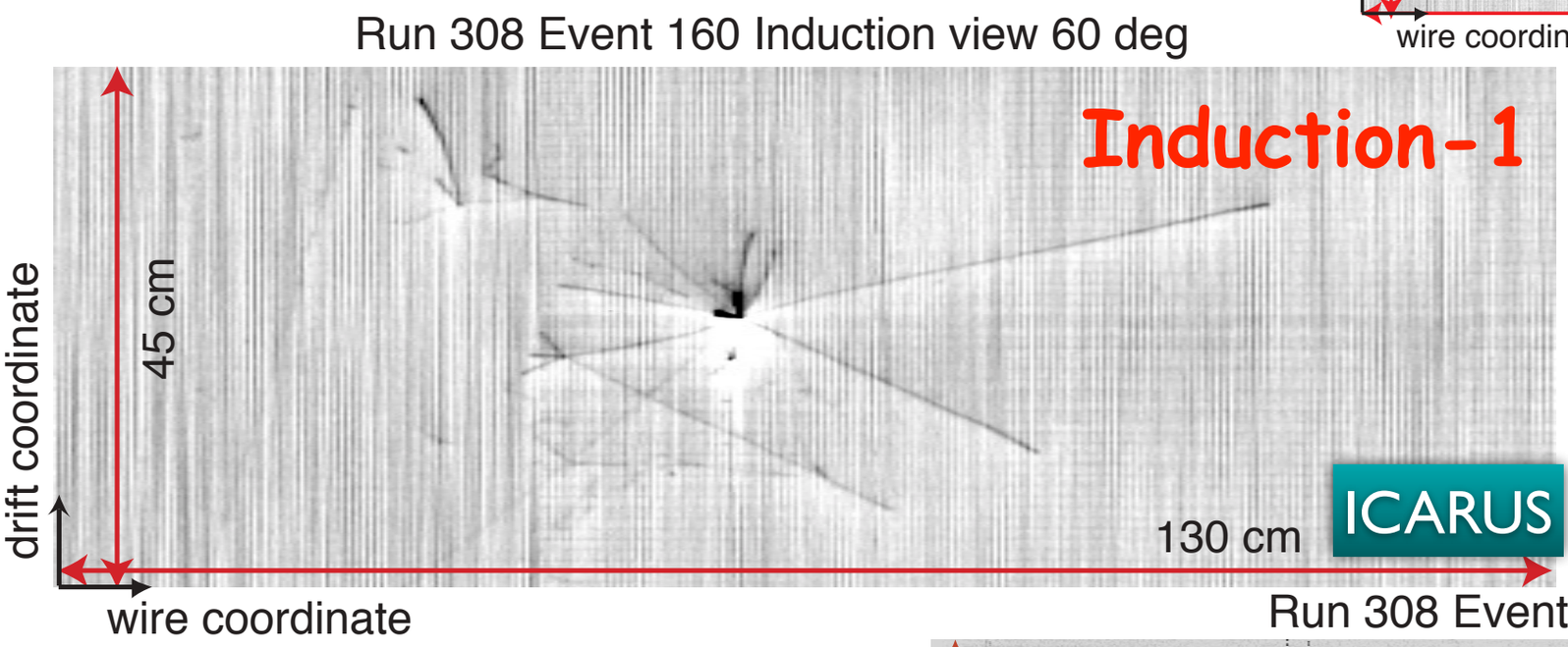
Automatic 3D track reco fully efficient above 4 MeV

3D reconstruction of events

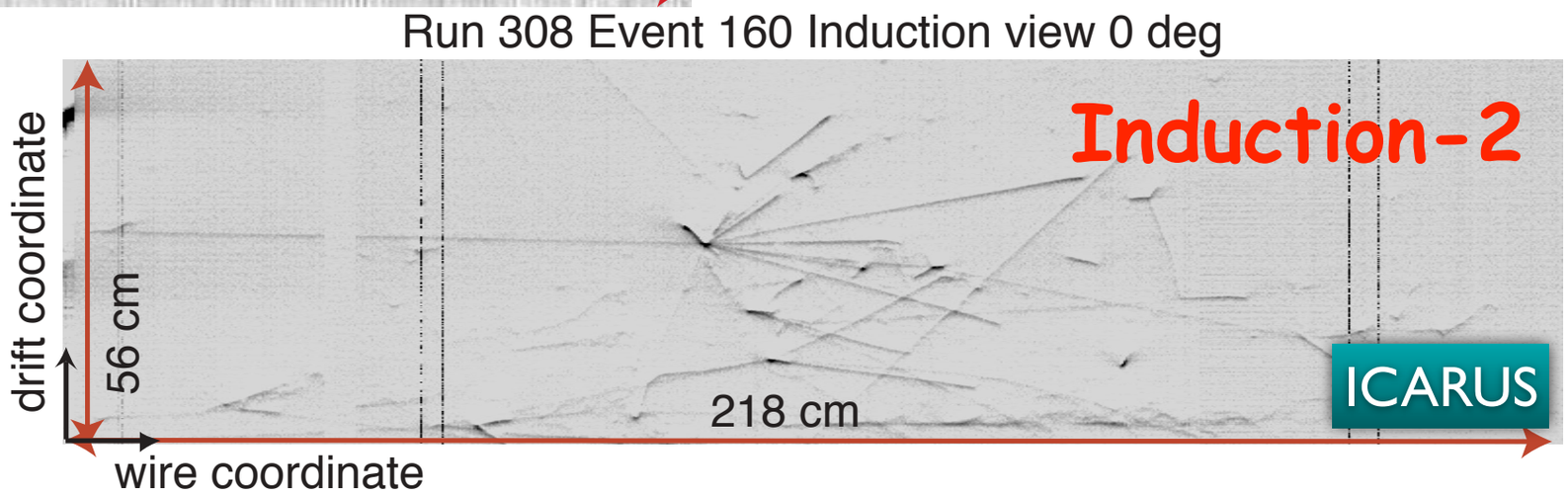
WA105

ICARUS T600: charge collection provides best imaging. Induction views necessary for 3D.





Difficultly to match 3D (white spots)
Rely on redundancy on several views

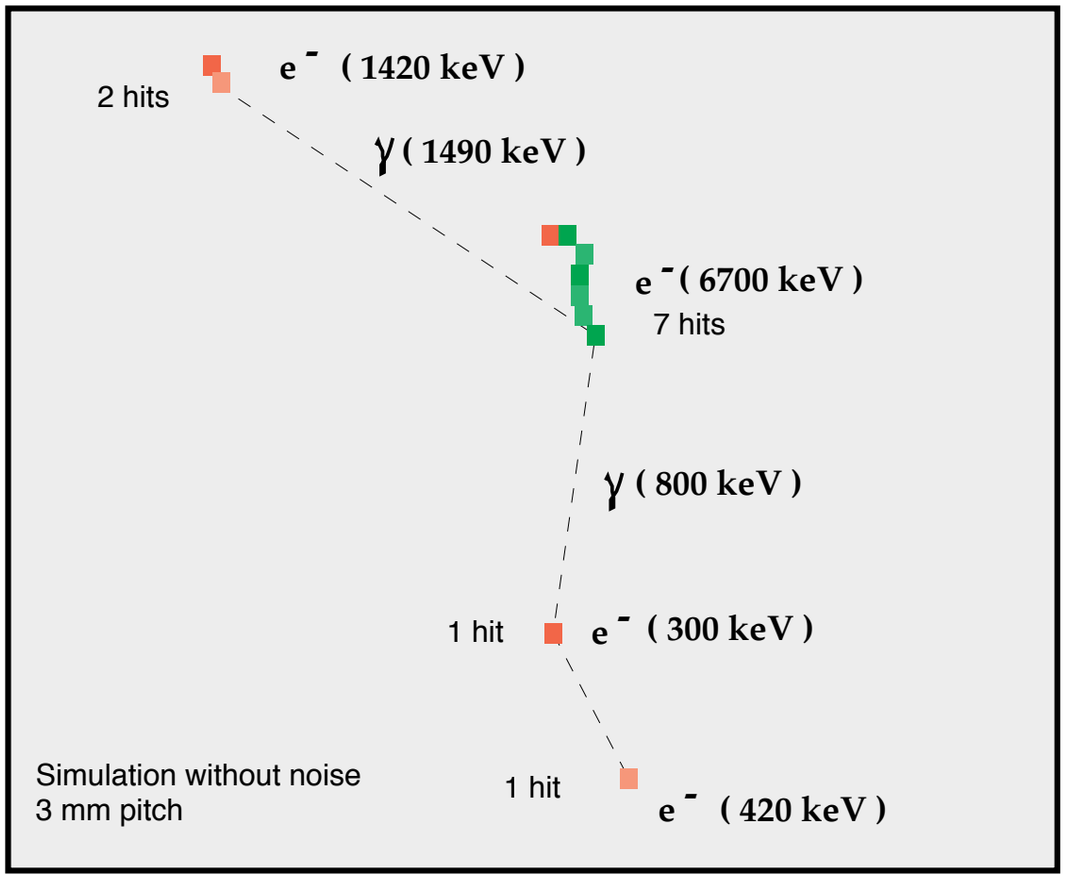


Double phase uses collection views only (thx to gain).

Tracking at low energies...

WA105

An example of beautiful event at low energy: e.g. supernovae, solar neutrinos



Charged-current absorption

$$\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$$

Dominant

$$\bar{\nu}_e + {}^{40}Ar \rightarrow e^+ + {}^{40}Cl^*$$

Neutral-current excitation

$$\nu_x + {}^{40}Ar \rightarrow \nu_x + {}^{40}Ar^*$$

Not much information in literature

Elastic scattering

$$\nu_{e,x} + e^- \rightarrow \nu_{e,x} + e^-$$

Can use for pointing

Track length !

$E_{\text{primary electron track}} = 6700$ keV

Associated Compton energy= 2140 KeV

Multiplicity of secondary tracks= 3

100 keV hit (i.e. S/N > 100 for mip) and 3mm wire pitch needed !

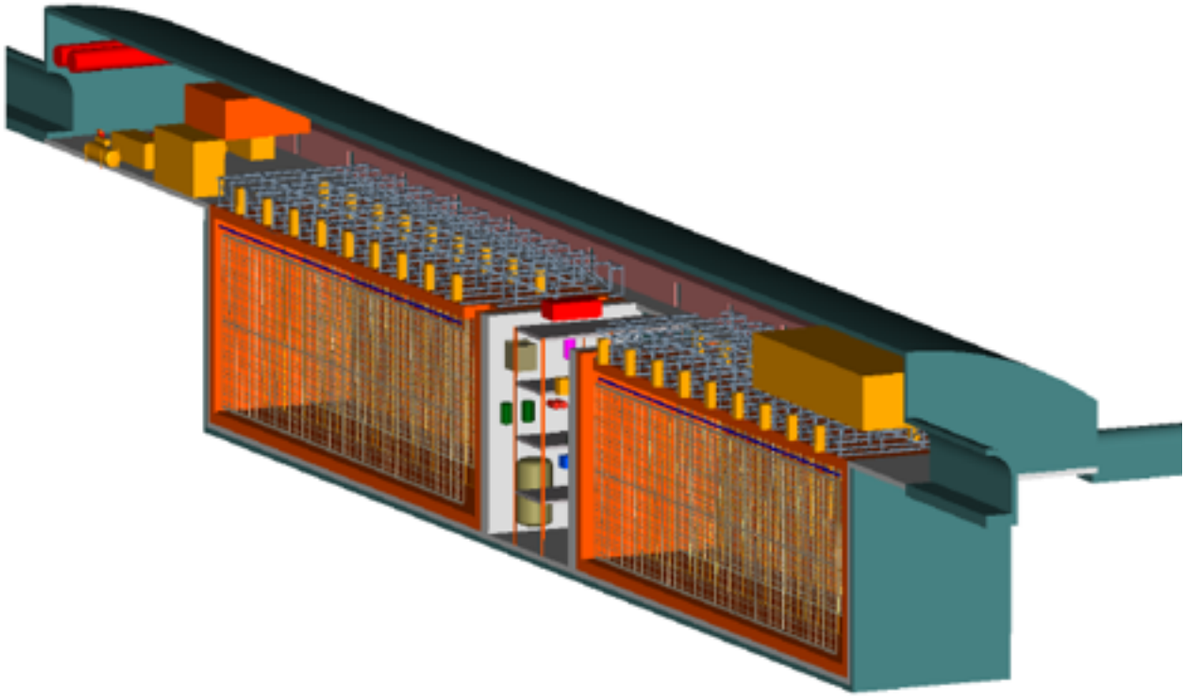
Double phase allows for very low thresholds

Potential implication for the big picture

(based on LAGUNA/LBNO design study and collaboration with LBNE project)

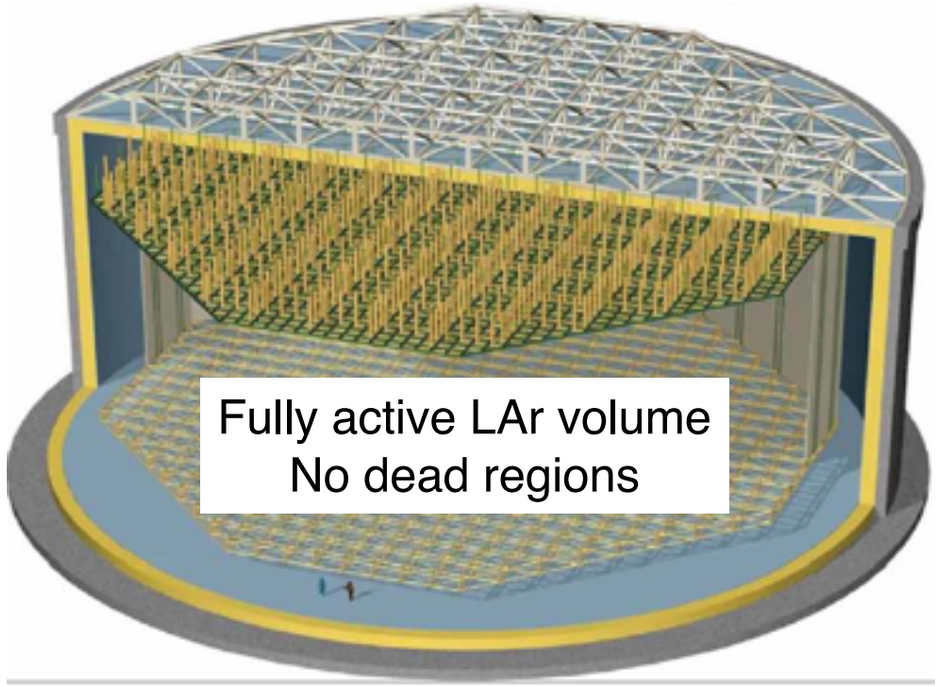
Initial discussions: LBNE vs. LBNO design

LBNE Design:
Rectangular, rock-supported cryostat



- Current reference design for LBNF
- Rectangular geometry makes maximum use of excavated volume
- Concept requires rock contact / support – **<u>are the risks acceptable ?</u>**

LBNO Design:
Cylindrical, free-standing cryostat



3D Tank & Detector Model Screen Shot (courtesy ETH Zürich)

- Follows <u>proven</u> industry standard design and construction methods
- Requires larger span cavern – is a **<u>large enough cavern feasible/affordable at SURF ?</u>**

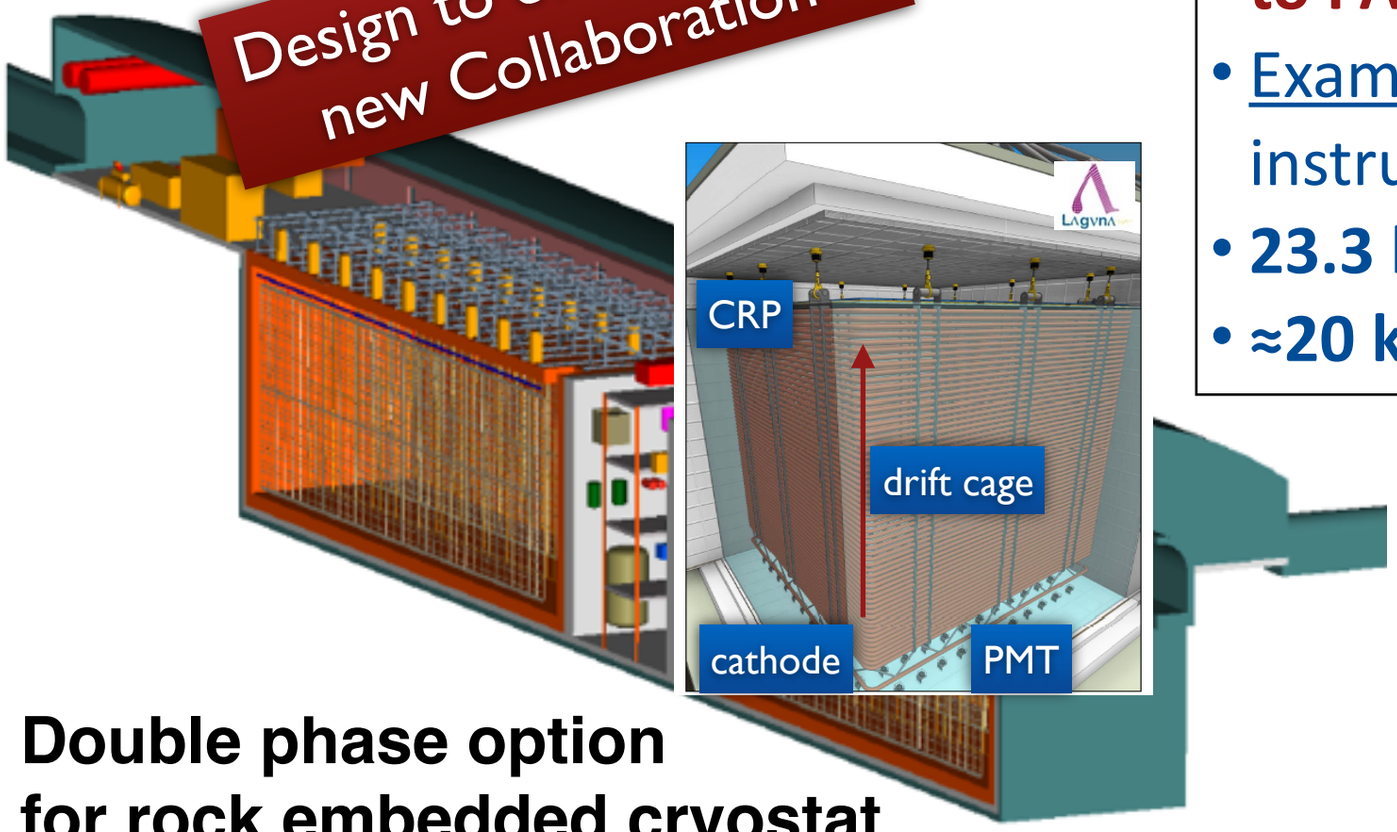
Cryostat Design & Configuration

- Reference design of rock-supported cryostat is at preliminary design level
  - Not advanced by LBNE further at this point due to need to engage cryostat vendor for design, and fiscal responsibility for the vendor not yet settled
  - Risk review of rock-supported design approach will be reviewed in meeting at BNL 2-4 February with former LBNO & LBNE engineers, as well as CERN engineers.
  - Also under consideration is steel as an alternate structural support material.
- Goal is to make a “generic” cryostat design suitable for either one or two-phase detector.
- Need collaboration confirmation of staged detector strategy and input into proportions and detector module sizes.

Double phase LAr 20 kton unit

WA105

Design to evolve within new Collaboration

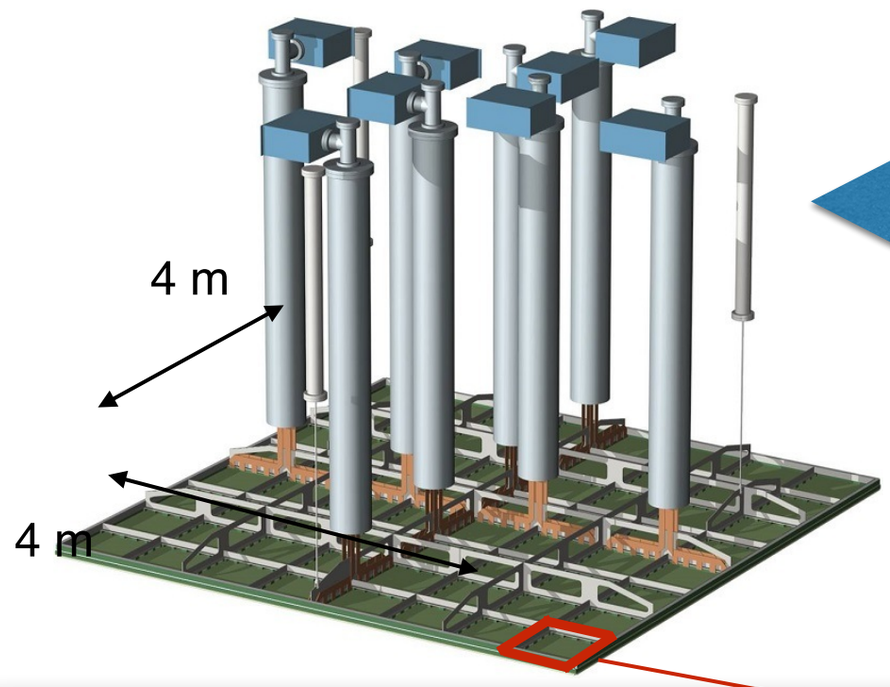


- **Described in Section 3.2.1 of LOI submitted to PAC (December 2014)**
- Example: 20m(w)x16m(drift)x52m(l) instrumented argon volume
- **23.3 kt active mass, fully homogenous**
- **≈20 kton fiducial for LBL beam events**

Double phase option for rock embedded cryostat

- Parallel production of **65 independent 4x4 m2** readout units, to be assembled and tested offsite before installation at SURF
- **Drift length 16m** (Cathode 800 kV @ 500 V/cm drift field or 600kV for 400V/cm)
- **332'800 readout channels** (each 4x4m2 has two views with 2560 channels/view)

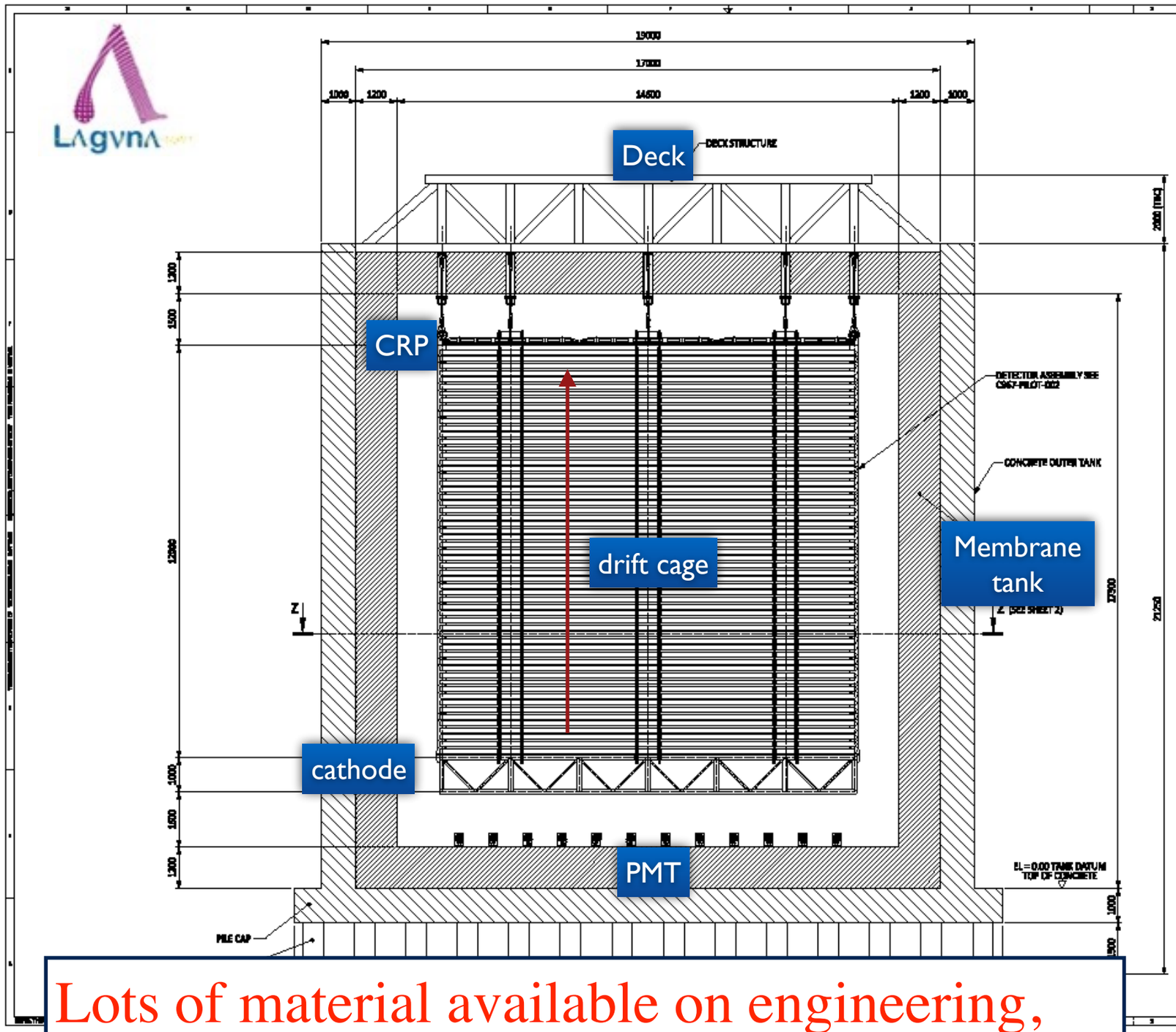
Independent 4x4m2 CRP module

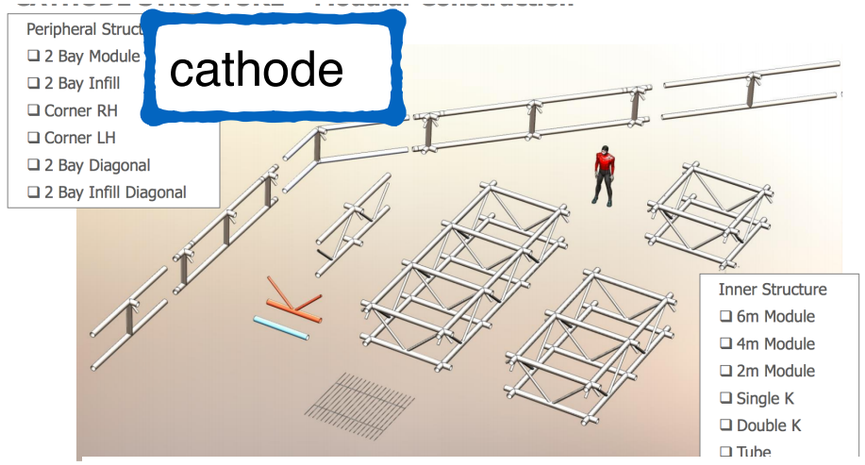


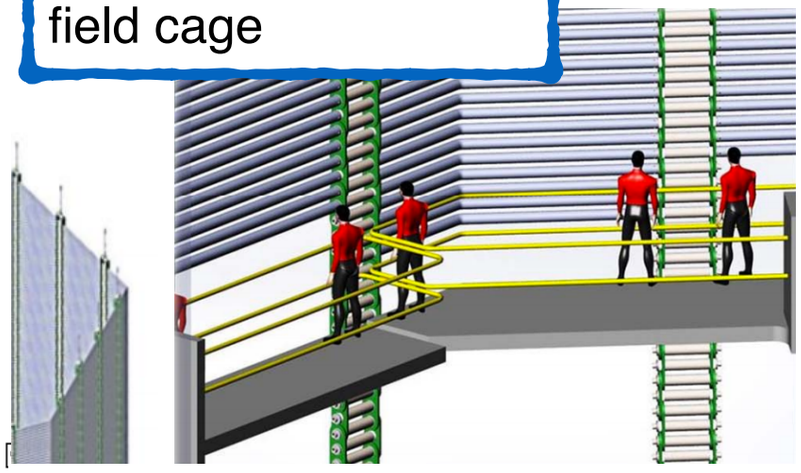
Consistent with "distributed" construction model (Lissauer)

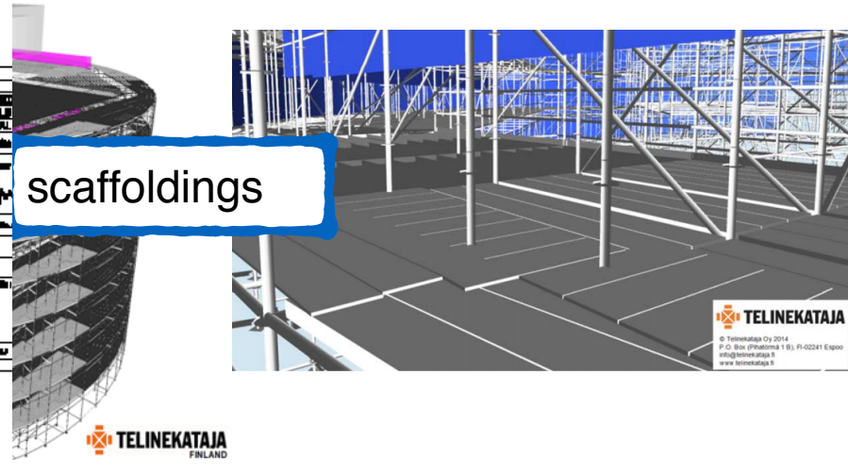
Double phase in non-cylindrical tank

Concept for parallepipedic geometry already studied in LAGUNA-LBNO







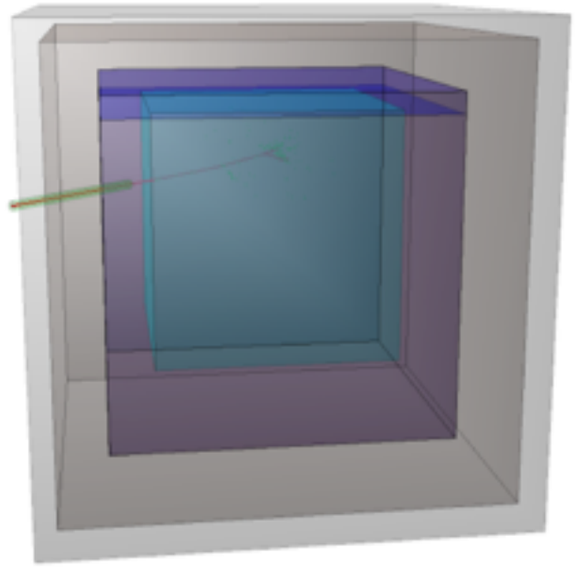


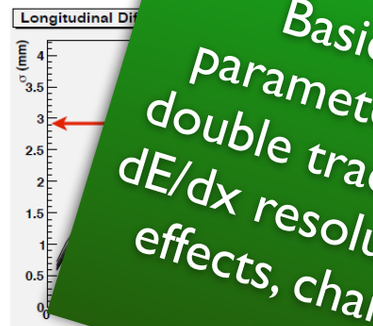
Lots of material available on engineering, installation plan, safety aspects, …

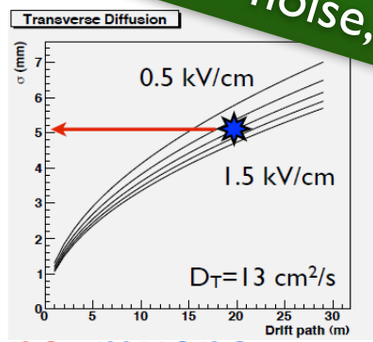
WA105 on-going activities

WA105 measurement goals

- LAr TPC provide a fully active homogeneous medium
- High granularity 3x3 mm^2 ← two orders of magnitude better than most granular calorimeters
  - e.g., CALICE AHCAL prototype has 3x3 cm^2
- Additional handle from dE/dx







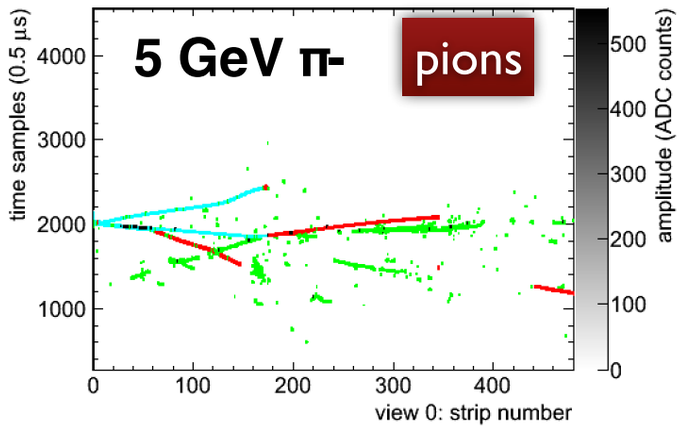
Basic detector parameters: diffusion, double track resolution, angular dE/dx resolution, charge effects, noise, …

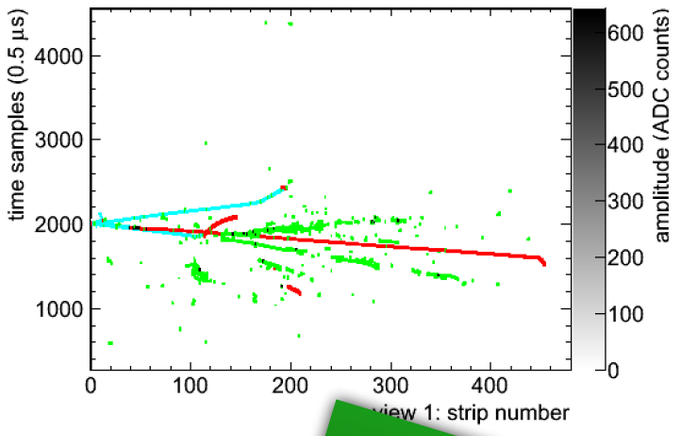
Opportunity to provide unprecedented measurements of hadronic shower development to HEP community

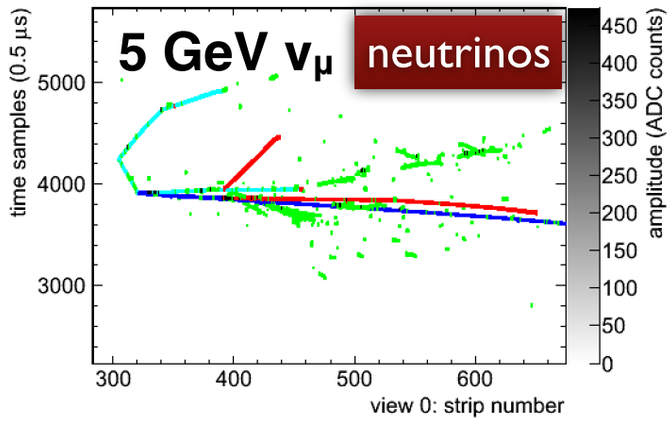
pions, electrons/positrons, protons, muons

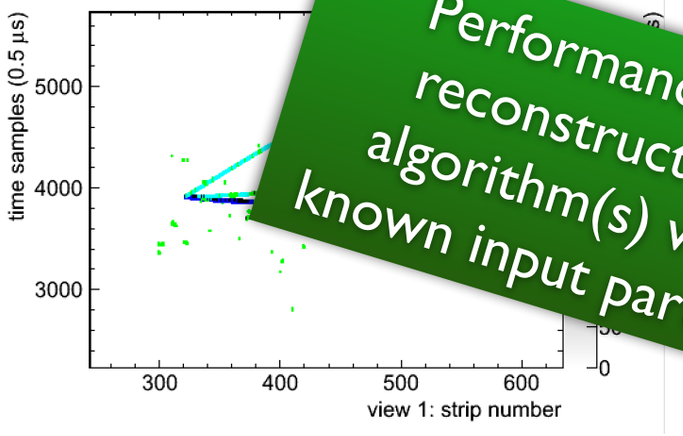
Some goals

- Development of automatic event **reconstruction**
- **test NC background rejection** algorithms on "ν_e free" events
- Charged **pions** and proton **cross-section** on Argon nuclei. Rate of pion production is important!
- What is the achievable **energy resolution?**
- **Development** and proof-check of industrial solutions







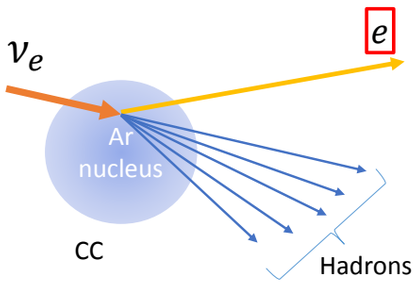


Performance of reconstruction algorithm(s) with known input particles

Developing analyses

- WA105 provides key information on the key assumptions for physics sensitivity

Electron selection efficiency



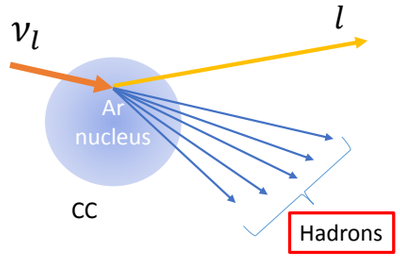
Excellent electron selection efficiency is required in future LBN program

Deliverables:

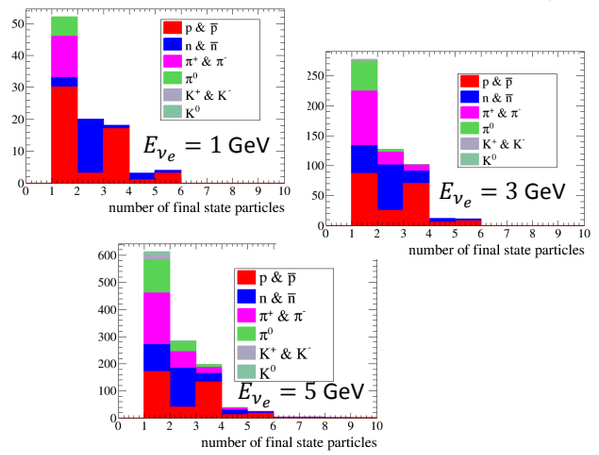
- Efficiency for electron identification as a function of E_{lep}
- Probability for separation from π^0, low energy μ
- Need analyses more complex than simply looking at beam electrons
- Associated systematic uncertainties

Big task!
Electron selection efficiency has to be understood at a level of 1% (or better)
→ Directly translates into the signal normalization uncertainty in LBN experiments

Hadron showers



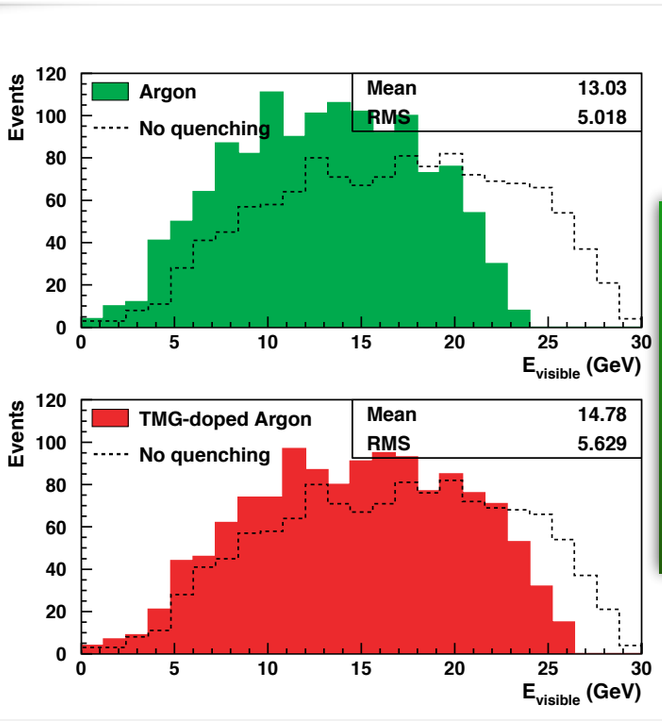
GENIE predicted hadron multiplicities in final state of ν_eCC + Ar



- Reconstruction efficiencies for $\pi^{\pm}$, π^0, $K^{\pm}$, p
- Measurement of energy and momentum resolution

Calibrate energy scale and estimate ν energy resolution from calorimetric measurement

1/20/2015



Calorimetry:

- No quenching
- Quenching
- TMG doping

Some key assumptions for LBNE sensitivity studies with GLoBES (General Long Baseline Experiment Simulator)

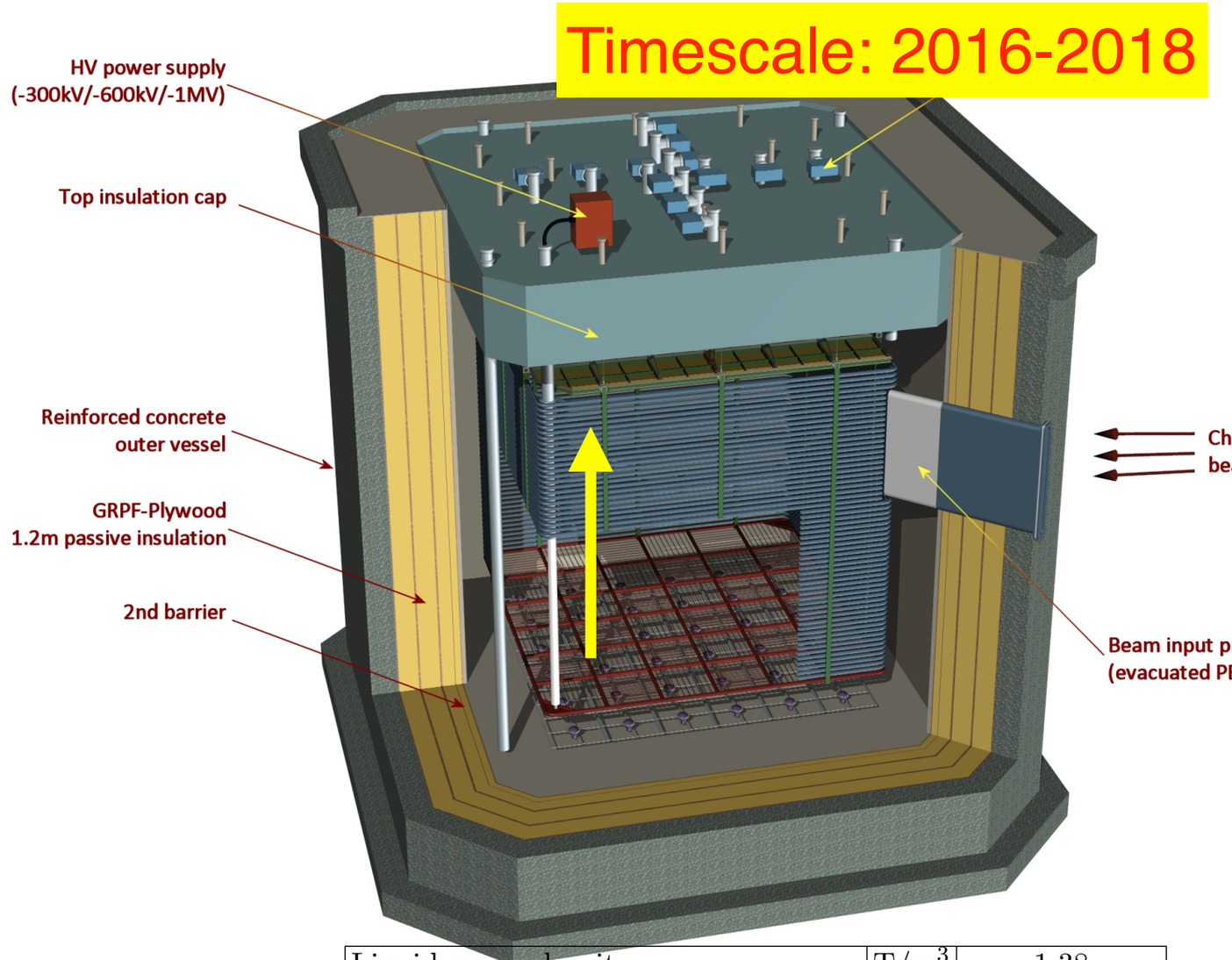
Parameter	Ran…	…lues	Value Used for LBNE Sensitivities
	For ν_e C…		
ν_e CC efficiency			80%
ν_μ NC mis-identification rate			
ν_μ CC mis-identification rate			
Other background			
	For …		
ν_μ CC efficiency			
ν_μ NC mis-identification rate			
Other background			
ν_e CC energy resolution			
ν_μ CC energy resolution			
E_{ν_e} scale uncertainty		under s…	
E_{ν_μ} scale uncertainty		1-5%	

Detector performance and systematics for LBN + non-beam physics analyses to be formulated in synergy with new Collaboration.

WA105 6x6x6m3 DLAr

- Membrane GTT® tank with passive insulation w/ top deck with chimneys and insulation
- **6x6m² anode large readout area**, **6m long drift length** (300 kV HV for 500 V/cm – R&D towards 600 kV)
- Charged particle beam window
- **300 ton LAr active**, fully homogenous
- **7680 charge readout channels, 36 PMTs** (baseline layout)
- **Accessible cold F/E electronics**

Timescale: 2016-2018

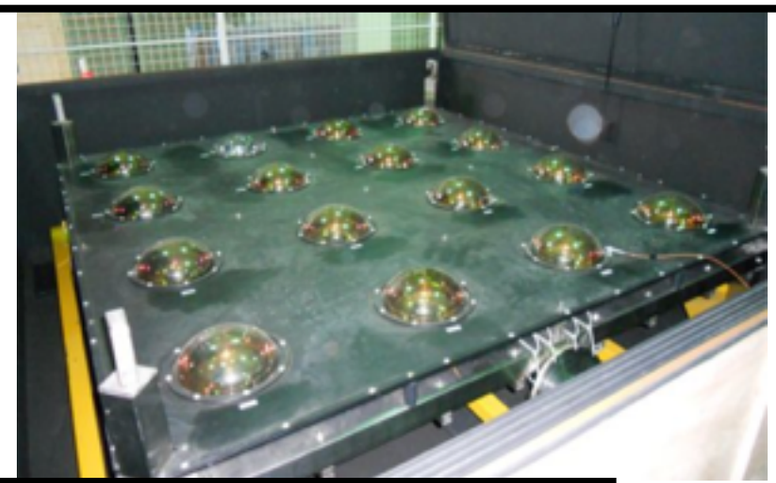


Liquid argon density	T/m^3	1.38
Liquid argon volume height	m	7.6
Active liquid argon height	m	5.99
Hydrostatic pressure at the bottom	bar	1.03
Inner vessel size (WxLxH)	m^3	8.3 × 8.3 × 8.1
Inner vessel base surface	m^2	67.6
Total liquid argon volume	m^3	509.6
Total liquid argon mass	t	705
Active LAr area	m^2	36
Charge readout module (0.5 x0.5 m^2)		36
N of signal feedthrough		12
N of readout channels		7680
N of PMT		36

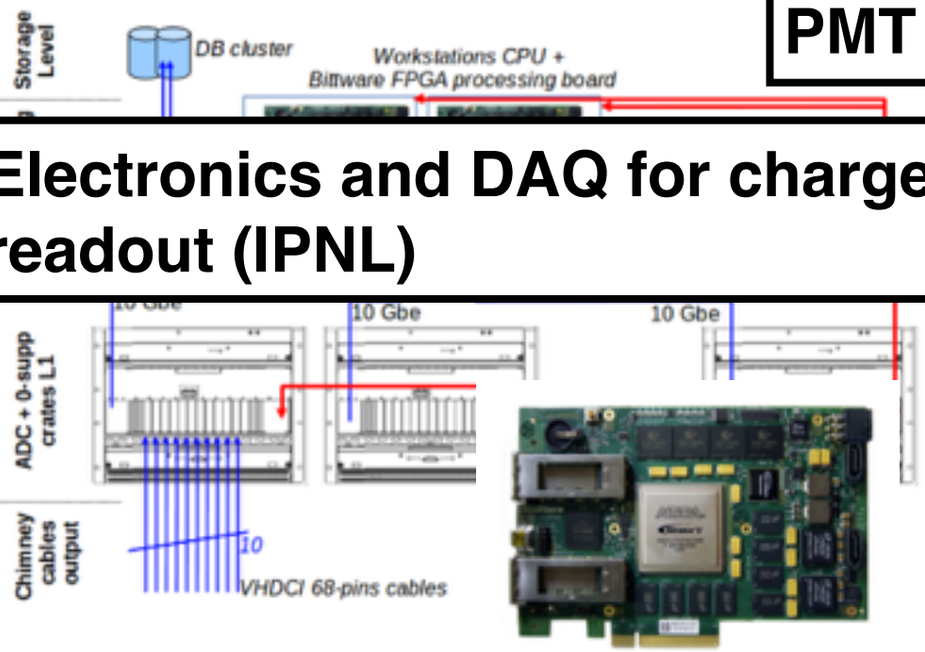
6x6x6m3 DLAr design work in progress

WA105

PMT light readout (APC, Barcelona, CIEMAT, KEK,LAPP)



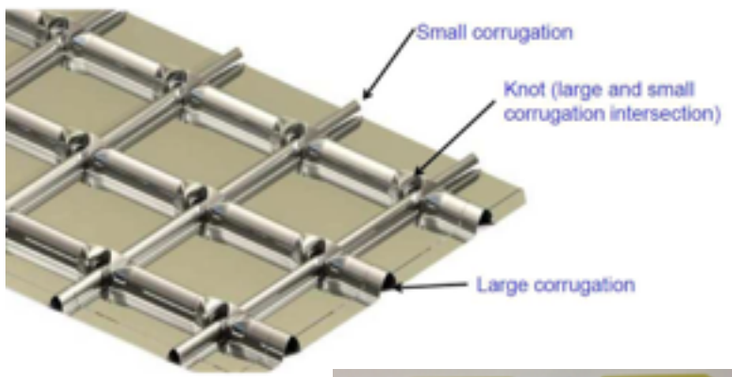
Electronics and DAQ for charge readout (IPNL)



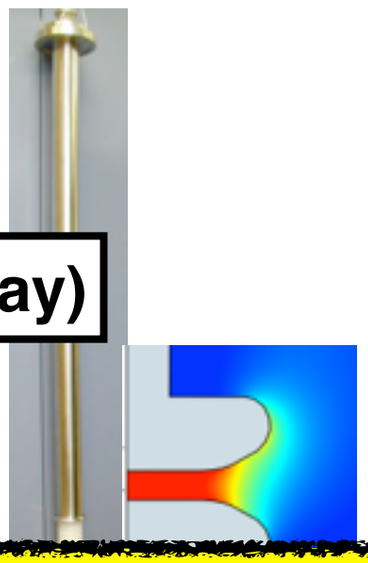
SiPM light readout (INR+Genève)

membrane tank (ETHZ, CERN)

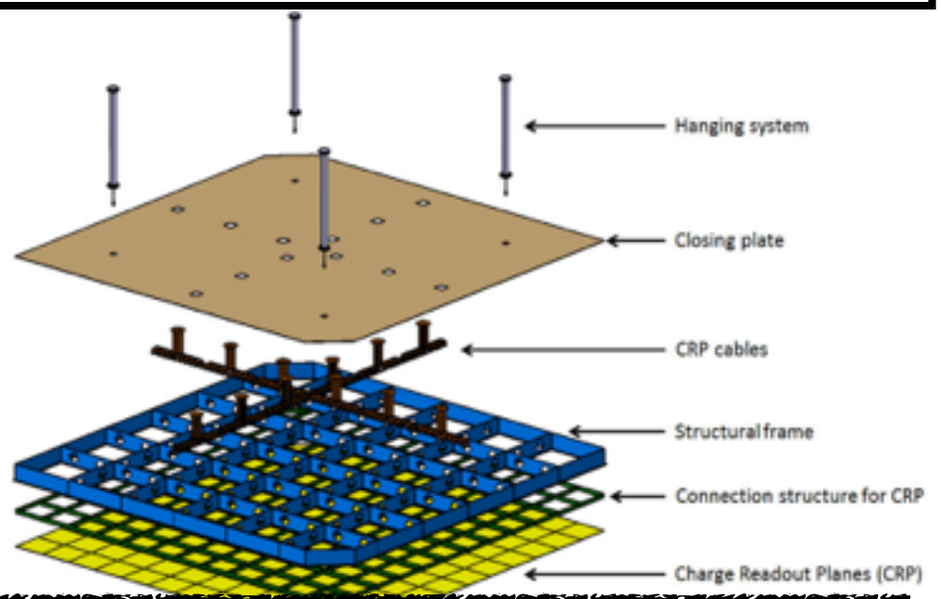
Field cage (CEA, Romania)



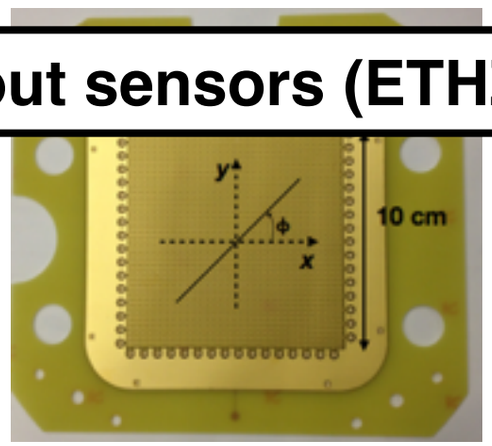
HV (LPNHE, ETHZ)



Anode deck suspension (LAPP)



charge readout sensors (ETHZ, Saclay)



all groups involved in software and data analysis

3x1x1m3 prototype

WA105

20 ton prototype to be exposed to cosmic rays

chimneys and feedthroughs

20 thick top-cap.

Steel outer-structure

4.7m

3m³ DLAr TPC

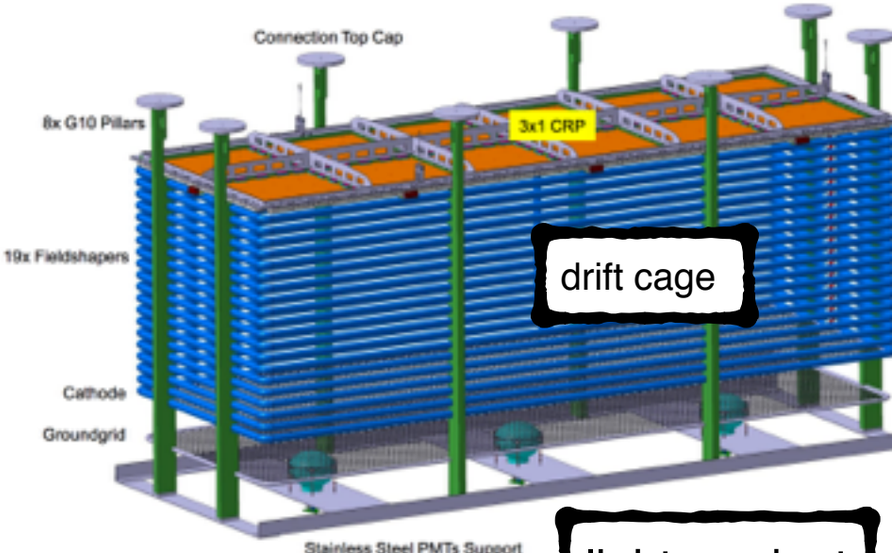
1 m thick insulation
(plywood + polyurethane)

corrugated membrane tank

7.3m

4.9m

CRP & hanging system



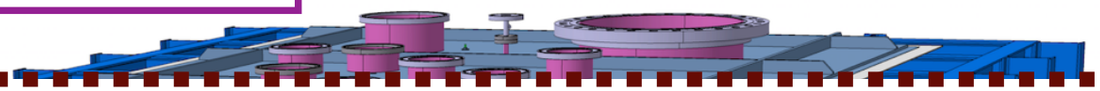
3x1x1m3 DLAr TPC
(5 ton active)
1280 r/o channels

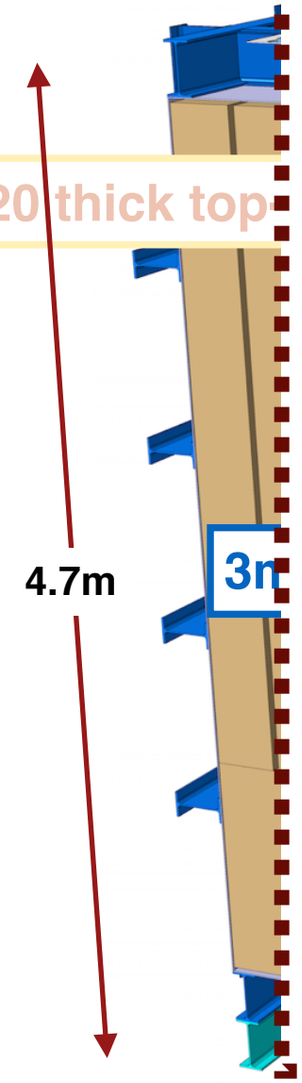
3x1x1m3 prototype

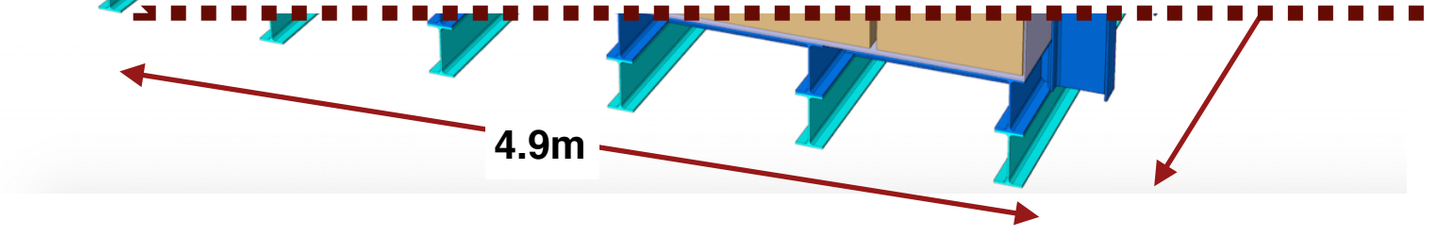
WA105

20 ton prototype to be exposed to cosmic rays

chimneys and feedthroughs



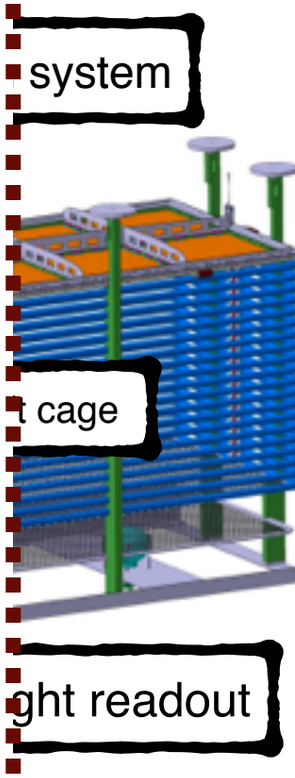




✳Serves as tool to prepare and **speed up the technical implementation work** needed for the 6x6x6 m3. For example:

- Routine procedure for mass production, QA tests and calibration of the LEMs.
- Similar considerations for cryogenic installation, feedthroughs, thermodynamic conditions of the membrane tank, …

✳ Has been very useful to anticipate all the legal and technical aspects related to the contracts for the realisation of a membrane cryostat at CERN under the GTT license. **Paving the way for a much easier and smoother tendering procedure for the future membrane vessels**



r TPC
(5 ton active)
1280 r/o channels

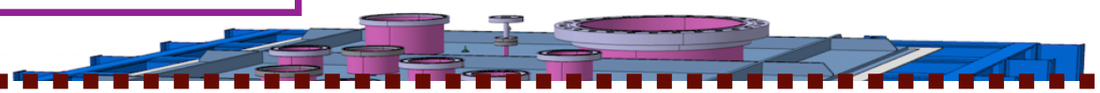
3x1x1m3 prototype

WA105

20 ton prototype to be exposed to cosmic rays

Timescale for construction: 2015

chimneys and feedthroughs



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- Routine procedure for mass production, QA tests and calibration of the LEMs.
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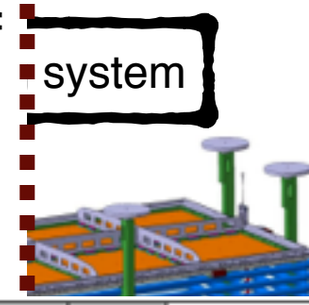


4.

Level	Activity	Responsible institute/person	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	July 15	Aug 15	Sep 15	Oct 15	Nov 15	Dec 15	Status
1	FINAL ASSEMBLY	CERN / ETH													
1.01	MILESTONE: ready for commissioning														
1.02	Outside connections (liquid pipes, electronic cables etc.) to tank / cap	CERN technicians / ETH											X X		
1.03	MILESTONE: welding of top cap														
1.04	Installing top-cap+CRP+drift-cage in tank	CERN technicians / ETH / Gabadi											X X		
1.05	Installing drift-cage below top-cap	CERN technicians / ETH											X		
1.06	Installing CRP under top-cap	CERN technicians / ETH										X X X X			
1.07	Inserting chimneys into top-cap	CERN technicians / ETH									X X				
1.08	Site preparations for final assembly (all components and cranes in place)	CERN technicians / ETH									X X				

BUFFER PERIOD (summer holiday)

1280 I/O channels

GTT membrane vessel

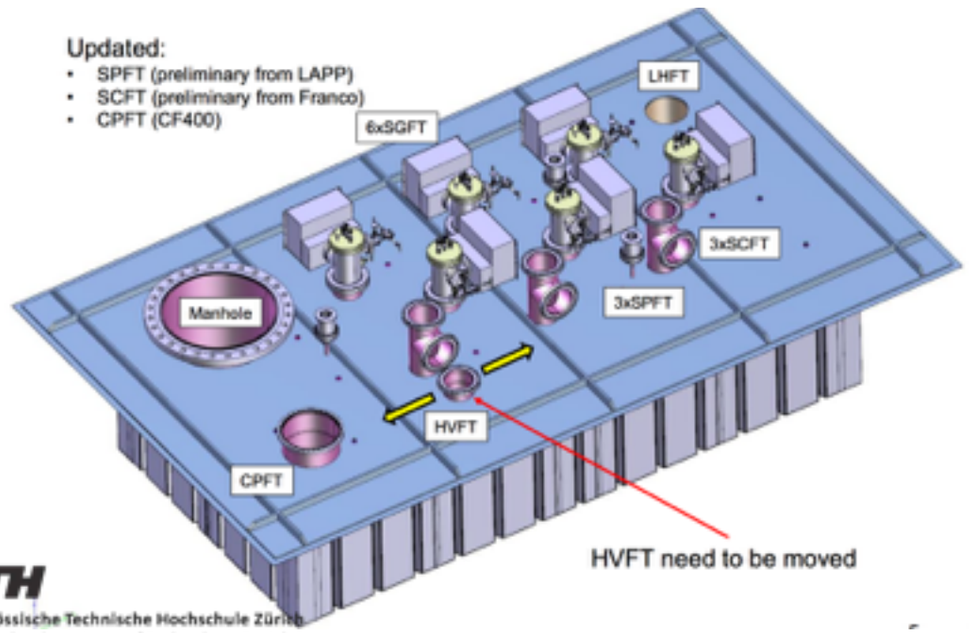
WA105

- CERN-ETHZ project Agreement with GTT → Paving the way to future membrane tanks (GTT press release)

GTT Expert in LNG

- Assembly by “outfitter” company

Panoramic view from inside the outer structure



Nombre de tarea	Duración
TANK	39,3 días
Marking of the rods position bottom and walls	2 días
Confirmation of the alignment tank and cover	2 días
Anchoring of the bottom rods	3 días
Installation of the bottom panels (3 layers)	4,8 días
Anchoring of the bottom rods	2 días
Installation of the wall panels (3 layers)	7,5 días
Installation and securing of the angle corner pieces	3 días
Fitting of the membrane sheet	5 días
welding of the membrane sheet	4 días
installation and weldings of the angle pieces	4,5 días
installation and weldings of the end caps	4 días
tightness test of the weld (Helium)	2 días
Cleaning of the tank	1 día
Cover	42,3 días
Marking and sizing according to tank size	3 días
Installation of the membrane sheet on base plate	5 días
Welding of the membrane sheet	3 días
Installation of insulting elements on cover	4 días
Installation of pipes penetration	5 días
Installation of lower plate	4 días
welding of lower plate periphery and pipes penetration	5 días
tightness test of the weld (Helium)	2 días
Clean cover	1 día
Assembly	9 días
Asselby of the cover on tank	3 días
Welding of cover on tank top	4 días
tightness test of the weld (DPT)	2 días

GABADI S.L.

Procurement and assembly of vessel on track for Spring 2015

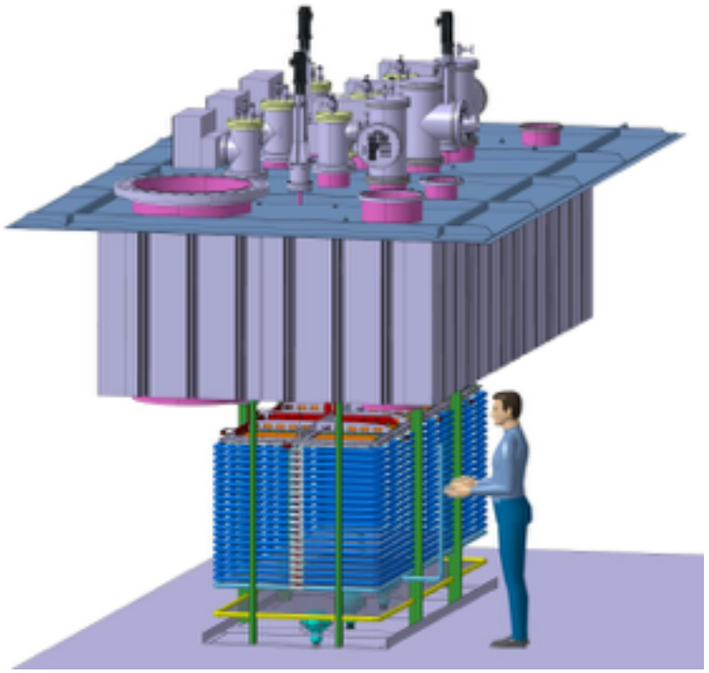
ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

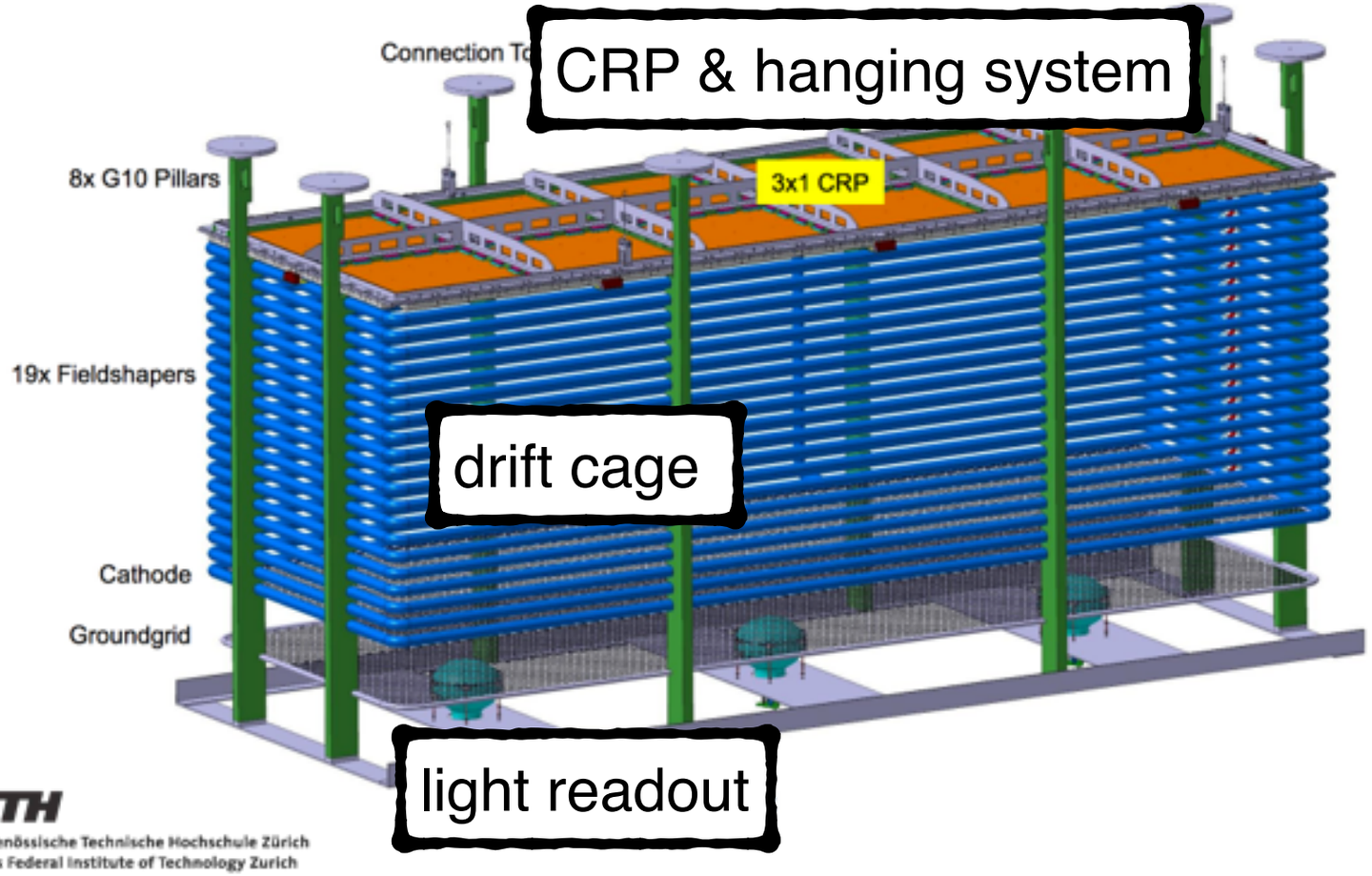
Detector hanging system

WA105

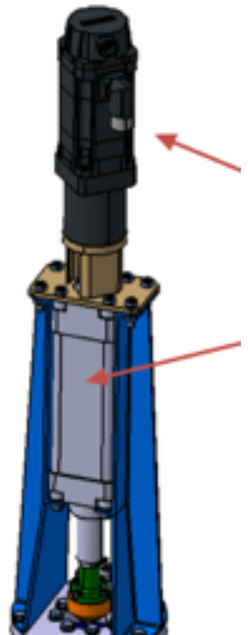
- All detector components hanging from roof
(no contact to floor of vessel)

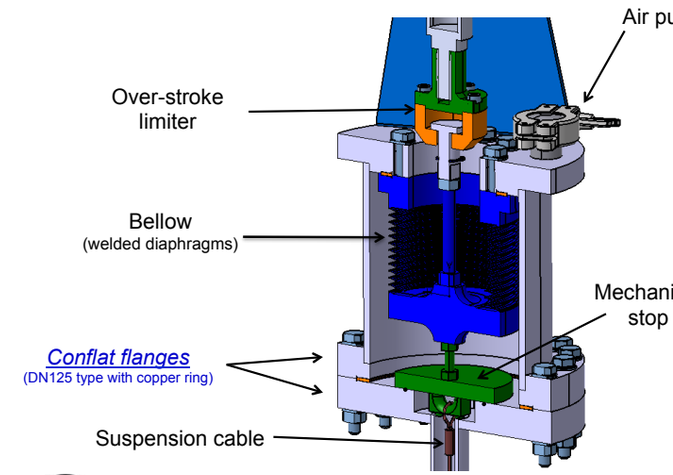
- Level precisely dynamically adjusted to liquid argon level



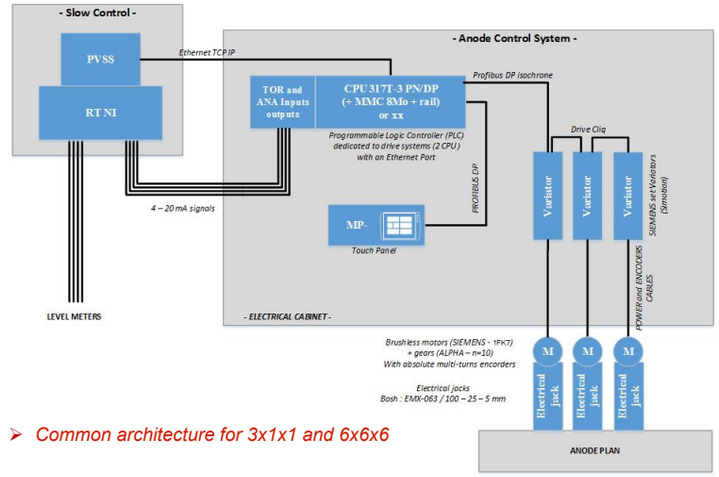


CRP suspension feedthrough





Drive automation



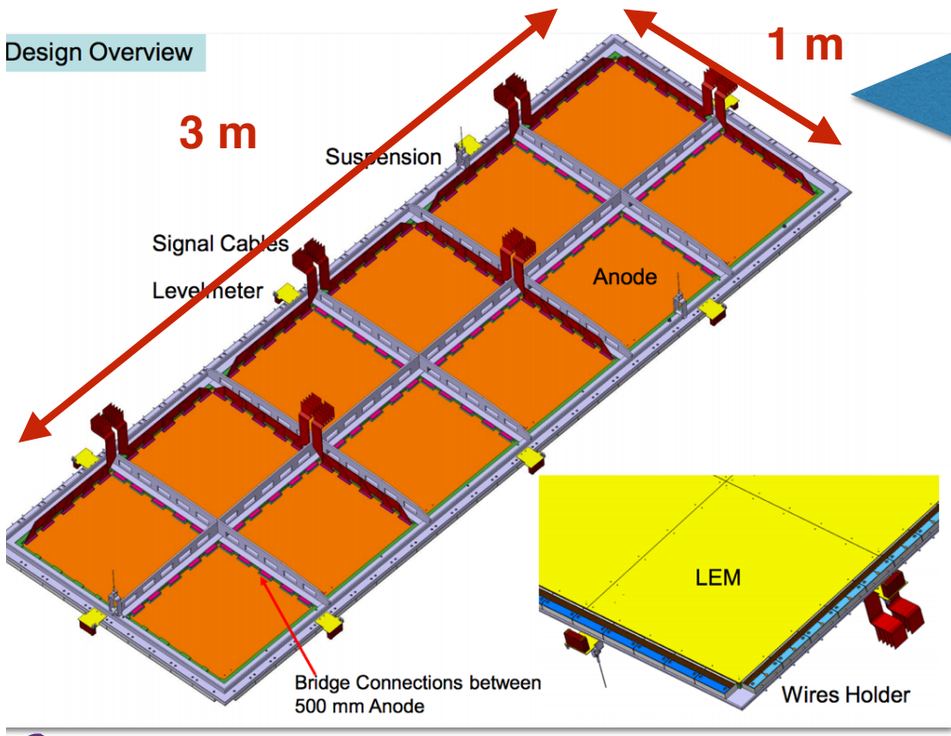
- *Common architecture for 3x1x1 and 6x6x6*

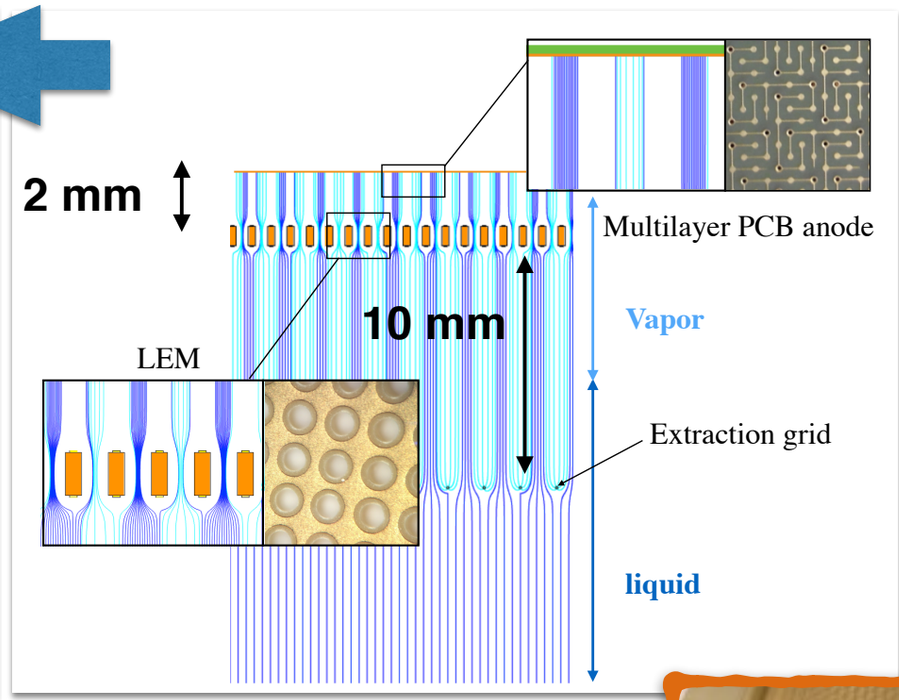
Charge Readout Plane (CRP)

WA105

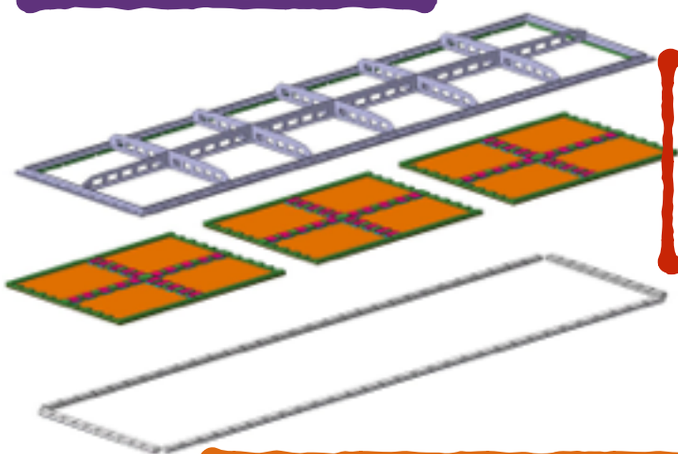
extraction grid-LEM and anode all in one single module

50x50 cm² LEM+anodes mounted in readout modules of 1m² on a 1x3 m² frame





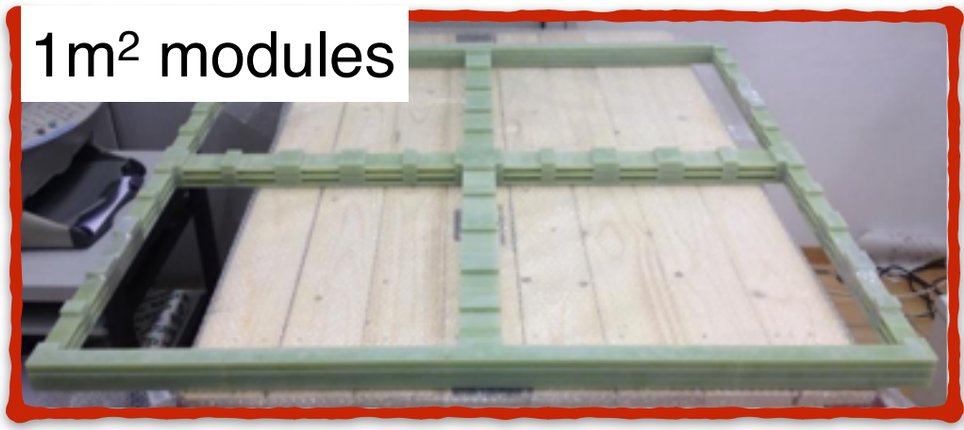
Aluminium frame

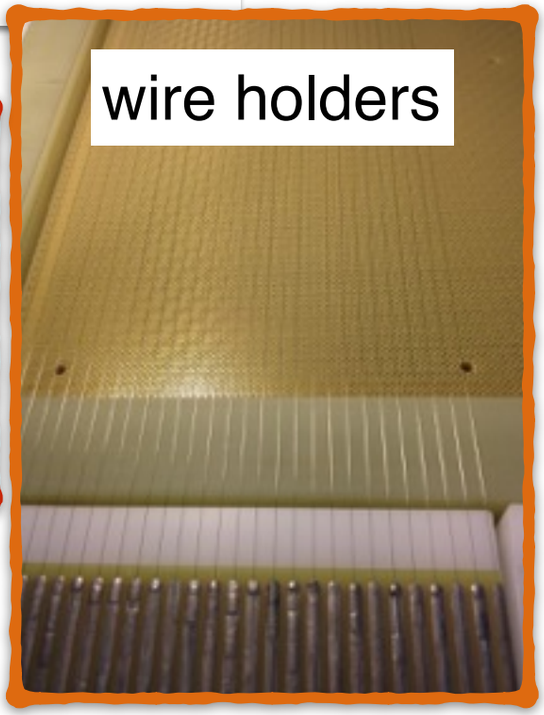


3 individual 1m² modules for anode+LEM

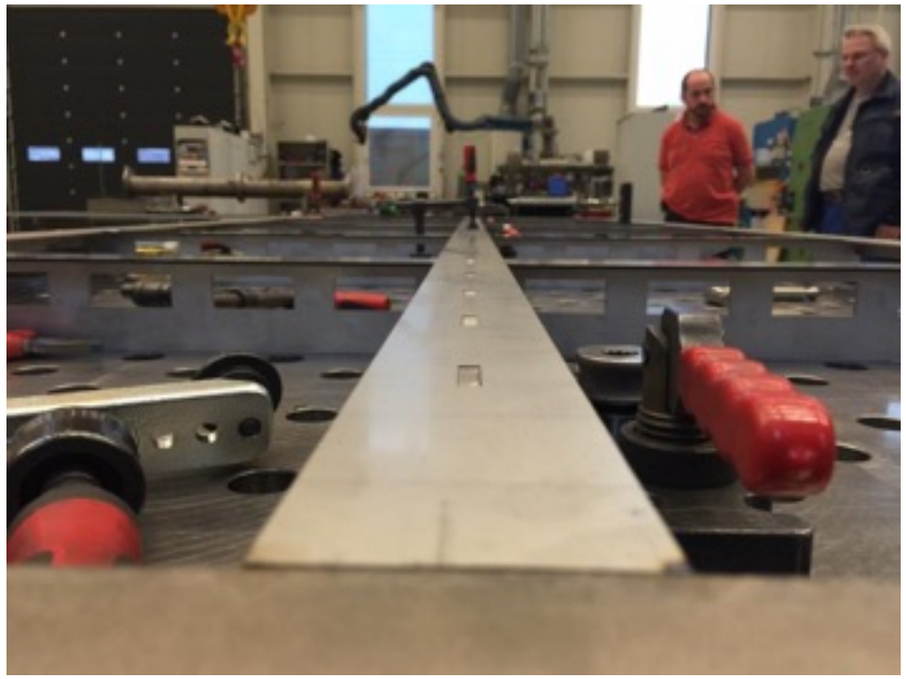
wire holders for extraction grid

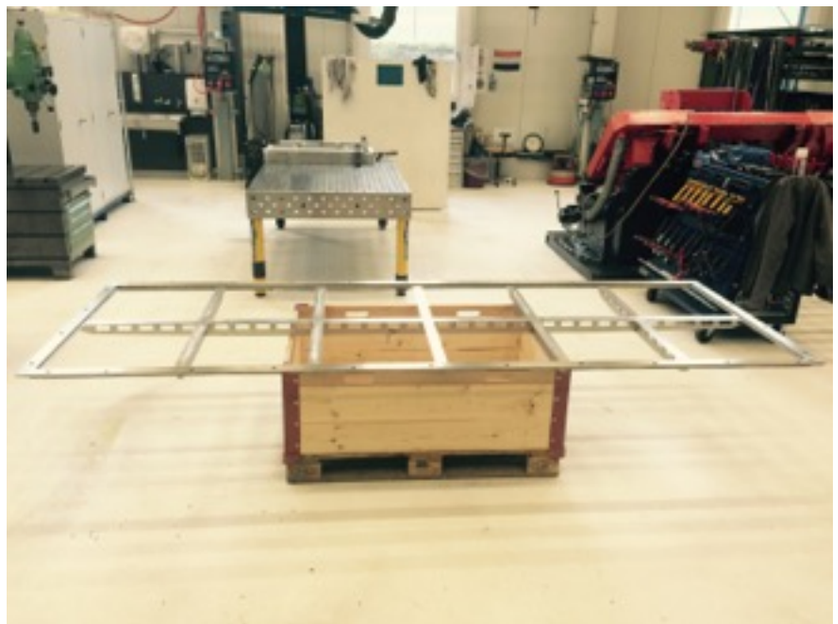
1m² modules

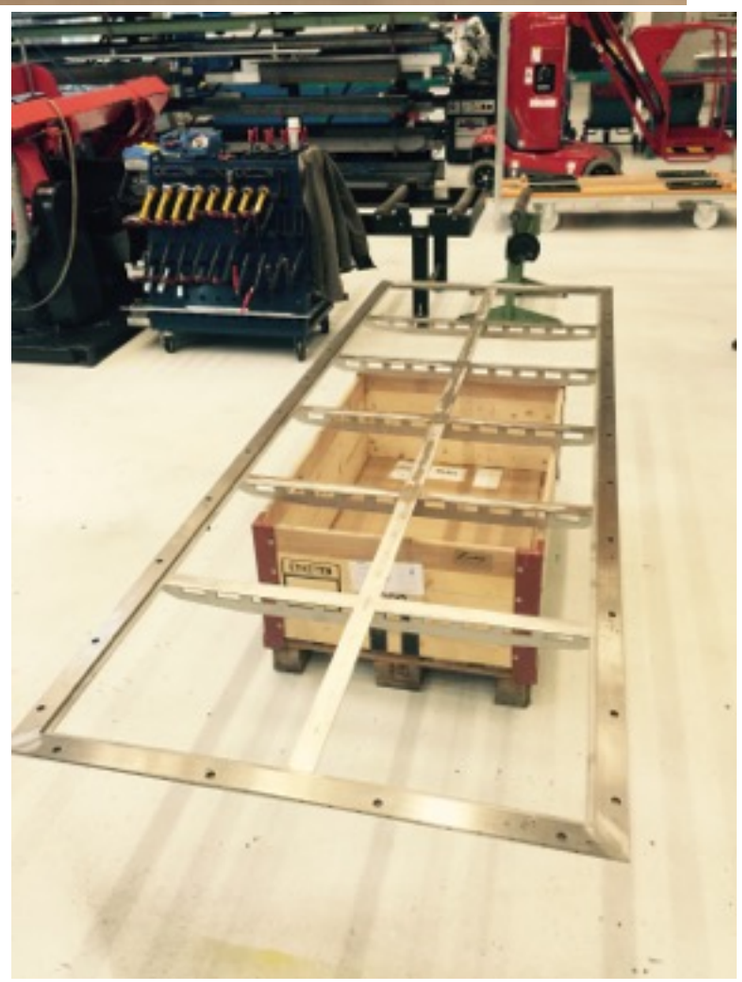




CRP mechanical structure

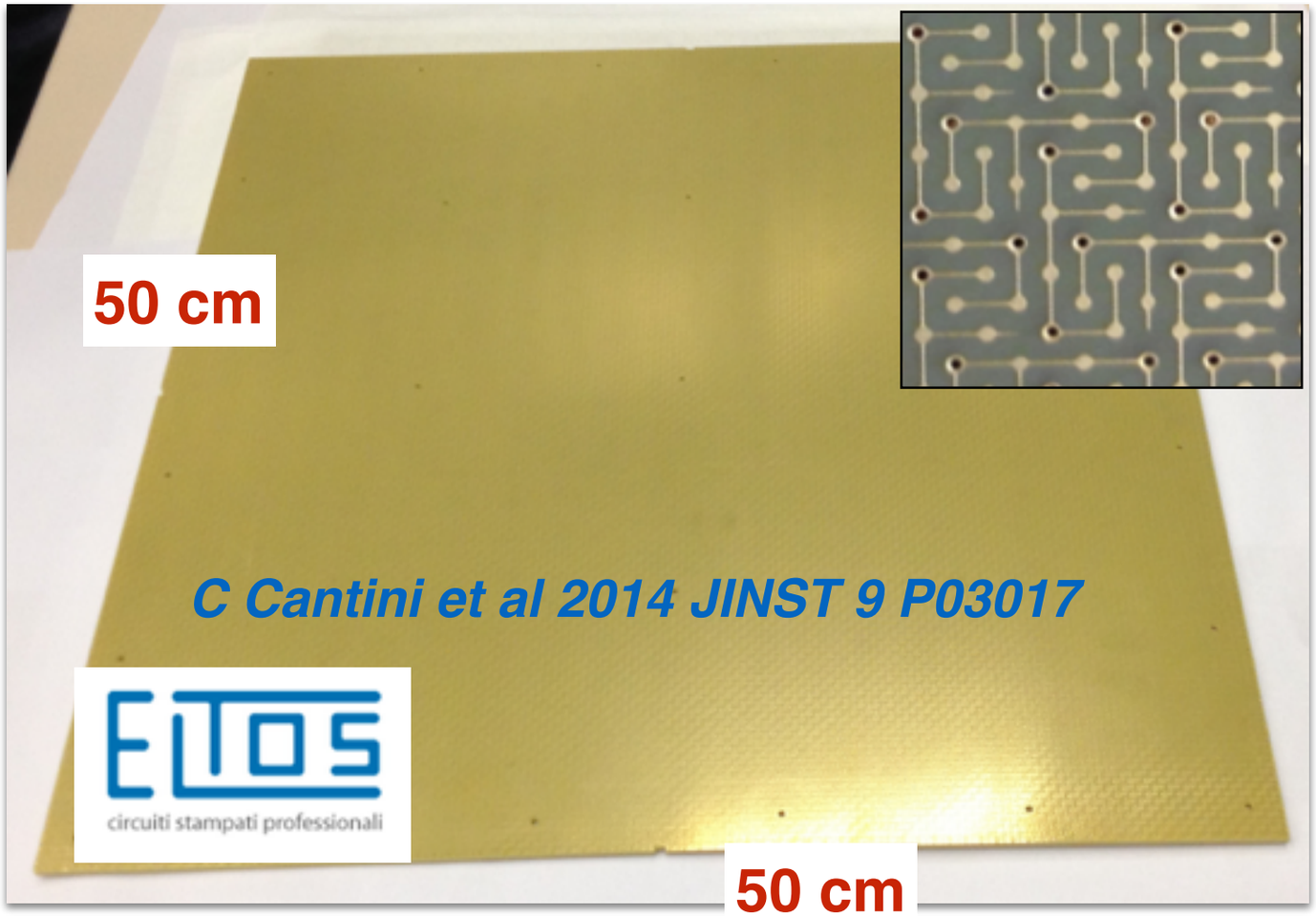


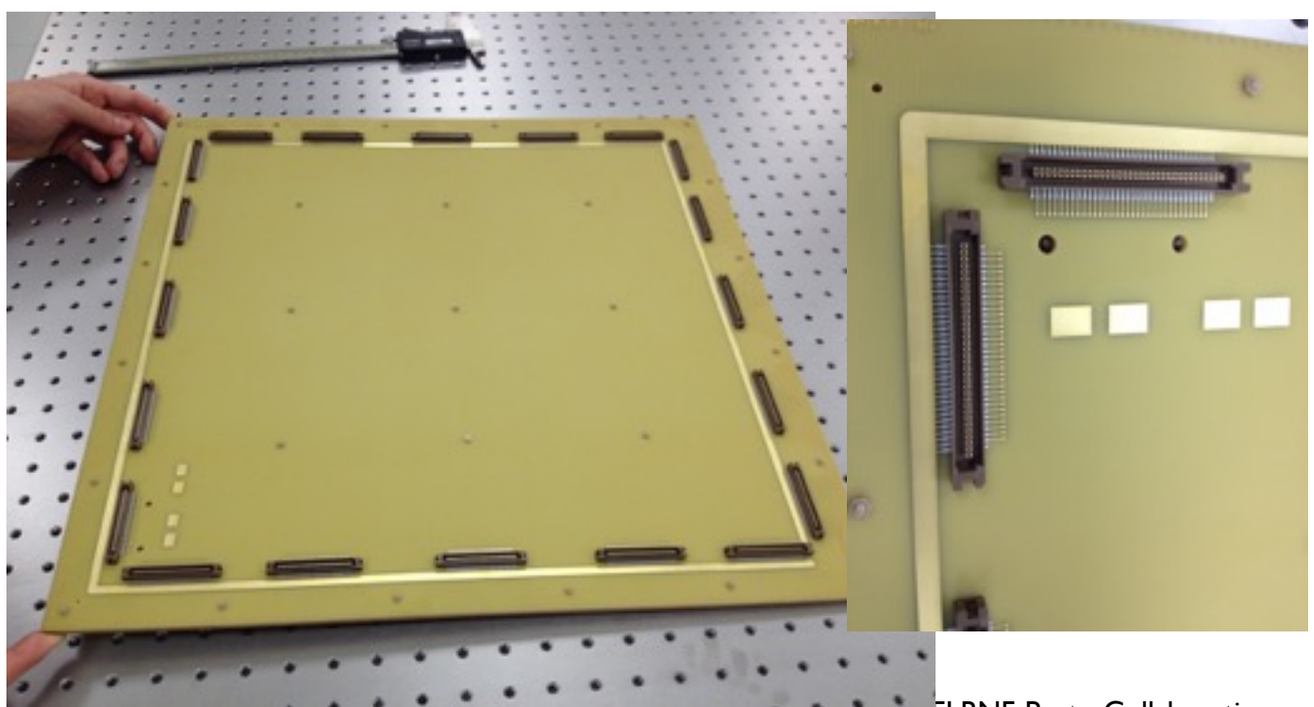




±1mm planarity over the 3m².

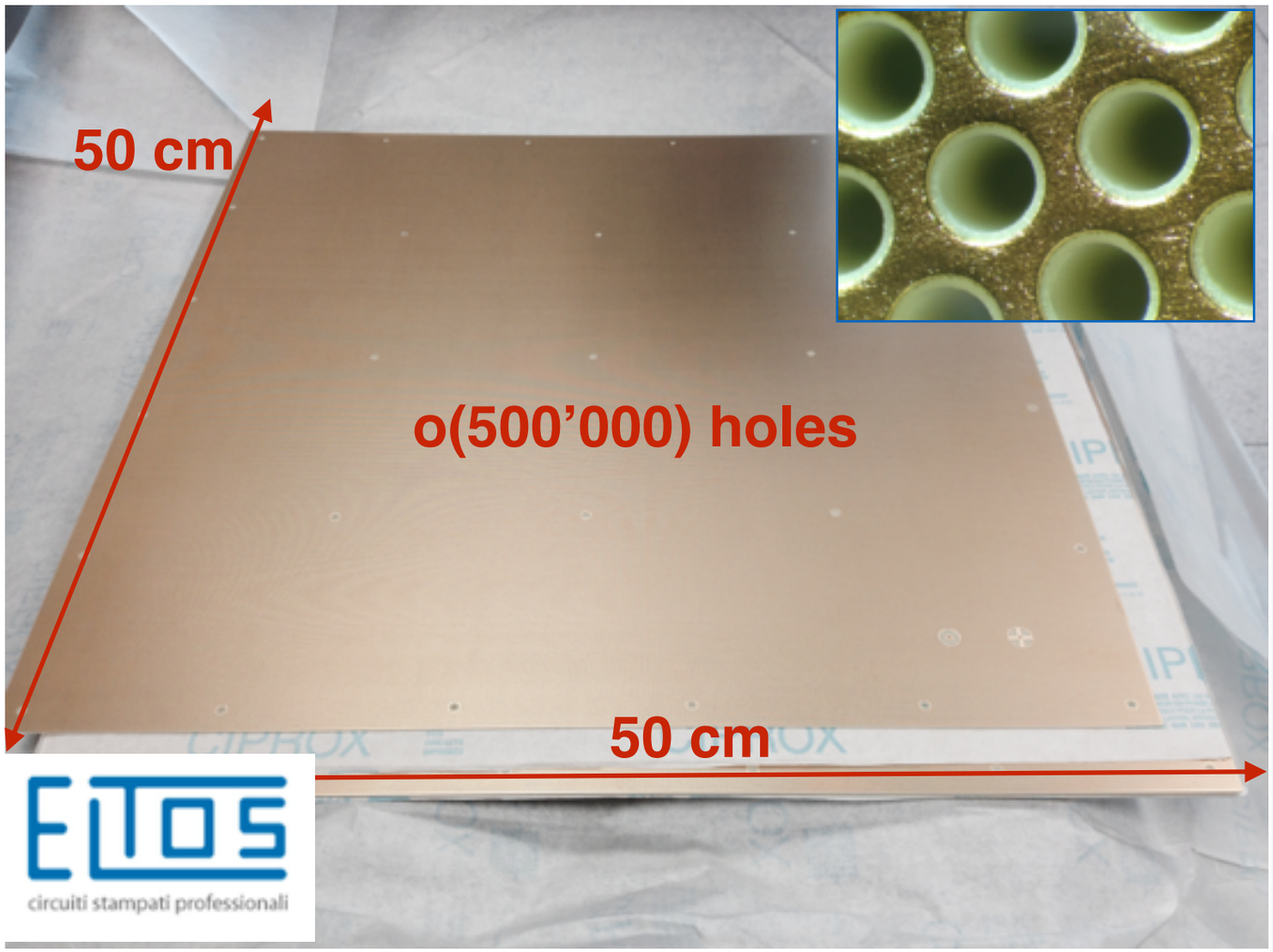
The anodes

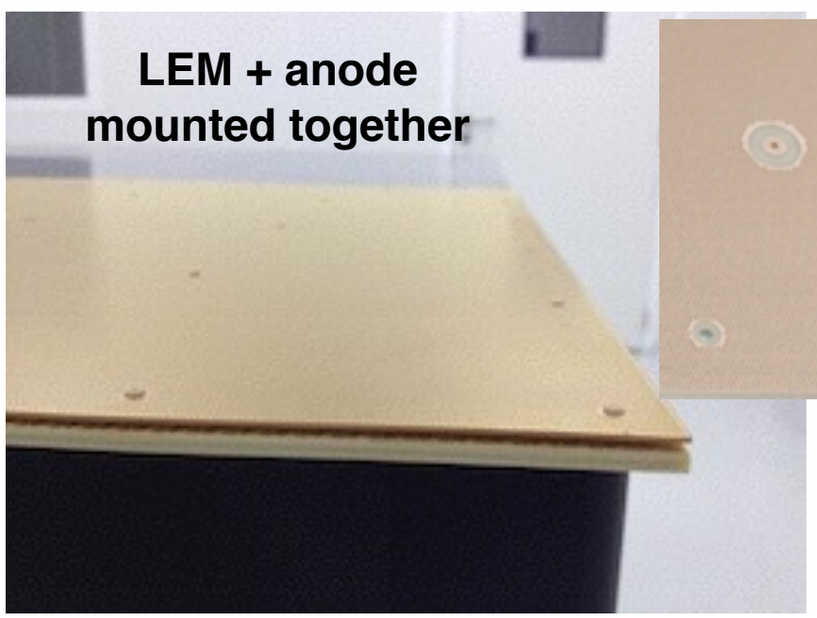


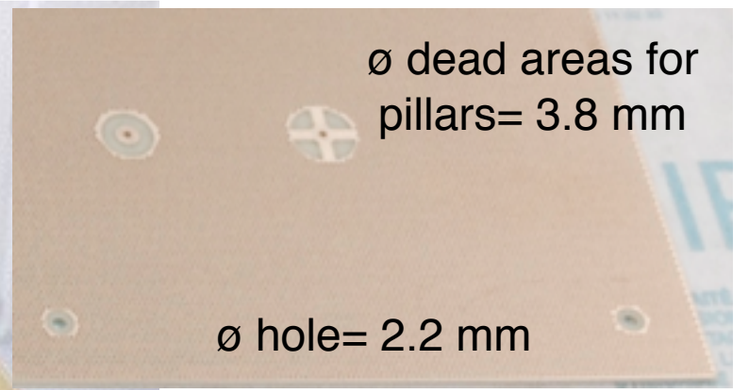


- ✓ “simple” multilayer PCB. 3.4 mm thick.
- ✓ 3 mm readout pitch
- ✓ Equal charge sharing on both collection views.
- ✓ low capacitance per unit length (~150 pF/m)
- ✓ design is a result of ~1 year R&D.
- ✓ relatively easy, cheap and fast to produce. All channels electrically tested by the company.
- ✓ soldering of the 20 KEL connectors at SMD CERN workshop. Takes about 2hrs for one board.

The LEMs





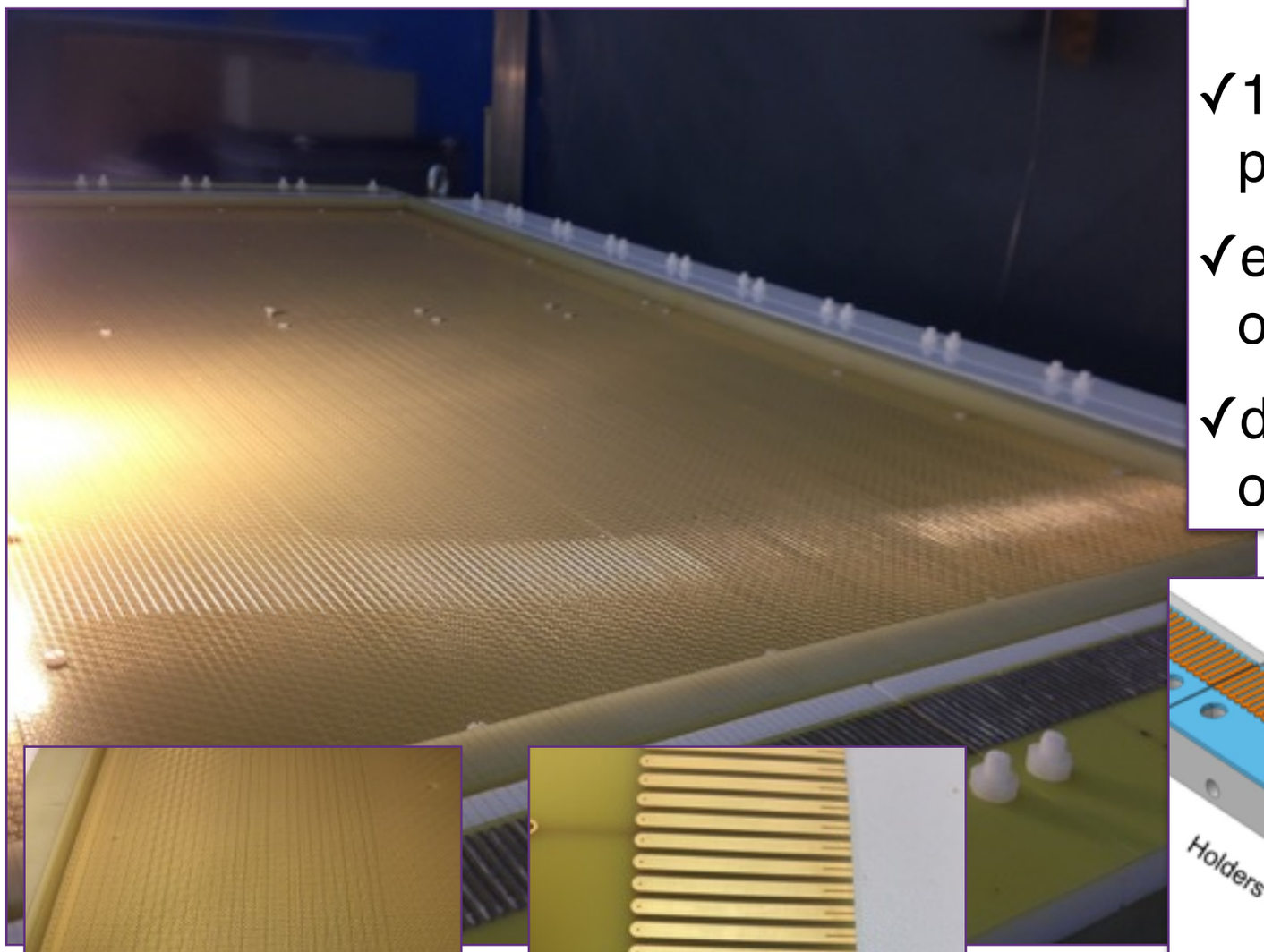


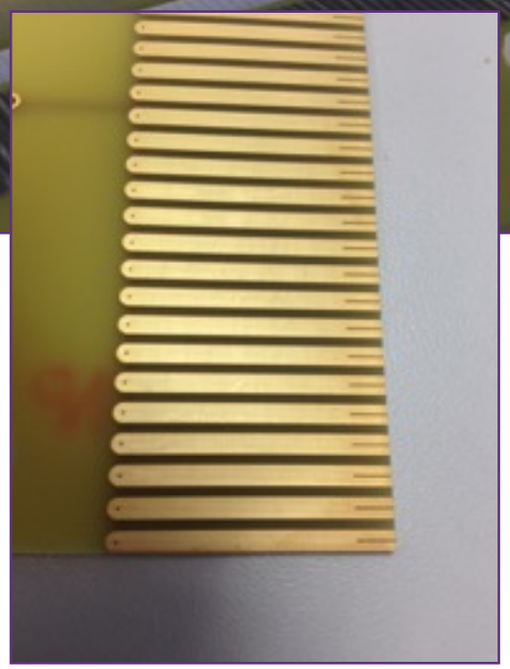
- ✓ PCB CNC drilled with o(150) holes per cm². 1 mm thick.
- ✓ 500 um hole diameter 800 um pitch.
- ✓ 40 um dielectric rim around the holes to avoid edge-induced discharges
- ✓ powered at around 30 kV/cm
- ✓ design is the result of many years of R&D on smaller scale prototypes.
- ✓ Latest paper on hole/rim size optimisation for stable gain in LAr:

  arxiv 1412.4402 Dec. 2014

The extraction grid

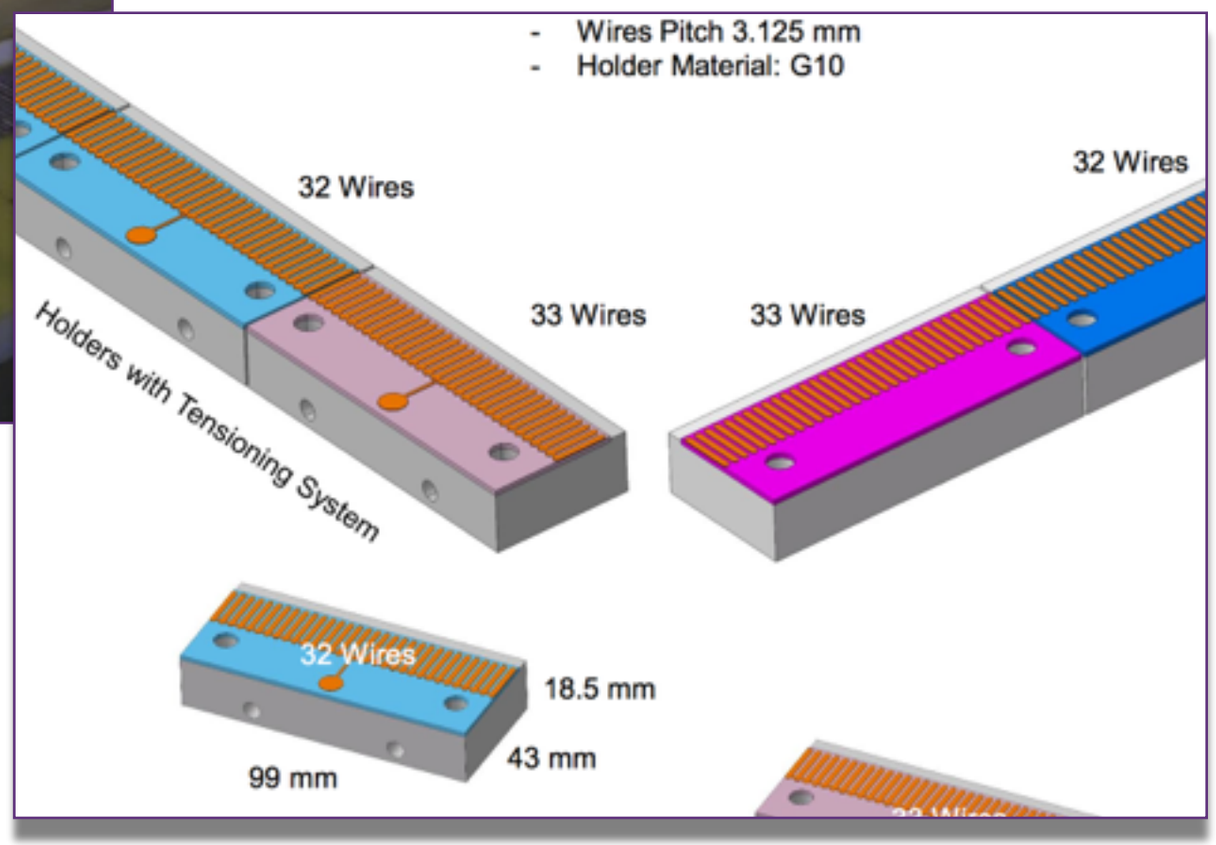
WA105





Extraction grid

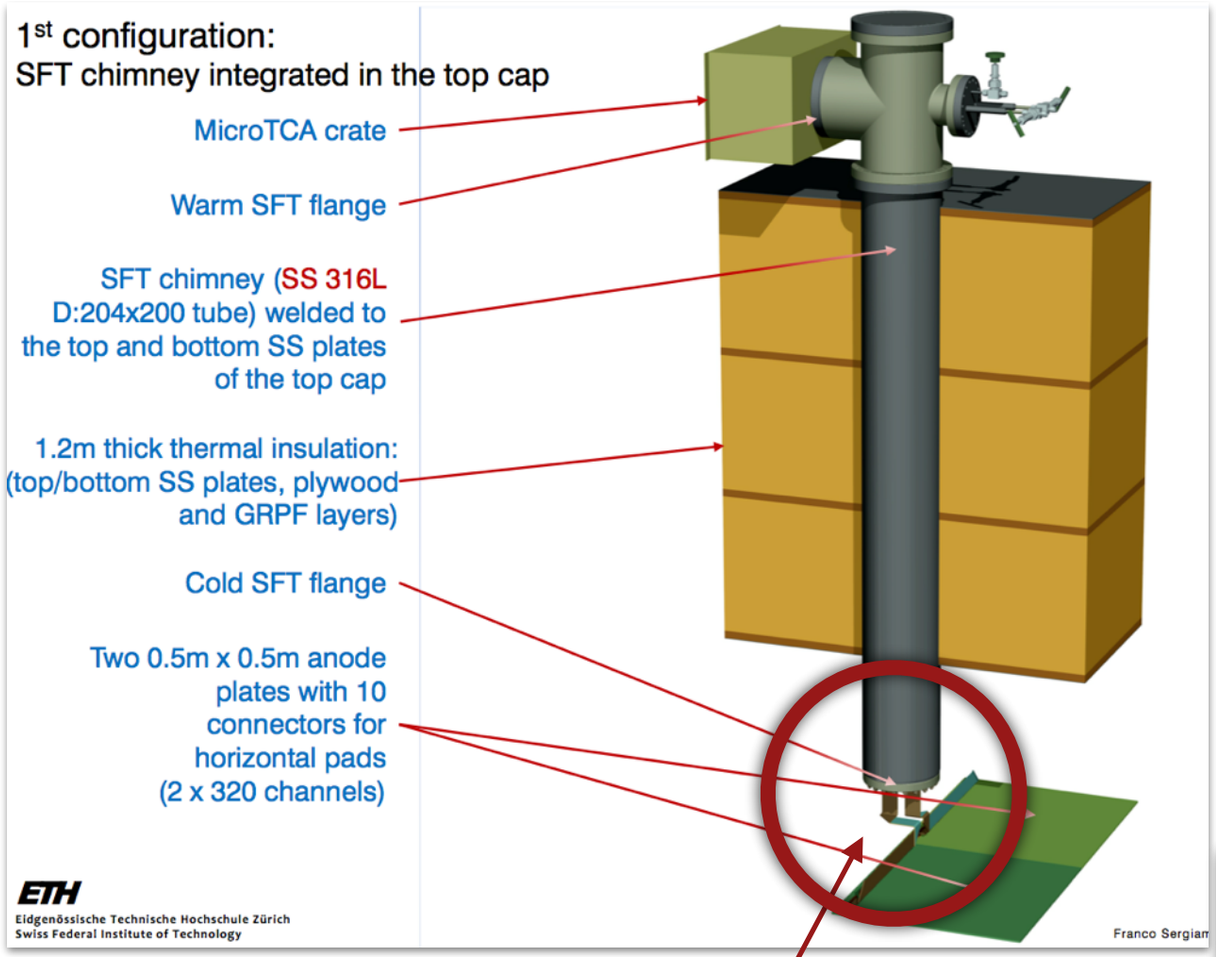
- ✓100 micron stainless wire with 3 mm pitch in x and y directions
- ✓effect on gain uniformity tested in LAr on 10x10 cm^2 readout
- ✓design has been extensively tested on a 1 m^2 prototype.

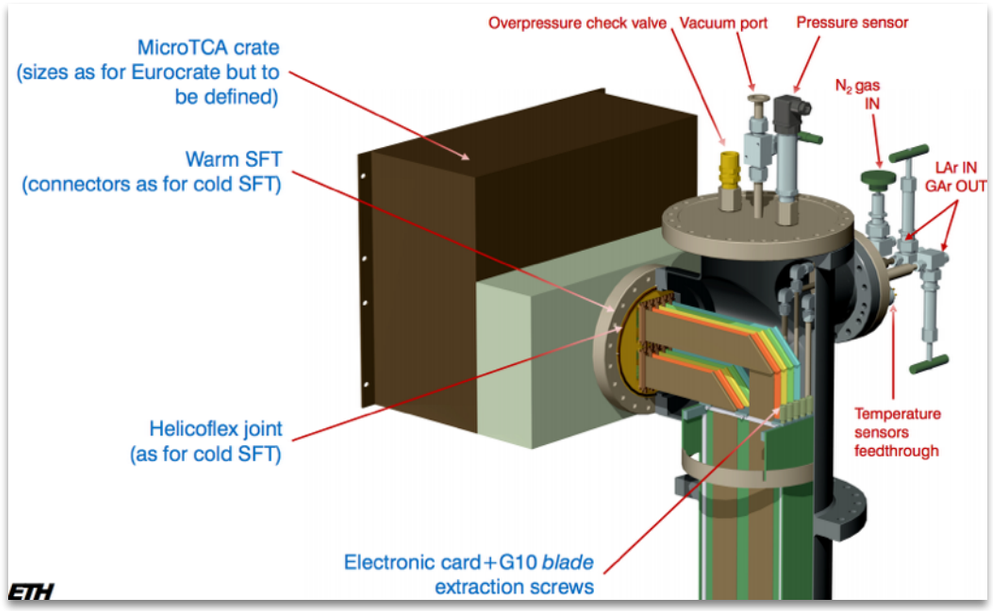


Accessible cold F/E electronics

WA105

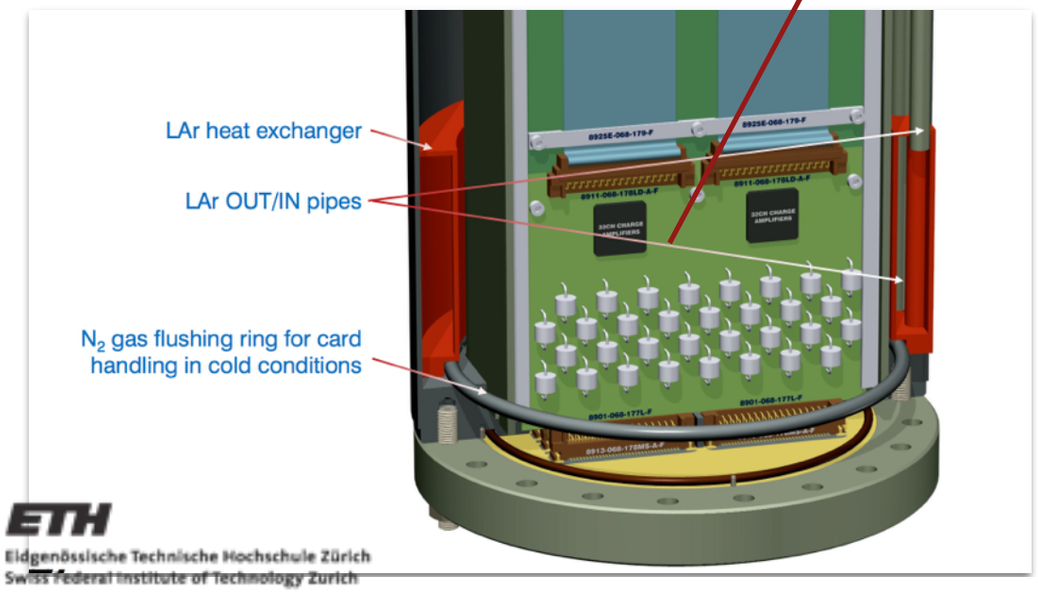
WA105-311 serves as test bench for double phase cold FE electronics.





Digitisation in micro-TCA crates located on top of the chimneys.

Replacement/repair of cold front-end electronics without emptying main detector vessel



voltage protection and amplification in cold (~110K). ASIC preamps as close as possible to the anodes (~50 cm cable). fixed on insertable cards thus can be accessed without opening the detector. 1 chimney has 5 cards and reads 320 channels.

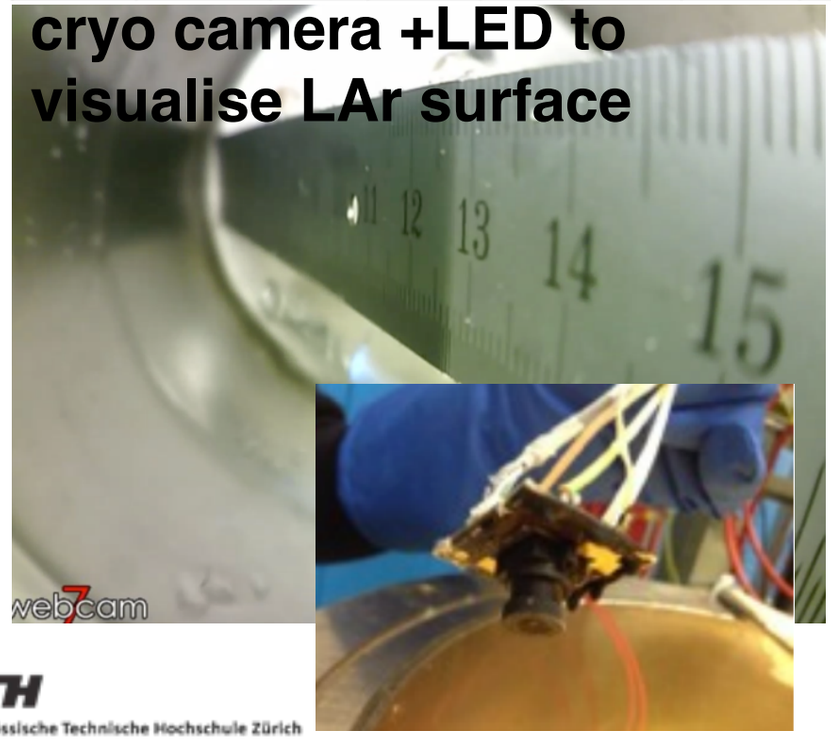
Detector slow control and safety

Since the WA105 311 is a first prototype the slow control will play a fundamental role. We want to understand e.g precision on LAr level, pressure inside vessel, temperatures, material deformations etc..

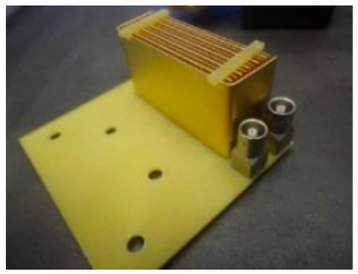
	Sensor	# Sensors	Range	Res.	# pins on FT flange	Electronic Interface	# NI module	PVSS
Temperature	Pt10K	80	80-300K	0.1 K	256 D-SUB 50	-	28 NI9219	PCS Remote IO
	Pt1K	24						
Pressure	Keller PAA-21Y	8	0-2 bar	10E-05mBar	Dedicated plug	EV 06 Keller Display 4-20 mA	1 NI9208	PCS Remote Monitor
Liquid Argon level	coaxial	2	all the drift length	T.B.T (below 100 um)	26 SMA	Self made electronics 4-20 mA	2 NI9203	PCS
	parallel plate	11	2 cm					
Strain Gauge	350 ohm	24	? To be understood ?	T.B.T	96 D-SUB 50	Full Bridge	6 NI9237	PCS Remote IO
Camera	CMOS	4	visible range, 1Pt 10k, resistor 15W	few cm focal length	10 pin each	USB	Real Time Controller	PCS
Heaters	10, 100 ohm	10	5-50 W	PID	20	-	3 NI9481+PSU	PCS
Trace Analyzer		3	< ppm	-	-	-	1 NI9203	PCS

		# Channels	Connectors on FT flange	Electronic Module	PROCESS
High Voltage	LEM, PMTs	27	SHV	CAEN SY1527	DCS
	grid, FFS	4	LEMO HV	CAEN SY1527	DCS
	100 KV	1	dedicated FT	Heinzinger	DCS
Signal	PMTs	3	SMA	(trigger gen)	NOT MONITORED
Low voltage	Lighting system, Silicon PMT	20	SMA	tbd	DCS

cryo camera +LED to visualise LAr surface



coax and parallel plates capacitor for LAr level



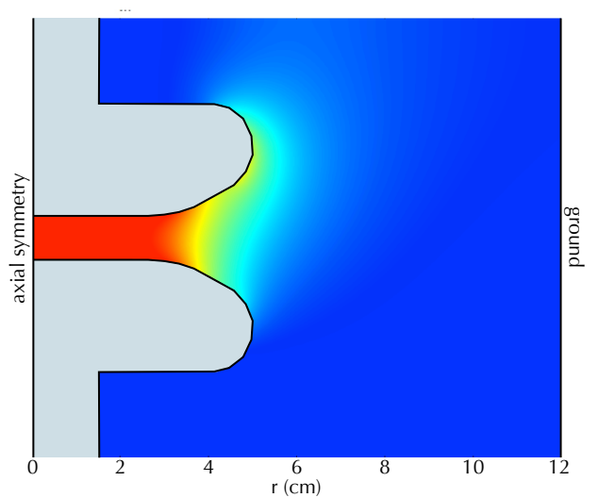
NI Compact RIO system. First tests planned in Feb.

Based on successful developments for ArDM by CERN

High voltage feedthrough

WA105

LAr electrical rigidity tests at 100kV



W. Rogowski, Arch. Electrotech., 12(1923), 1

Evidence of electric breakdown induced by bubbles in liquid argon

F. Bay, C. Cantini, S. Murphy,
F. Resnati, A. Rubbia,
F. Sergiampietri, S. Wu
http://arxiv.org/abs/1401.2777

NEXT STEPS: Adapt the present HVFT to the 300kV cable and test in the range 100-300kV

Build a new HVFT suitable for the 6x6x6m^3 and adapt it for the 3x1x1m^3

-300kV High Voltage Power Supply
(from HEINZINGER)

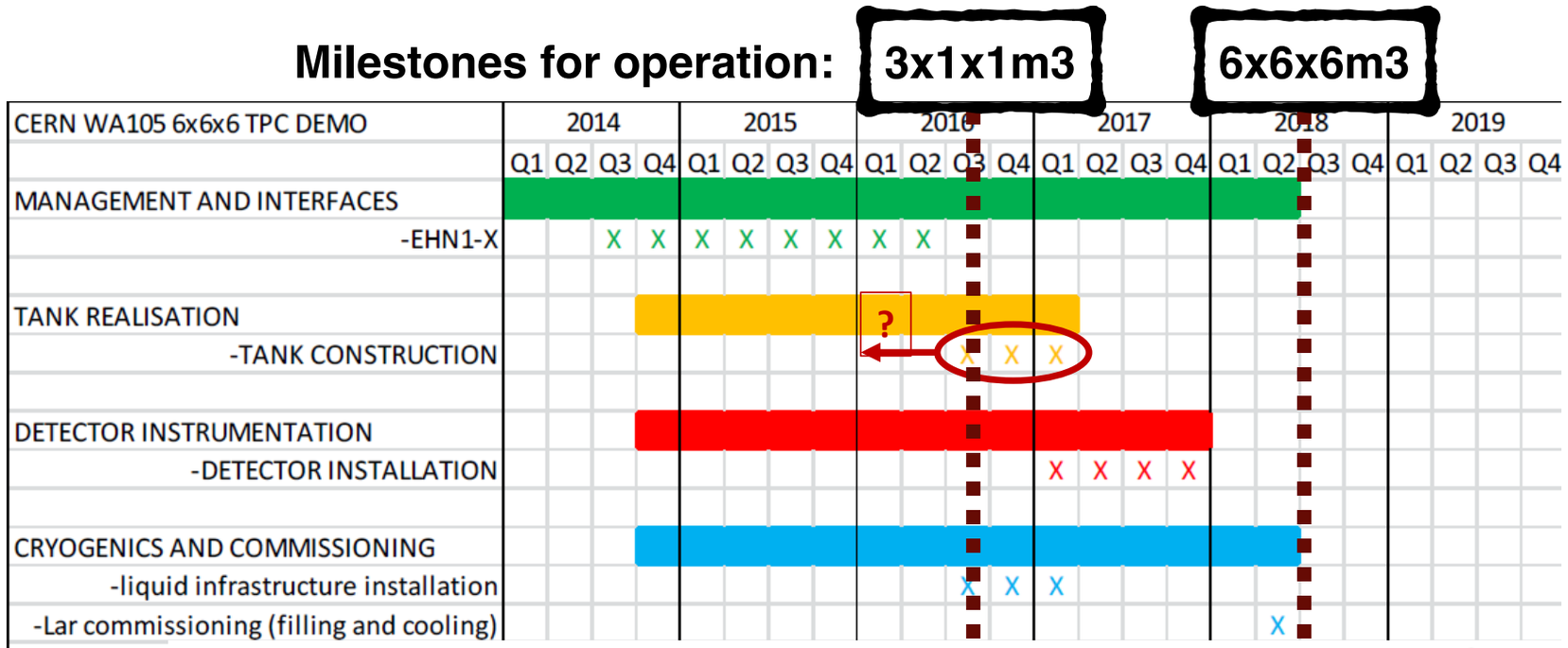
Residual ripple: ≤0.001% U_{NOM} ± 50mV
Residual Ripple at -300kV ≤3V ± 50mV

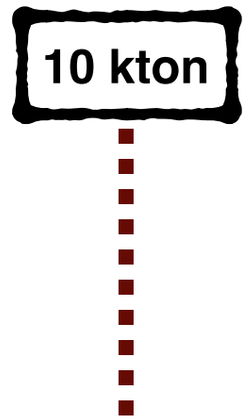
Can be reduced by the RC filter in the load:
with a fieldcage-to-GND capacitance of 5.5nF and a switchi
frequency of 34kHz, a series resistor of ~1kΩ is required.

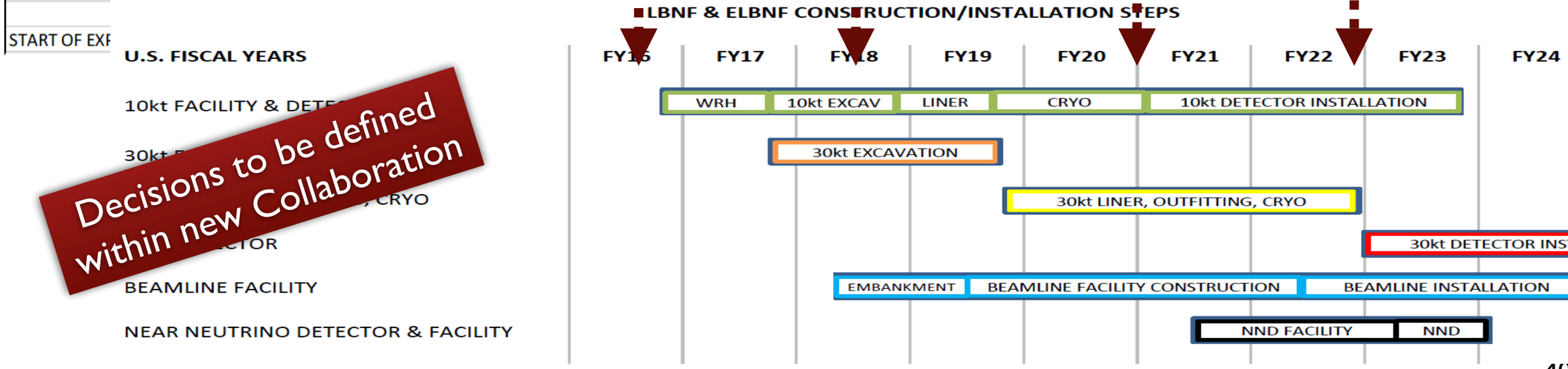
300 kV test by summer 2015

Matching plans

- 3x1x1m3 prototype now under construction → warm gas operation in Q4 2015 → full LAr operation in 2016 ?
- 6x6x6m3 cryogenic vessel available in 2016 → detector subcomponents installation planned in 2017 → beam operation in North Area in 2018 ?







Decisions to be defined within new Collaboration

How to join WA105 ?

1. **Many hardware and software tasks to do !!**
2. **Contact spokesperson**
3. **Discuss contribution (HW/SW/…)**
4. **Triggers decision at the WA105 Institution Board**
5. **Approve admission**

- **General meetings:** every two or three months
  - **October 16th-17th 2015 Kickoff meeting@ CERN**
  - **January 21st-22nd 2015 @ CERN**
    http://laguna.ethz.ch/indico/conferenceOtherViews.py?view=standard&confId=89
  - **Next one: 25-26th MARCH 2015 @ CERN**
    (For Sergio: if not again overlapping with ELBNF GM !)

- **Weekly meetings:**
  - **3x1x1m3 weekly meetings (Chair: Sebastien Murphy)**
    ➡ **construction of 3x1x1m3 prototype**
  - **Technical Board meetings (Chair: Dario Autiero)**
  - **Science/Analysis Board meetings (Chair: Takuya Hasegawa)**

Conclusions

- **WA105 is an approved CERN experiment which can provide vital input for ELBNF.** We have a set of well defined technical and physics goals to deliver which will have implications for the long baseline neutrino programs being developed.

- **It's not only about liquid argon mass**: In order to meet the challenges, we must build the far detector with **best possible performance** (pitch, threshold, resolution, …) to **best exploit the ELBNF physics opportunities**.

- From the several years of R&D and successful operation of several prototypes and supported by the 6 years LAGUNA/LBNO studies, we have a large amount of expertise, conceptual designs, etc… that can form the basis for a "double phase" for ELBNF CDR: **we are confident that we can develop a "double phase option" for the summer 2015 CDR.**

- **We are committed to an overall WA105 time schedule, which foresees the operation of the 6x6x6m3 in 2018, matched to inform the ELBNF TDR process.**

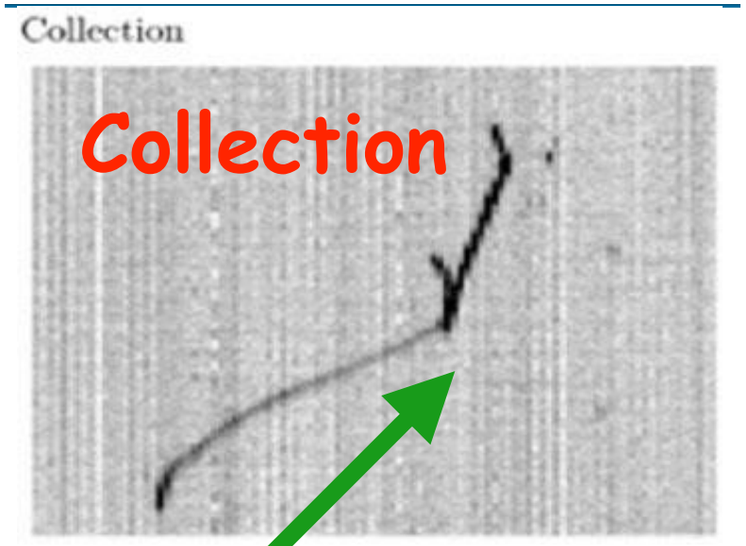
- WA105 is a unique opportunity for young PhD/postdoc to learn how to design, build and commission large liquid argon detectors, which represents a fundamental training for those who will want to lead the deployment and startup of the underground detectors. **With more people on board, we can move faster towards the final goal.**

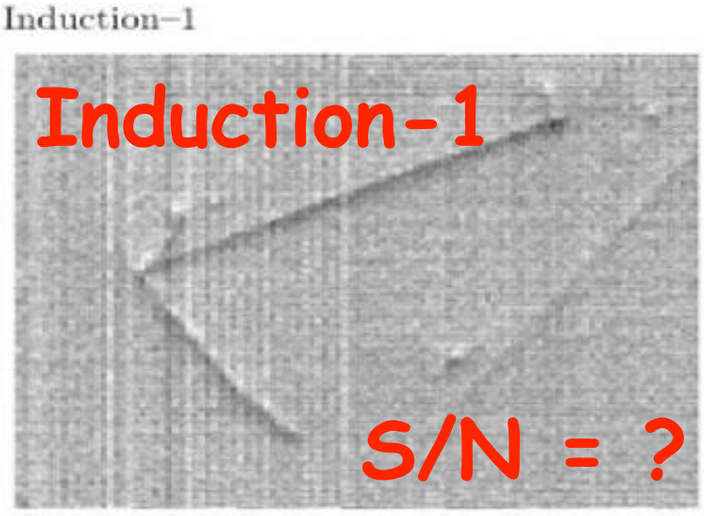
Backup slides

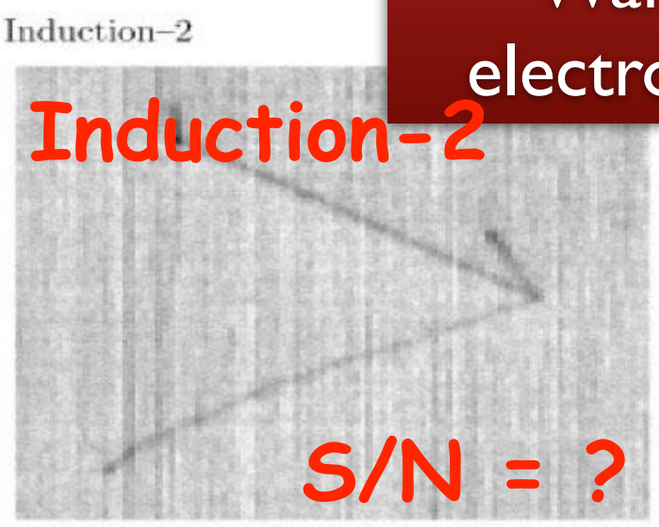
Single phase gallery

WA105

"Warm" electronics







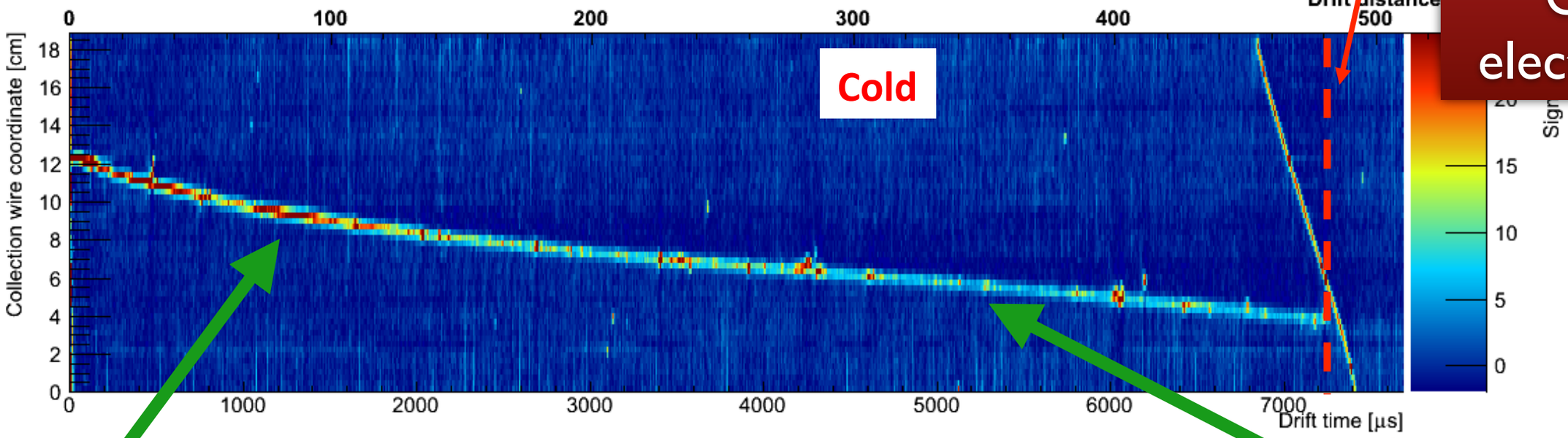
wires

Slide:

"An S/N > 10 was obtained during the whole LNGS run",

ICARUS T600, 13/1/2015

"Cold" electronics



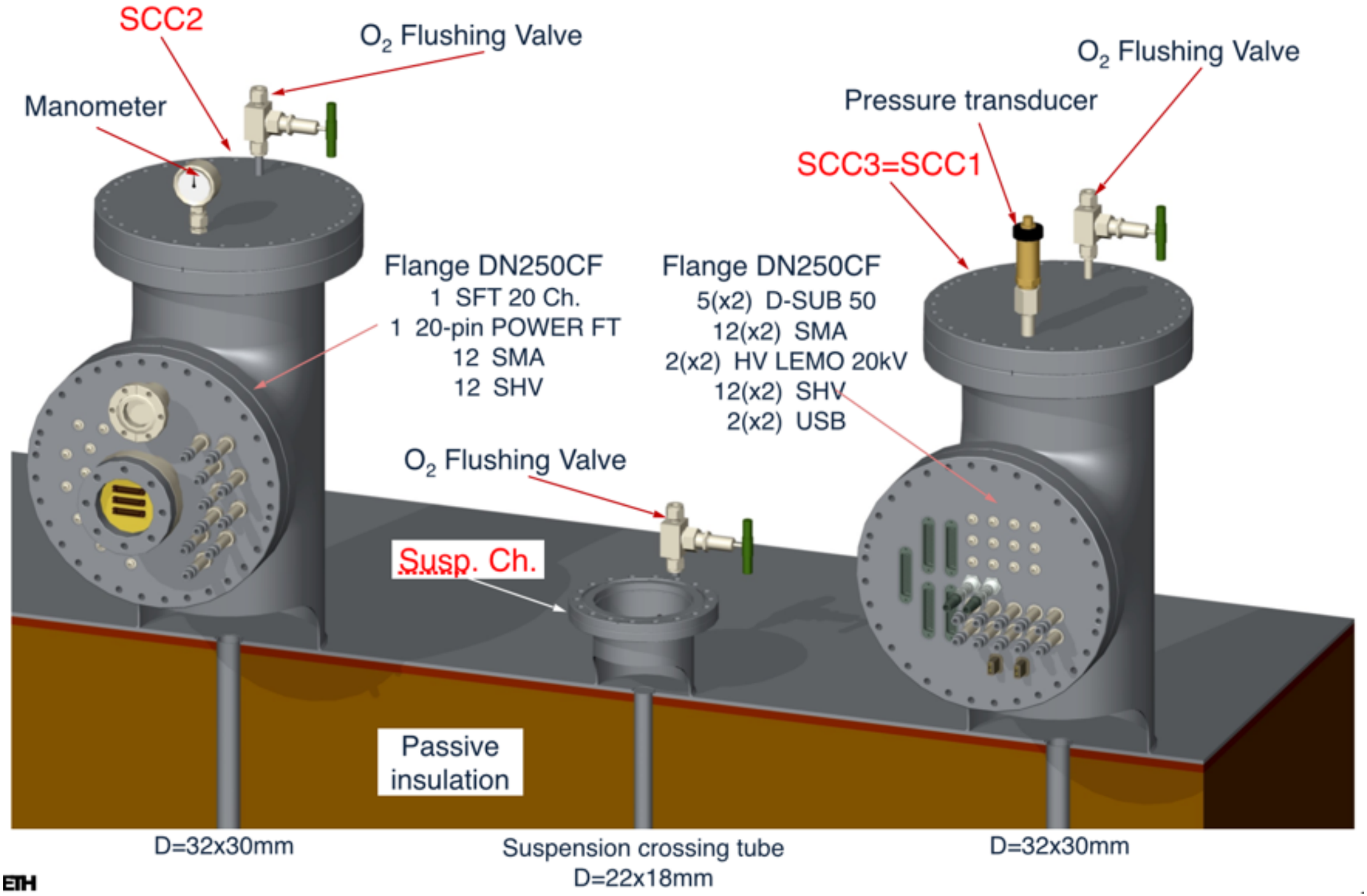
"S/N = 15.7±3.8", ArgonTube, 13/1/2015

S/N for induction view ?

S/N < 10 for drift > 1m

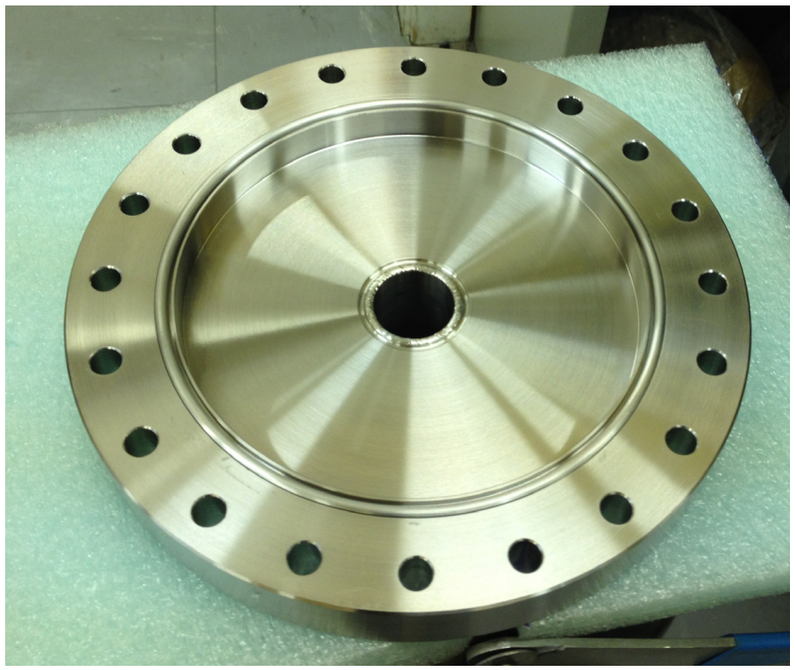
slow control chimney

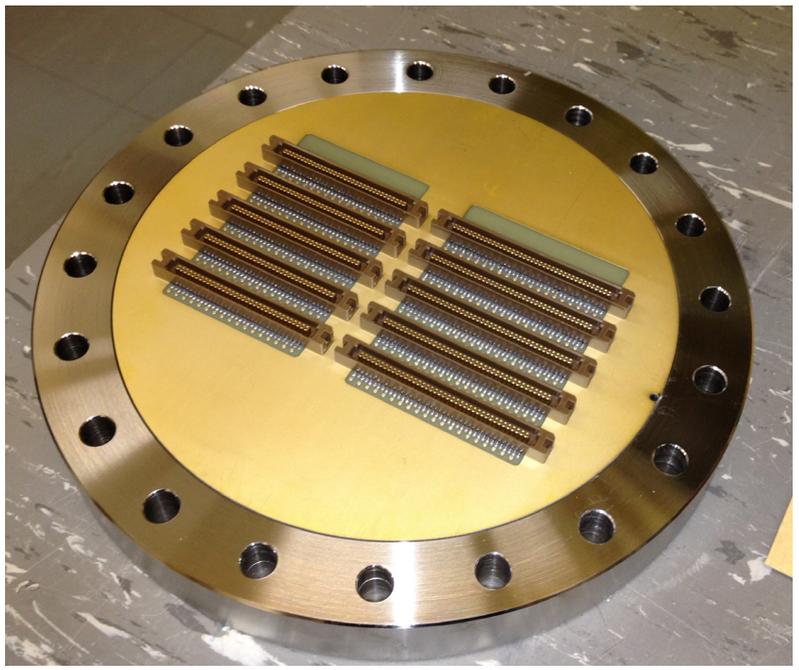
last month: significant progress on slow control chimney

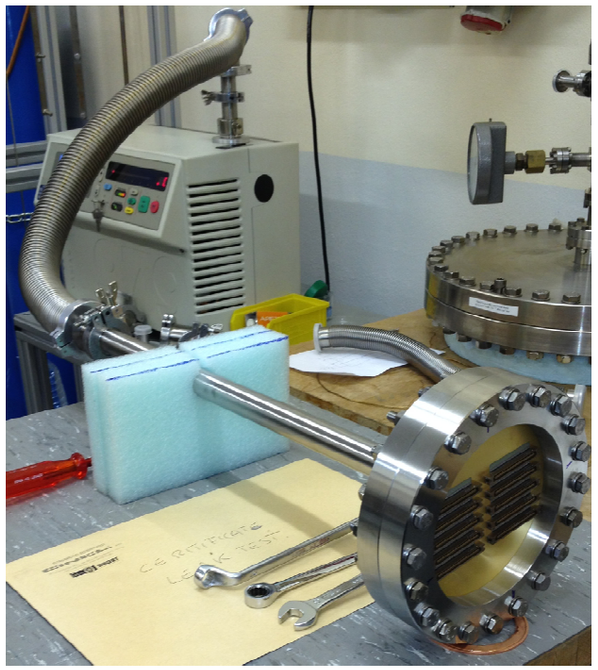


Feed-throughs

Charge readout chimneys – Vacuum test of the SFT pcb

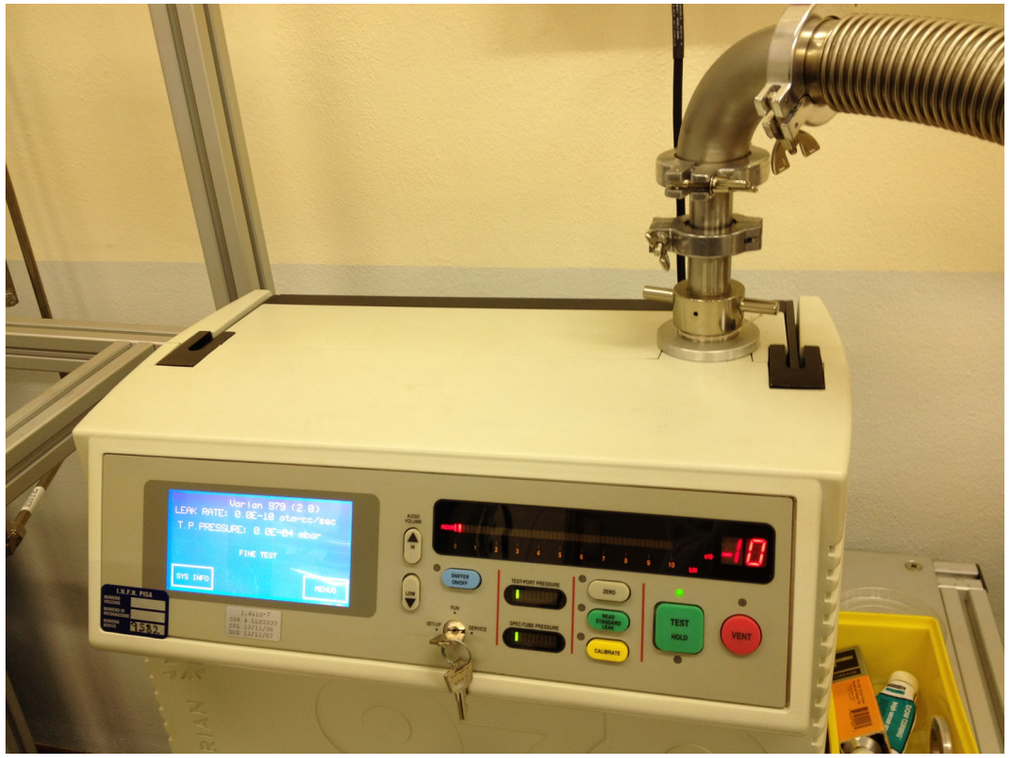






Vacuum tightness tested with He leak detector: $<10^{-12}$ Atm·cm^3/s (end od scale)

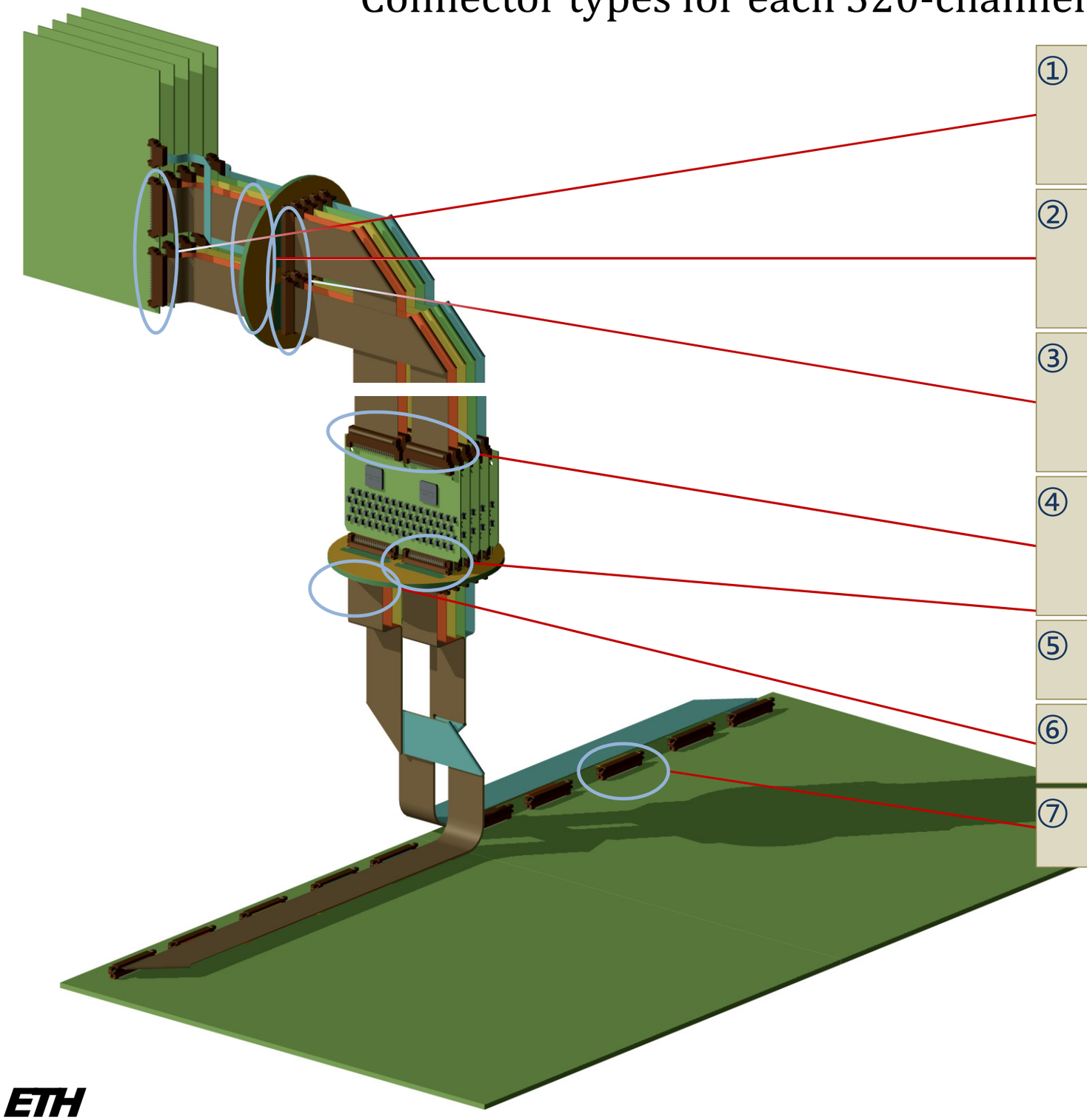
(Helicoflex gasket + indium to compensate the 0.1mm non planarity of the multilayer PCB)



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology

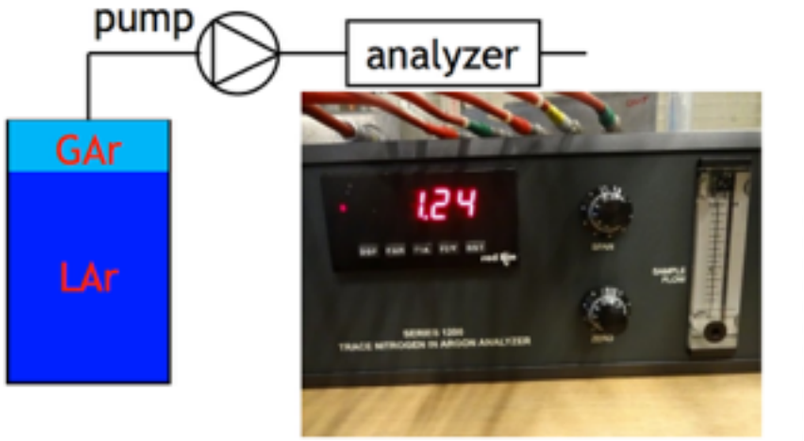
Signal Feed-through

Connector types for each 320-channels SFT chimney



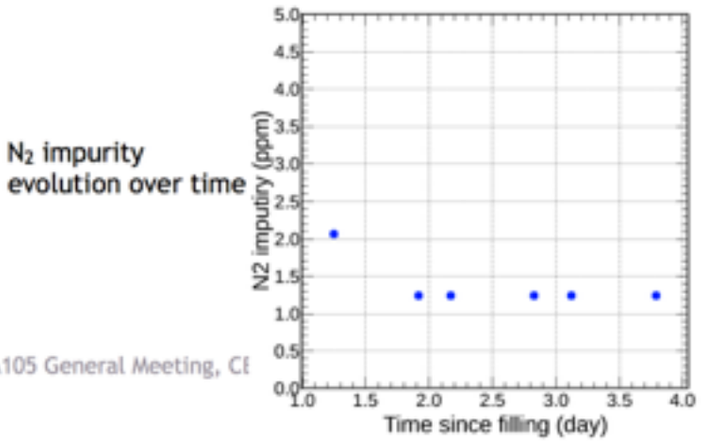
①	Plug Through Hole 90°	N.	5	KEL 8931E-080-178L-F
		N.	5	KEL 8931E-068-178L-F
	Rec. Twisted Pair	N.	5	KEL 8925E-080-179-F
		N.	5	KEL 8925E-068-179-F
②	Rec. Twisted Pair	N.	5	KEL 8925E-080-179-F
		N.	5	KEL 8925E-068-179-F
	Plug SMT	N.	5	KEL 8930E-080-178MS-F
		N.	5	KEL 8930E-068-178MS-F
③	Plug SMT	N.	5	KEL 8930E-080-178MS-F
		N.	5	KEL 8930E-068-178MS-F
	Rec. Twisted Pair	N.	5	KEL 8925E-080-179-F
		N.	5	KEL 8925E-068-179-F
④	Rec. Twisted Pair	N.	5	KEL 8925E-080-179-F
		N.	5	KEL 8925E-068-179-F
	Plug Through Hole 90°	N.	5	KEL 8931E-080-178L-F
		N.	5	KEL 8931E-068-178L-F
⑤	Rec. Through Hole 90°	N.	10	KEL 8901-068-177L-F
	Plug SMT	N.	10	KEL 8913-068-178MS-AF
⑥	Plug SMT	N.	10	KEL 8930E-068-178MS-F
	Rec. Twisted Pair	N.	10	KEL 8925E-068-179-F
⑦	Rec. Twisted Pair	N.	10	KEL 8925E-068-179-F
	Plug SMT	N.	10	KEL 8930E-068-178MS-F

Liquid infrastructure



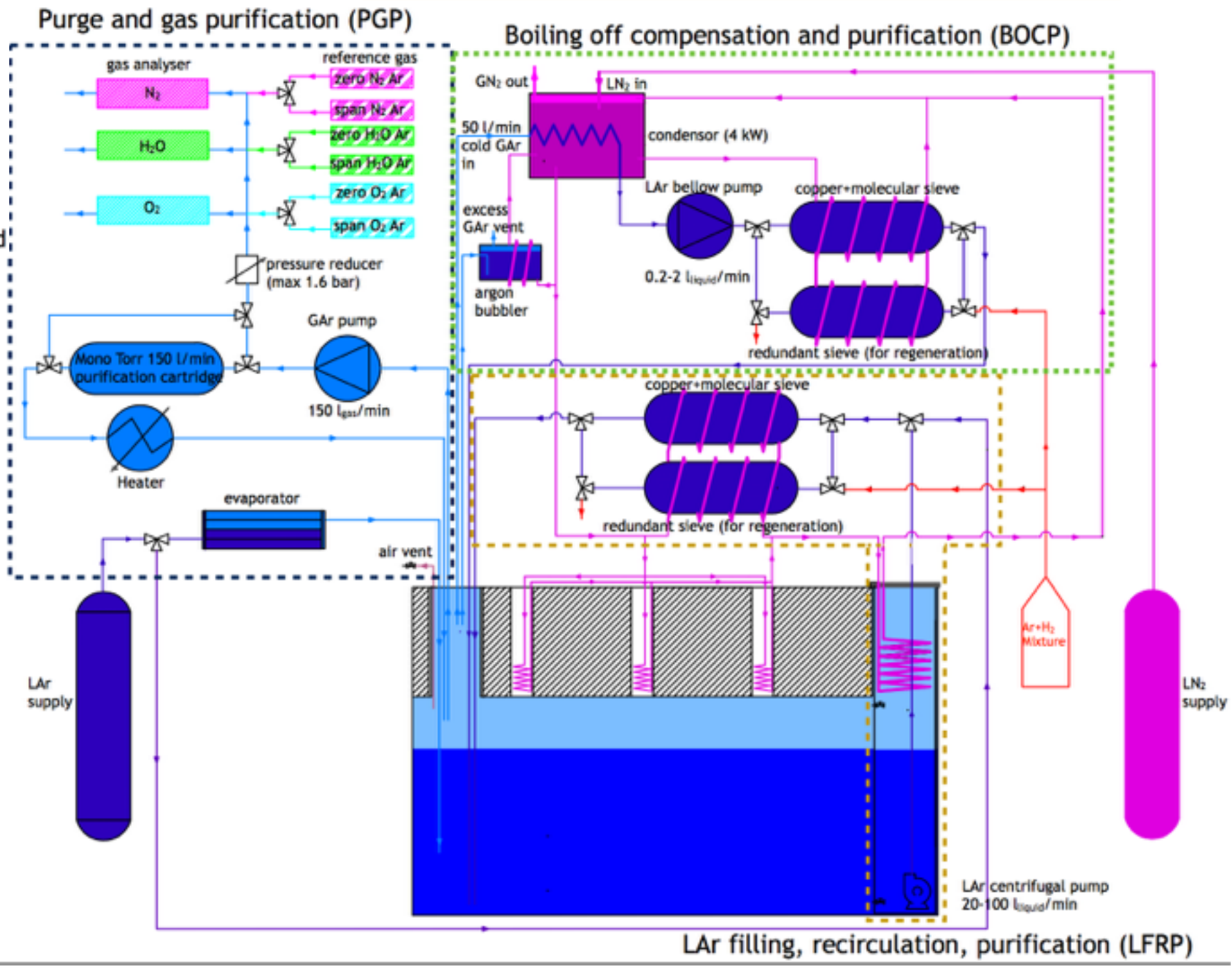
1.24 ppm in gas == 1.55 ppb in liquid

see slides from S. Wu and J. Bremer

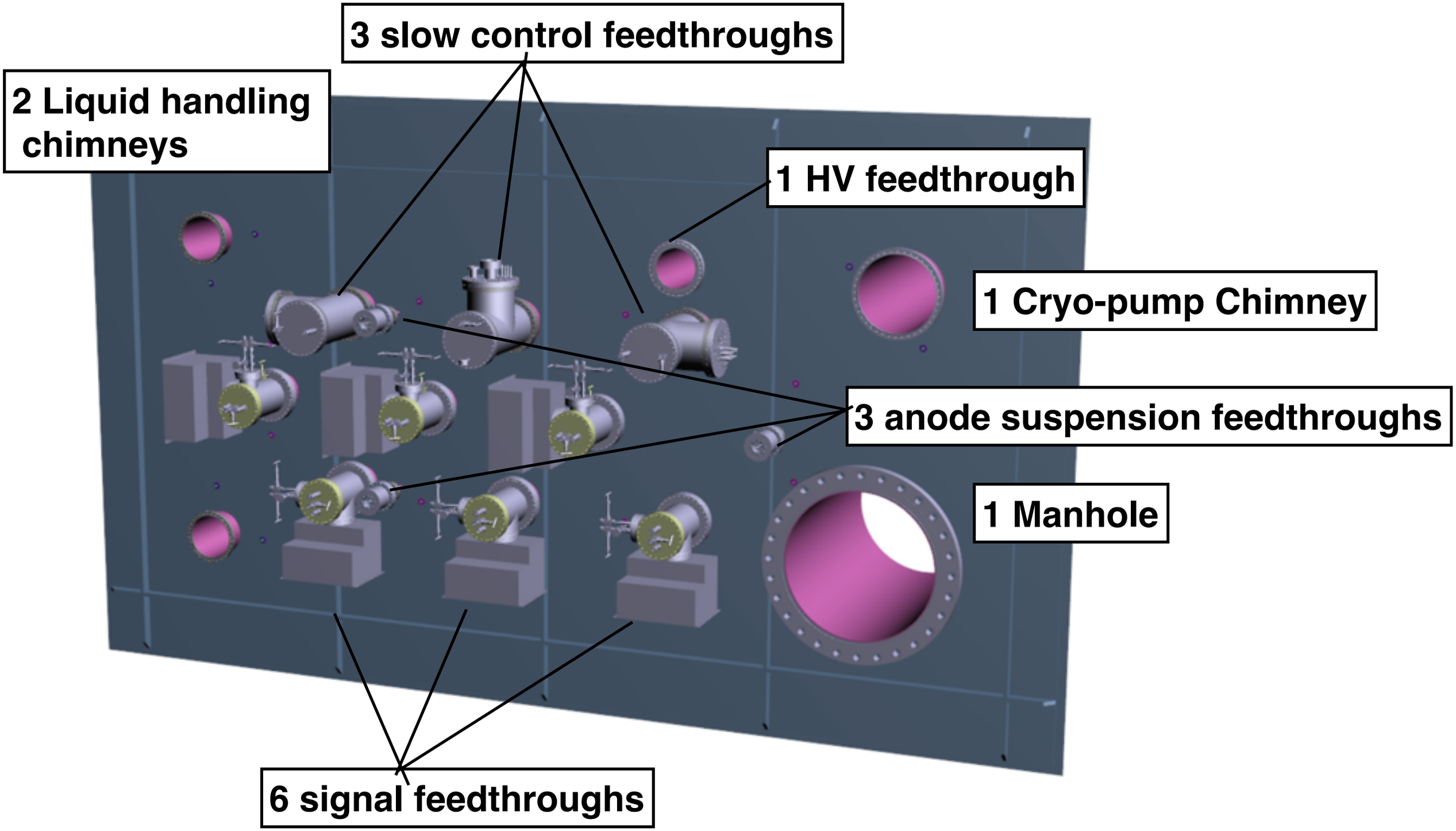


N_2 impurity evolution over time

WA105 General Meeting, CE

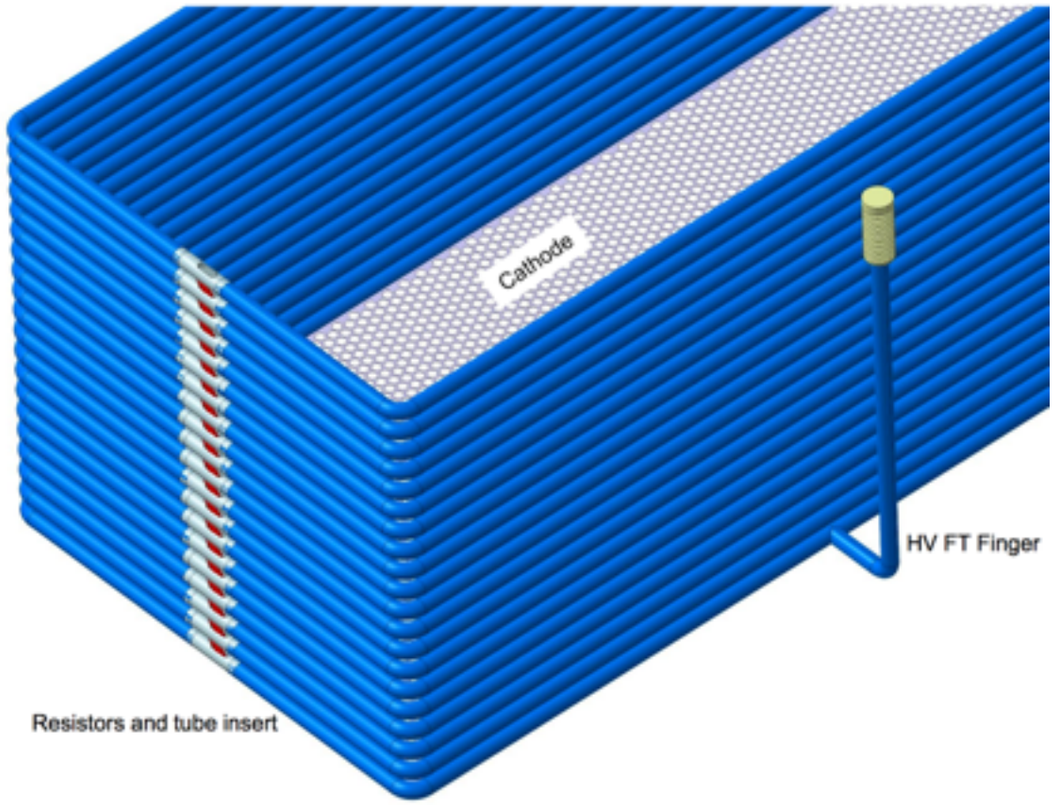


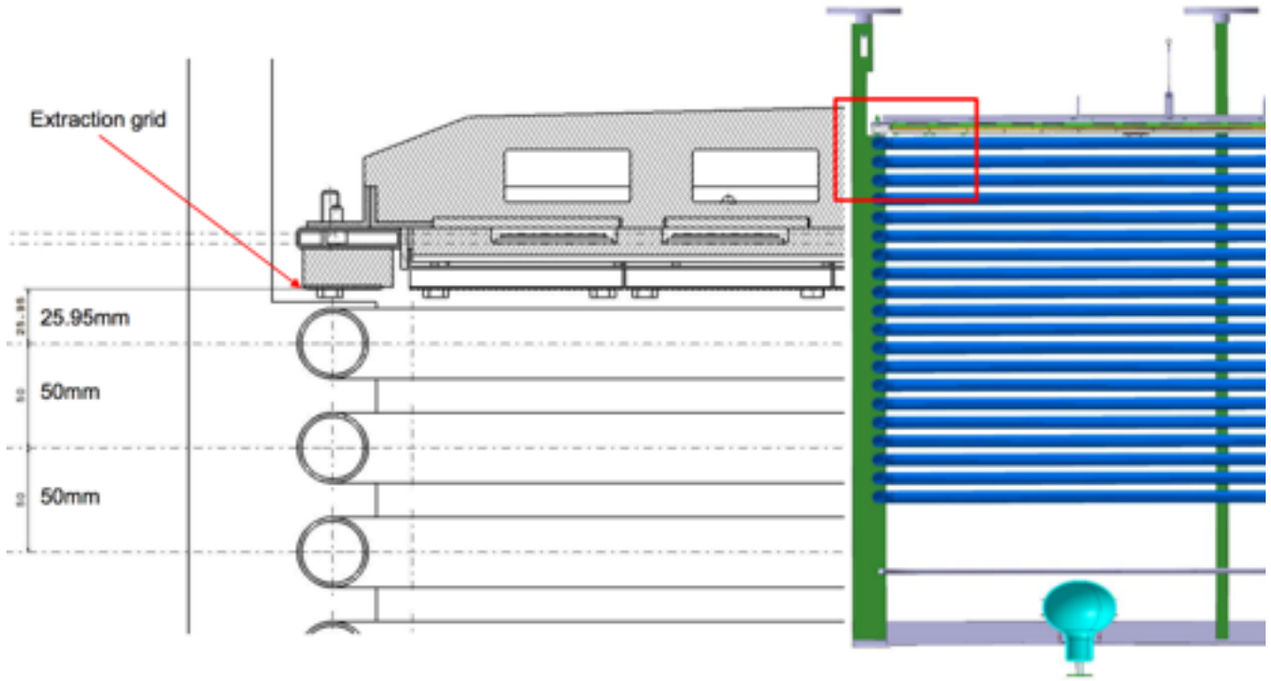
Top Cap

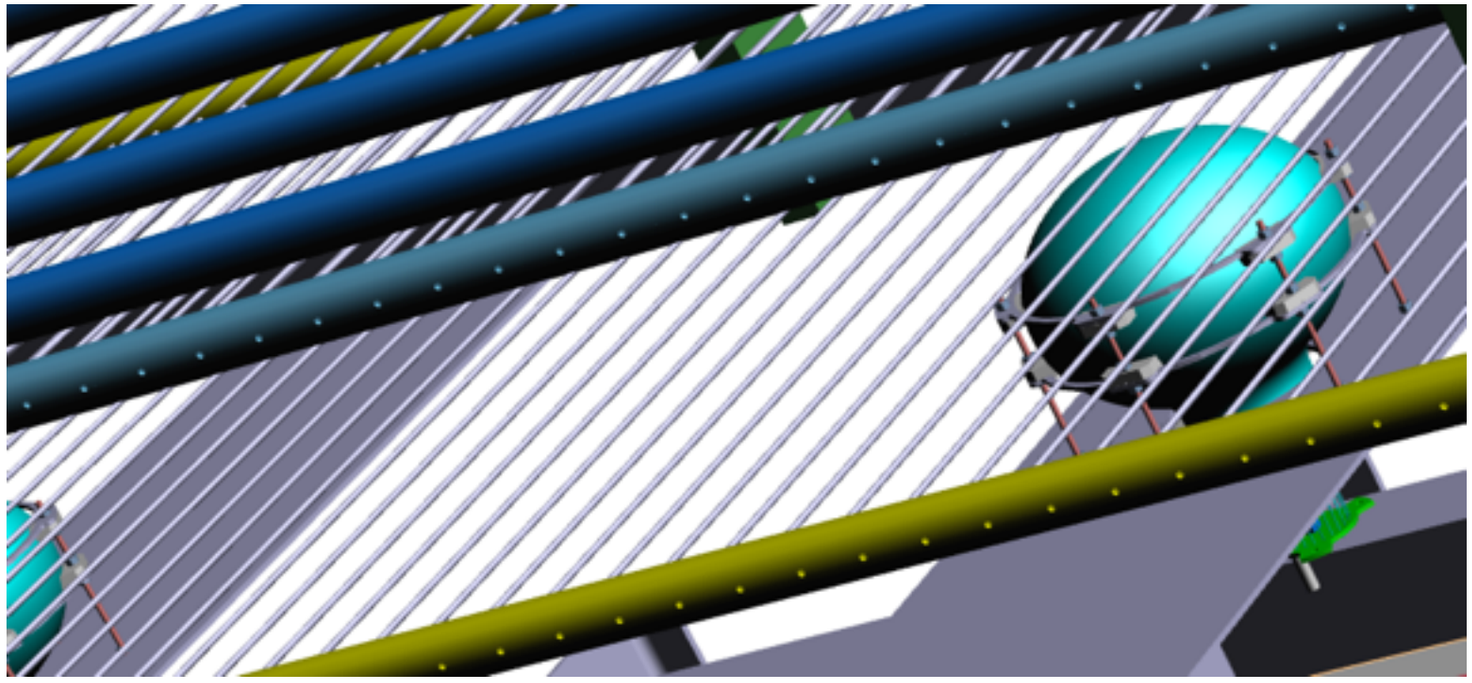

3 slow control feedthroughs
2 Liquid handling chimneys
1 HV feedthrough
1 Cryo-pump Chimney
3 anode suspension feedthroughs
1 Manhole
6 signal feedthroughs

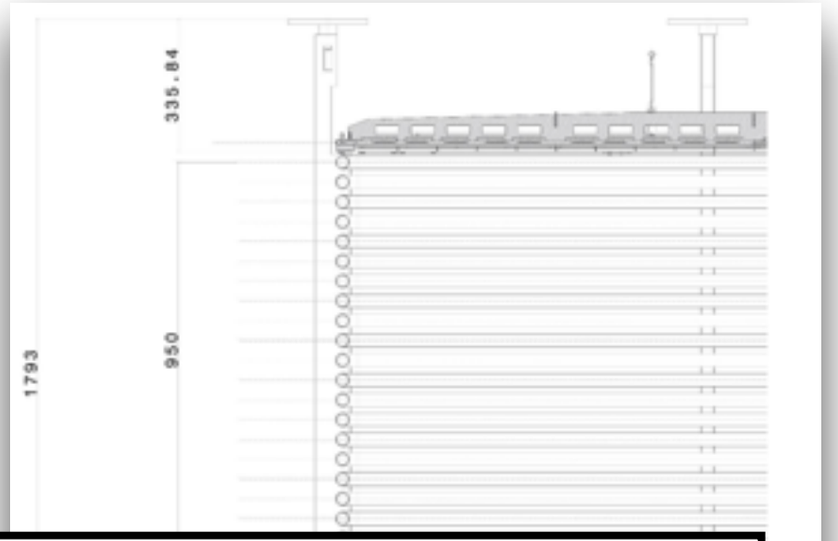
The drift cage

ess Steel
pper?







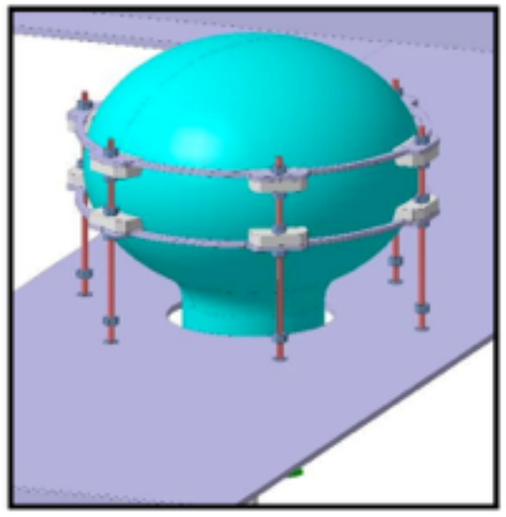


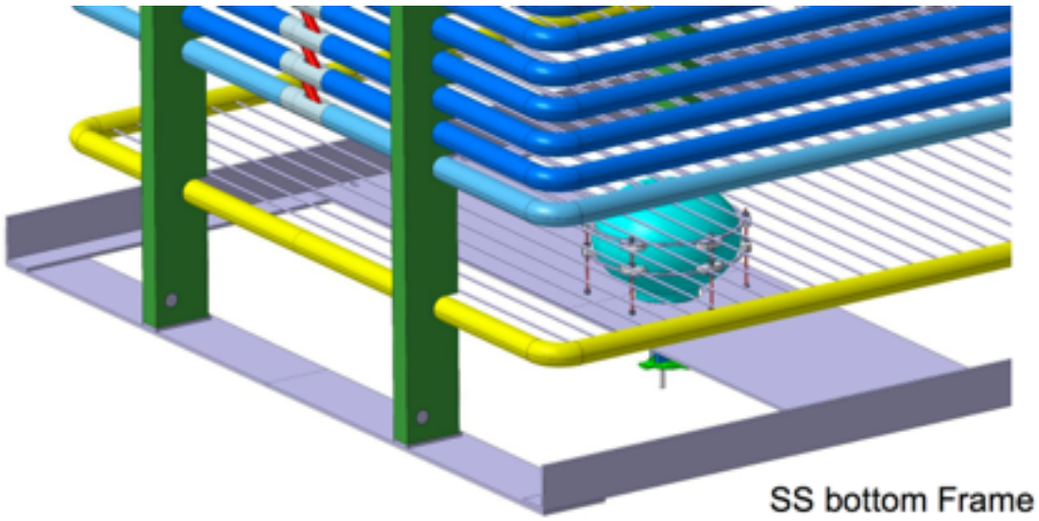
- ✓Following similar design to ArDM's drift-cage.
- ✓Assembled off-site and delivered to CERN.

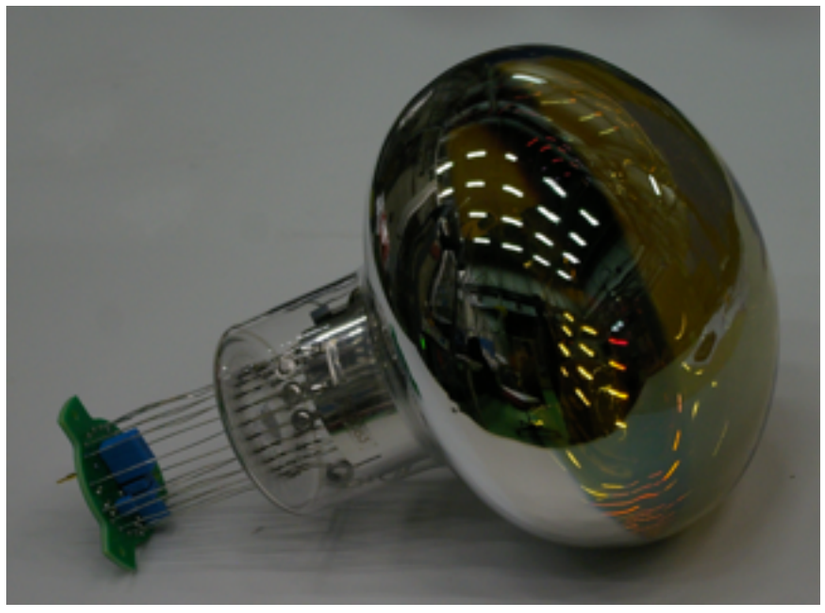
The PMT-based light readout

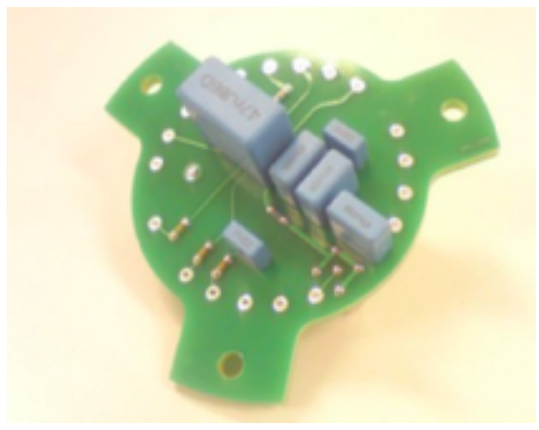
Baseline design: 3 Hamamatsu 8” R5912 PMTs. Same installation as ArDM.

R5912-02MOD





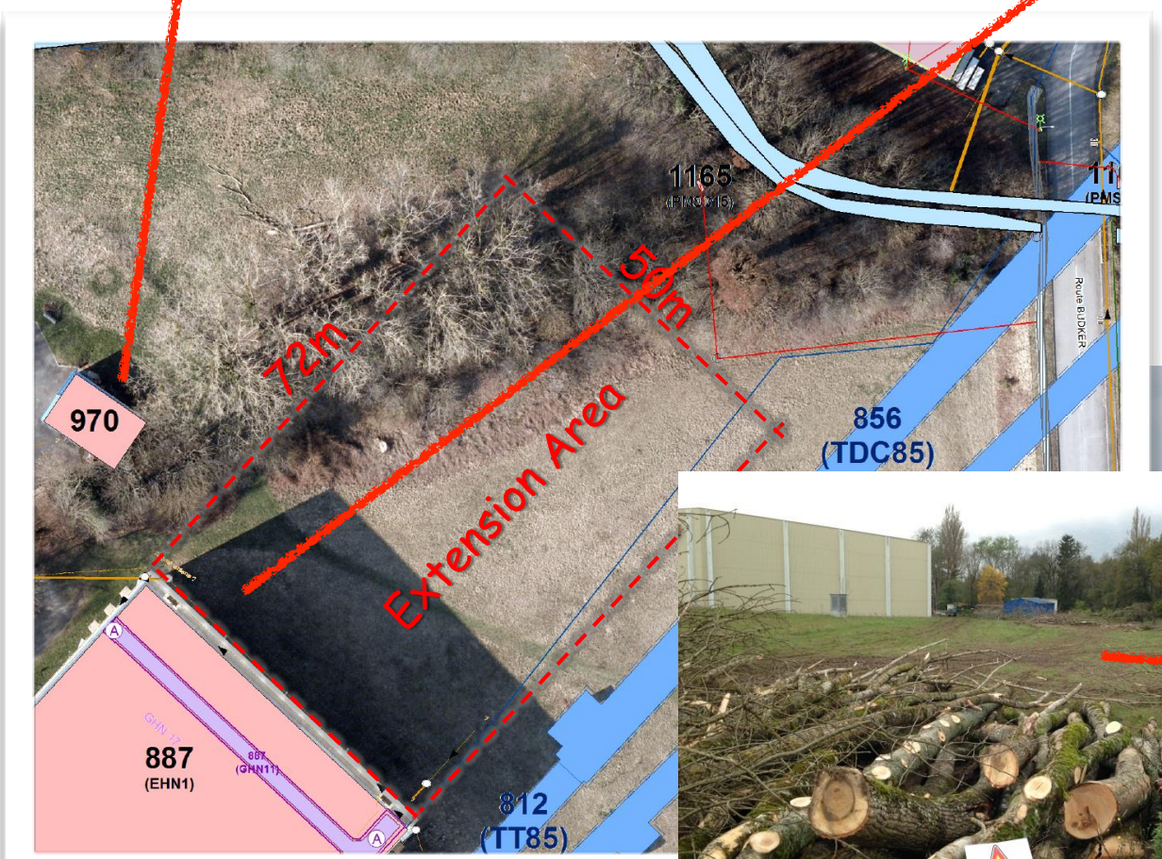




- ✓PMT ordered and bases are fabricated at KEK following design from ArDM.
- ✓WLS coating and testing at CERN planned in April.

North Area Extension (EHN1-X)

Extension area: 72m x 50m

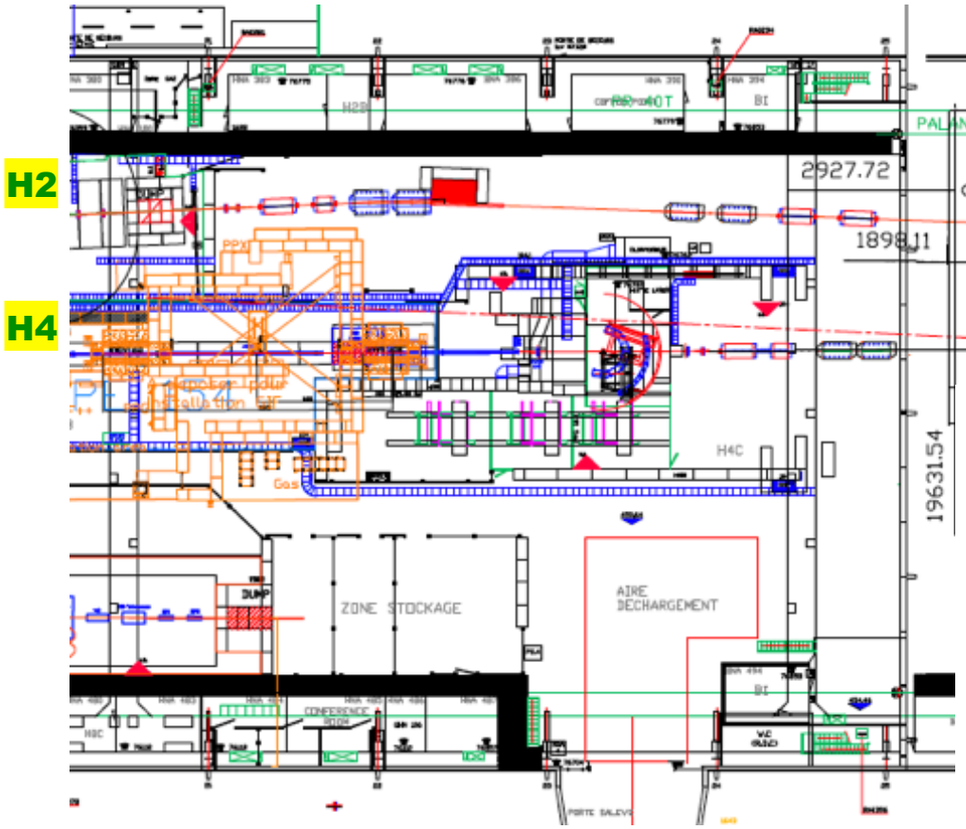


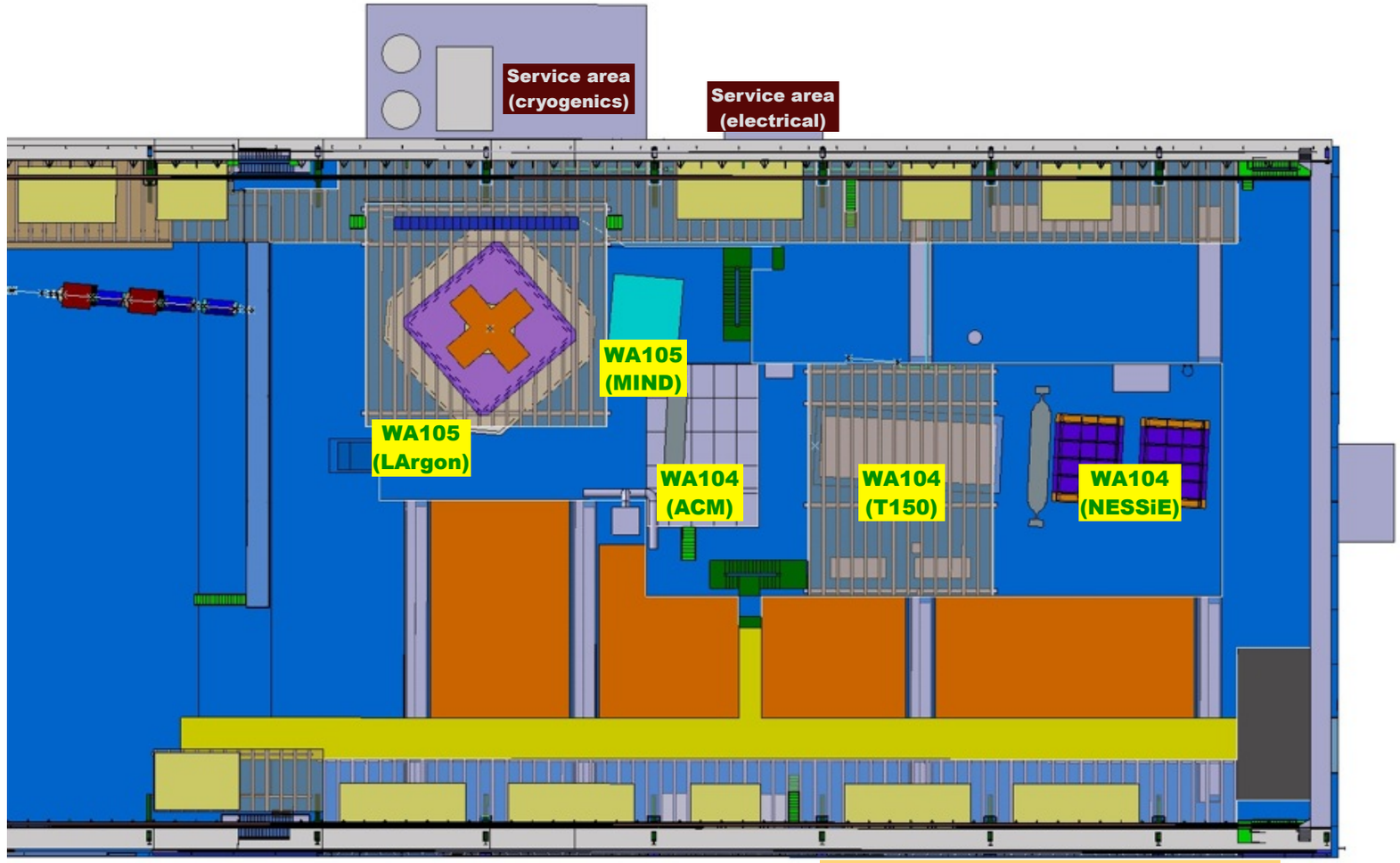
- ✓ Construction Design Phase (**ONGOING, completion by end-November**)
- ✓ Adjudication foreseen in December 2014 FC
- ✓ Contract signature
- ✓ Start of the works officially in January 2015 (anticipation, if possible)

EHN1-X: charged beams

- VLE tertiary beams for the ν detectors
  - H2 extension: **1-20 GeV/c**, hadrons ($\pi^{\pm}$, $\mu^{\pm}$, p - mixed beam), electrons($e^{\pm}$)
  - H4 extension: **1-5(7) GeV/c**, hadrons ($\pi^{\pm}$, $\mu^{\pm}$, p - mixed beam), electrons($e^{\pm}$)
    - interest to go lower, down to 0.2 GeV beams for LBN TPC test

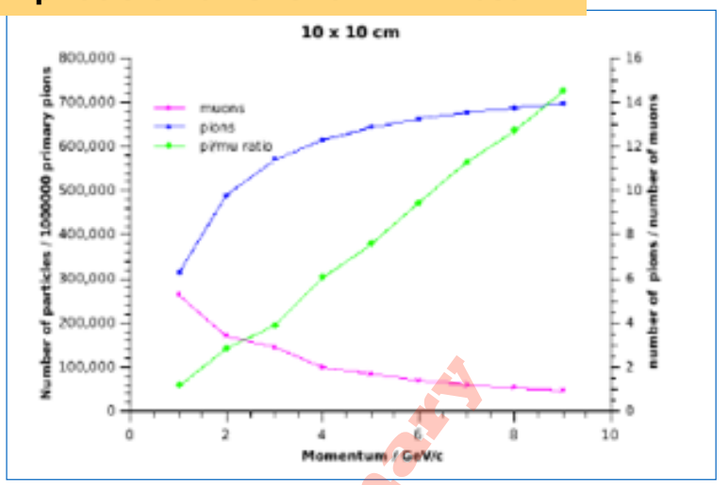
Courtesy I. Efthymiopoulos





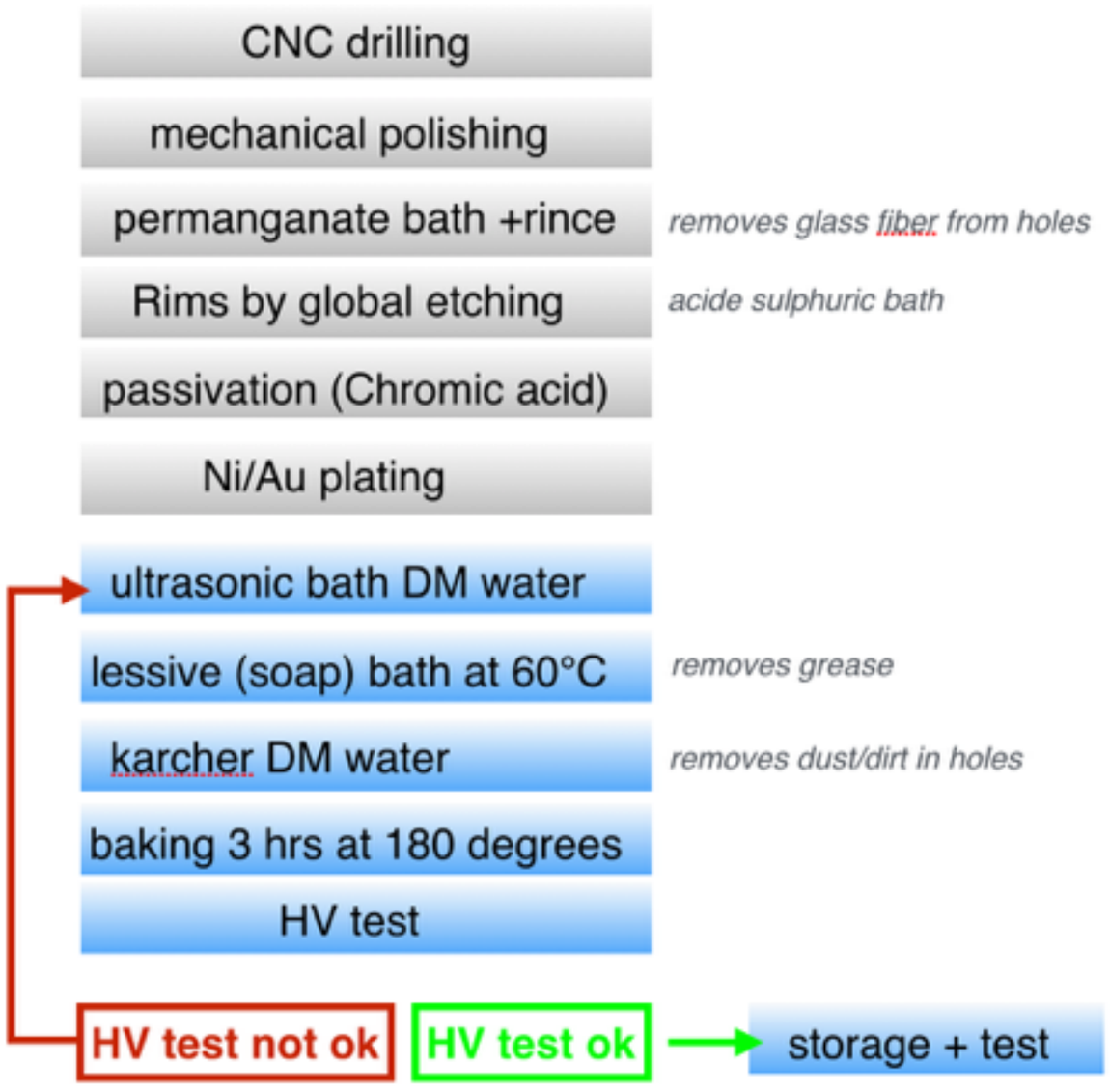
Integration designs: V. Clerc EN/MEF

- **π/μ ratio on axis for a π VLE beam**

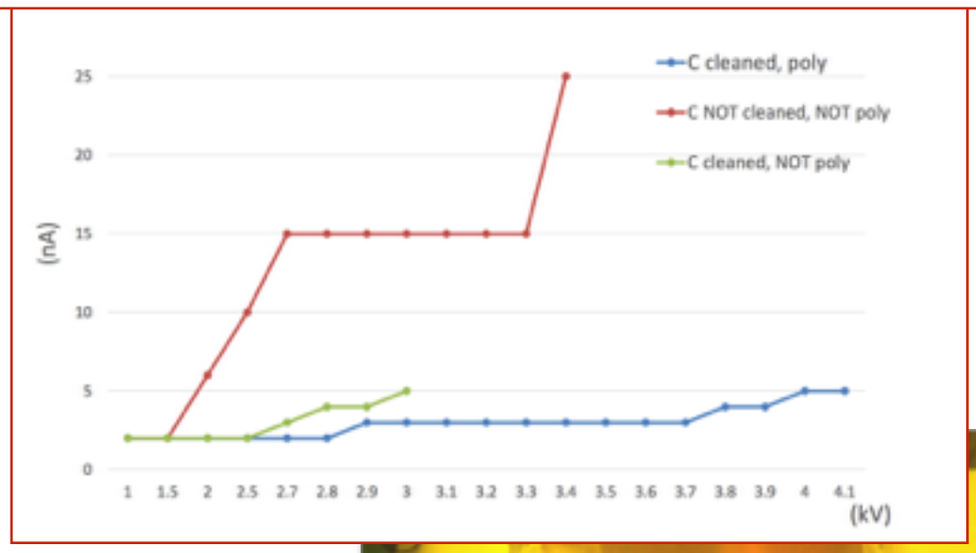


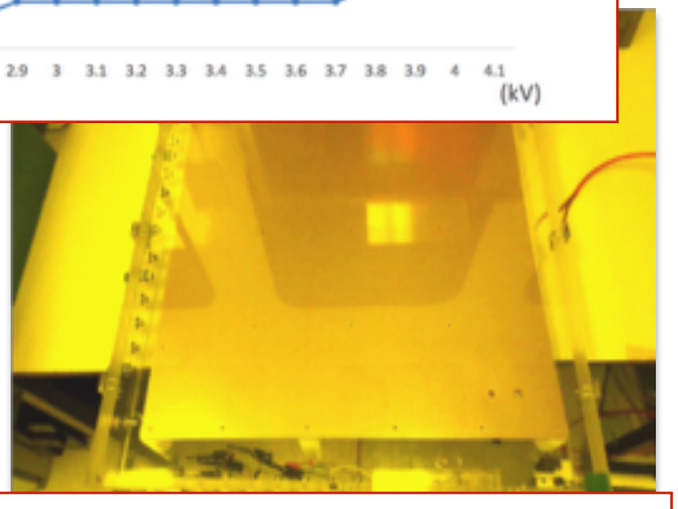
LEM validation

- The LEMs are the most delicate par of the CRP and requires careful handling & testing.
- 20 LEMs have been ordered at ELTOS. First batch of 5 arrives end of January.
- Cleaning procedure at the CERN PCB lab (Rui de Oliveira) has been defined and tested on 4 LEM prototypes.



LEM cleaned then powered in controlled atmosphere to check spark threshold + leakage current.

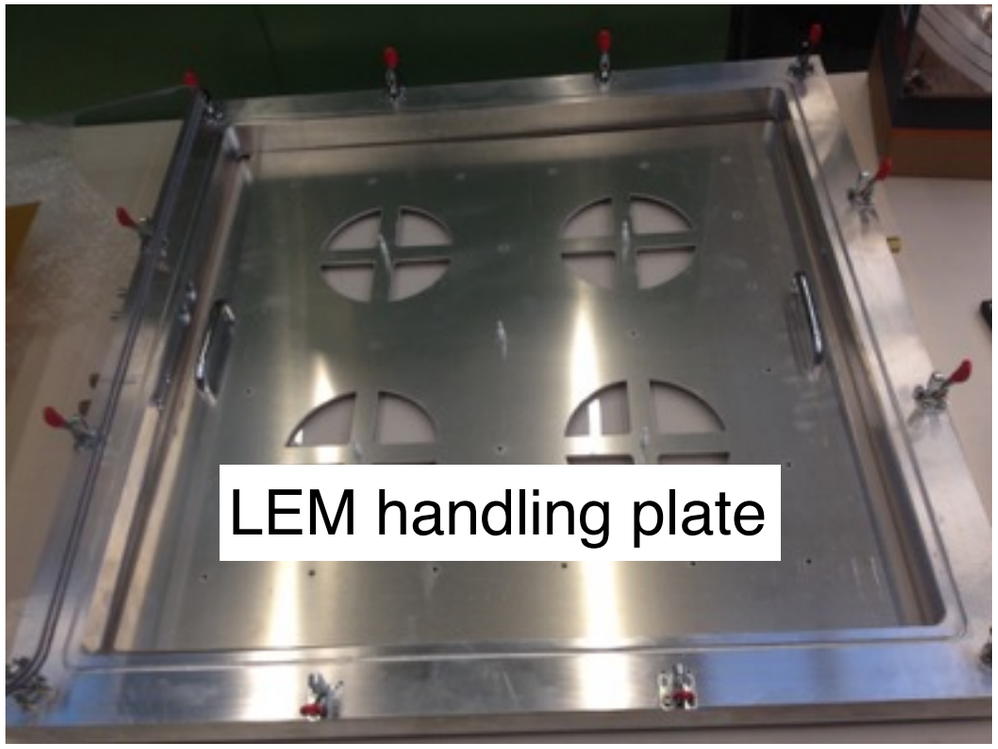


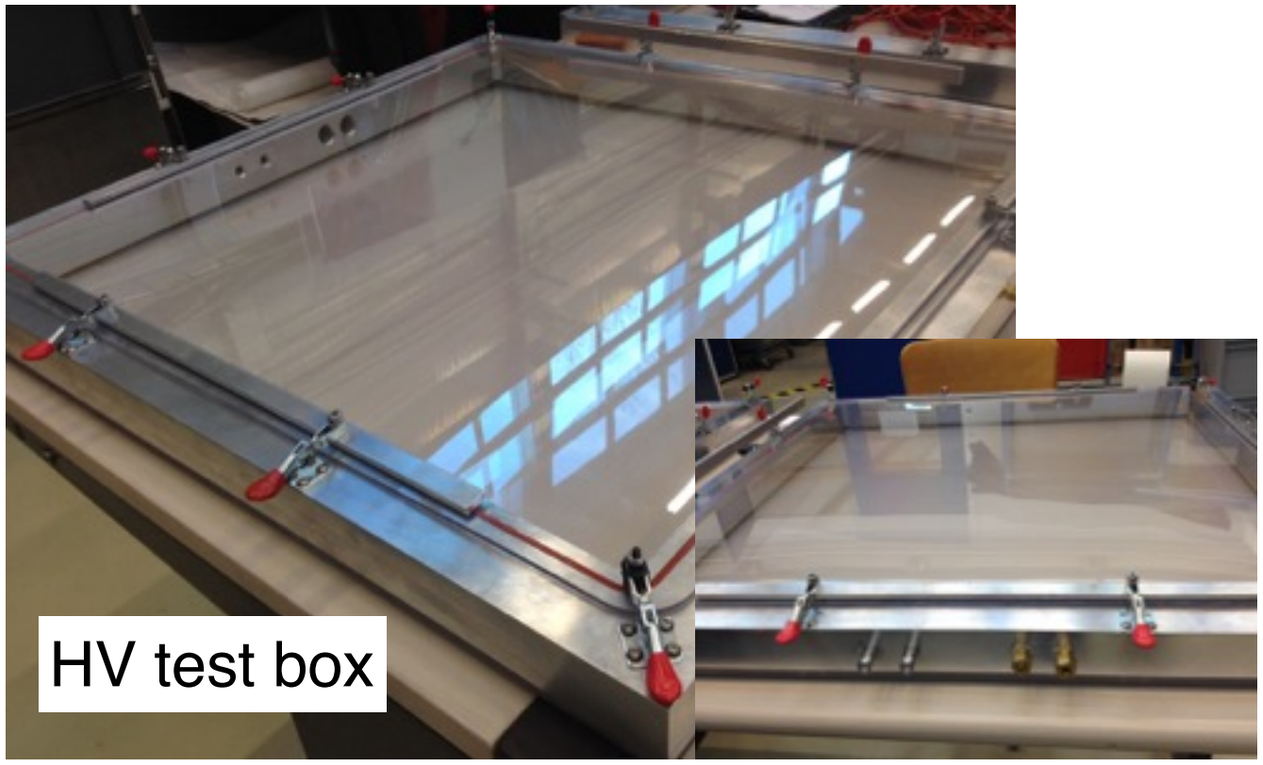


Goal: negligible (i.e < 10nA) leakage current at 4 kV

LEM validation

- Cleaning will take place in February. Each LEM has its “handling plate” (an Al frame with handles) and once accepted will be stored in a box (currently in production) under N2 atmosphere.
- Also designing HV test boxes to make the HV test under controlled atmosphere. This way each LEM is tested under the same conditions. HV box may also be used for longer term characterisation of the LEM.

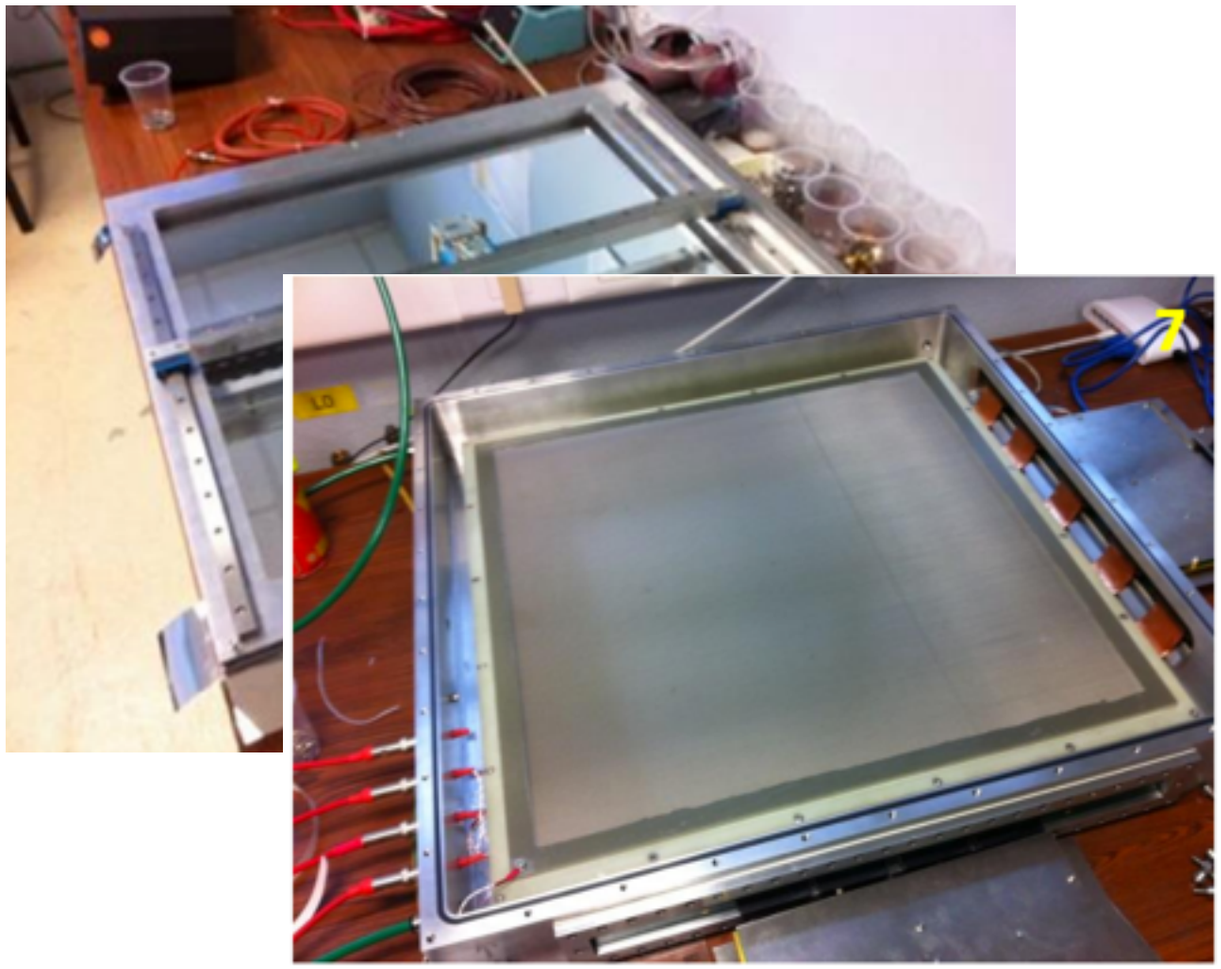




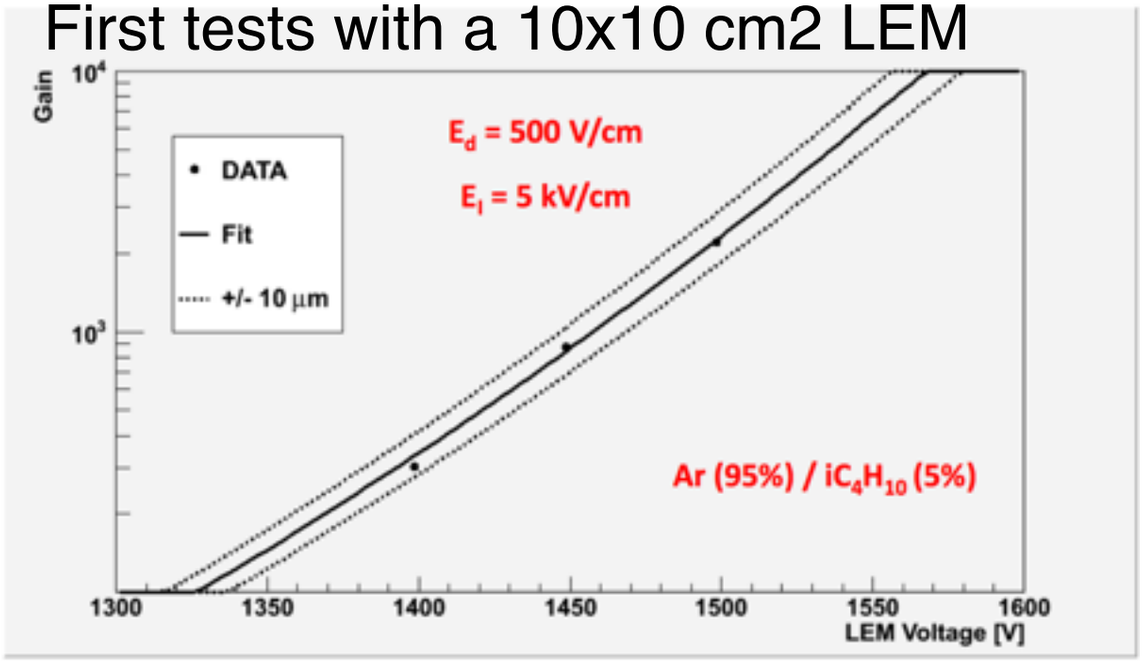
CAEN controllable 50 pA resolution HV power supply for long term characterisation of the LEMs

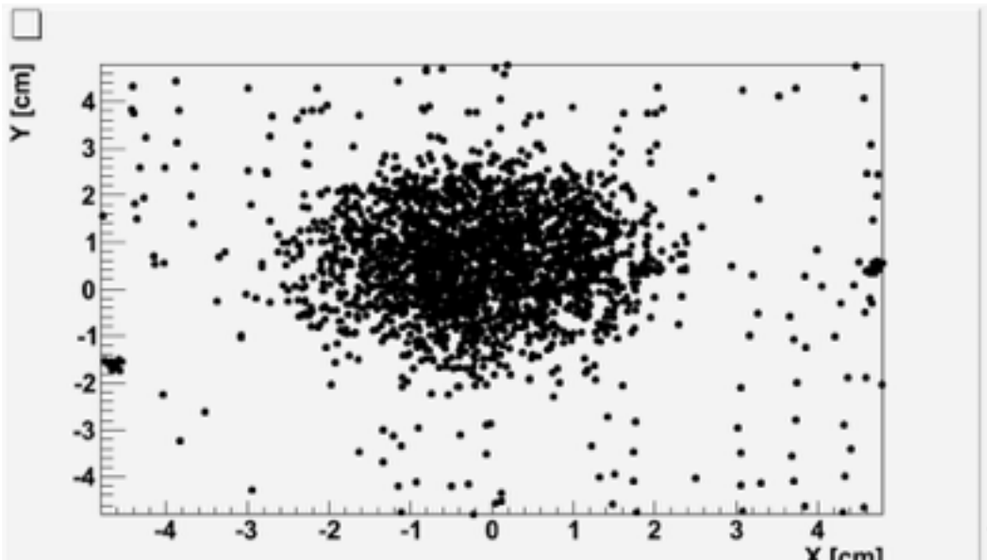
LEM characterisation

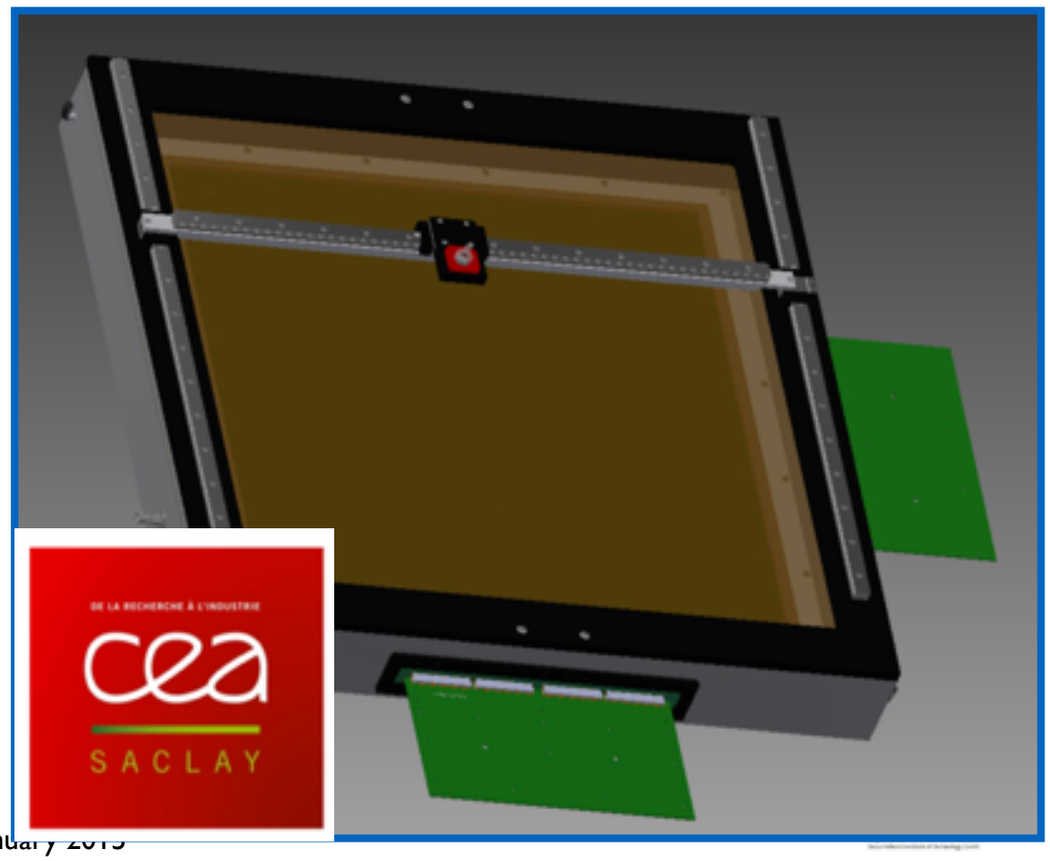
X,Y scan of the LEMs with ^{55}Fe to characterise the gain.



First tests with a 10x10 cm2 LEM

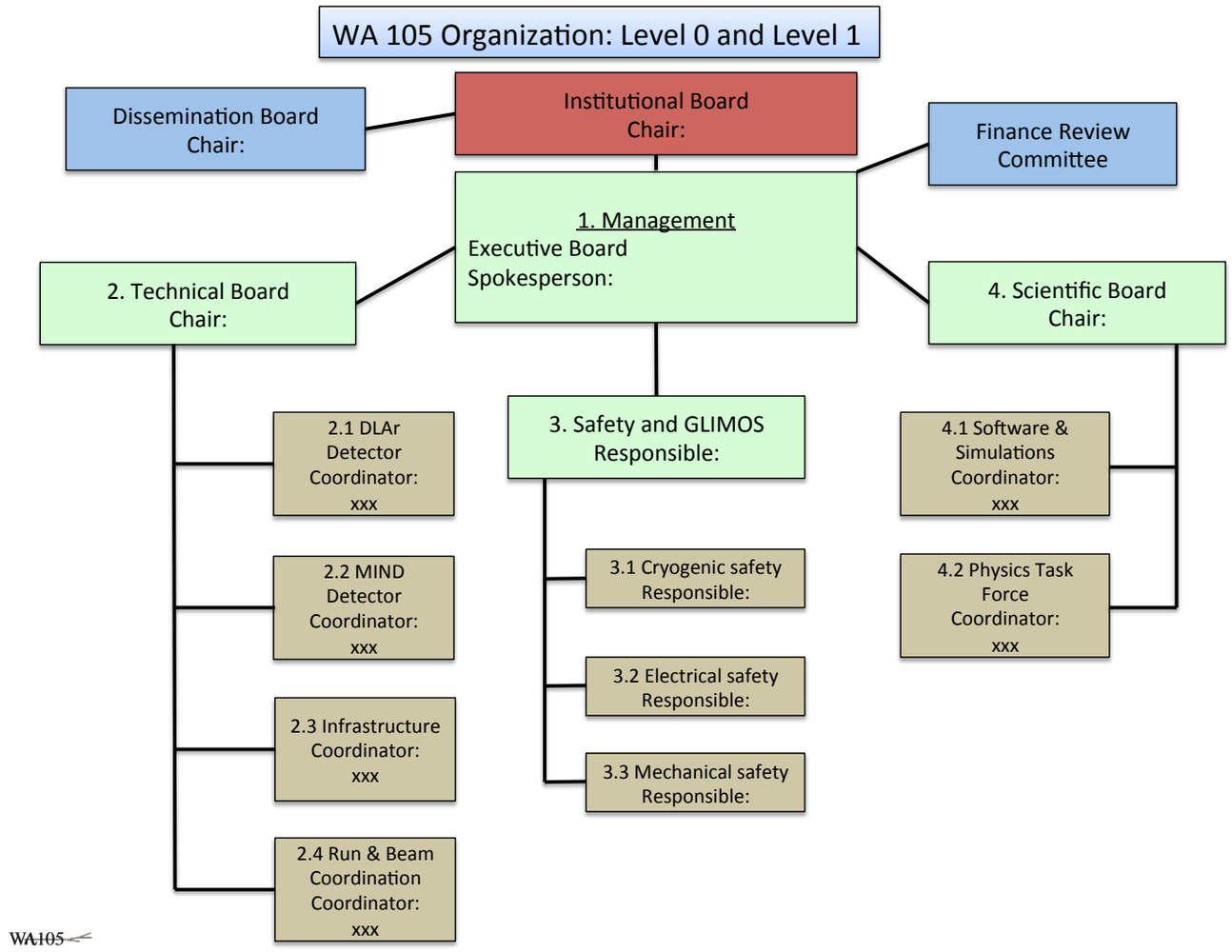






WA105 organisation

- The organisation of the Collaboration was defined in the **bylaws document**. It contains 16 articles approved by the Institution Board on December 8th, 2014.



- **Institution Board**
- **Executive Committee**
- **Spokesperson, Deputy-spokesperson**
- **Technical Board**
- **Scientific Board**
- **Dissemination Board**
- **Safety and GLIMOS**
- **Level 1 coordinators:**
  - ✤ DLAr detector coordinator
  - ✤ MIND detector coordinator
  - ✤ Infrastructure coordinator
  - ✤ Run coordinator
  - ✤ Software & simulation coordinator
  - ✤ Physics analysis coordinator