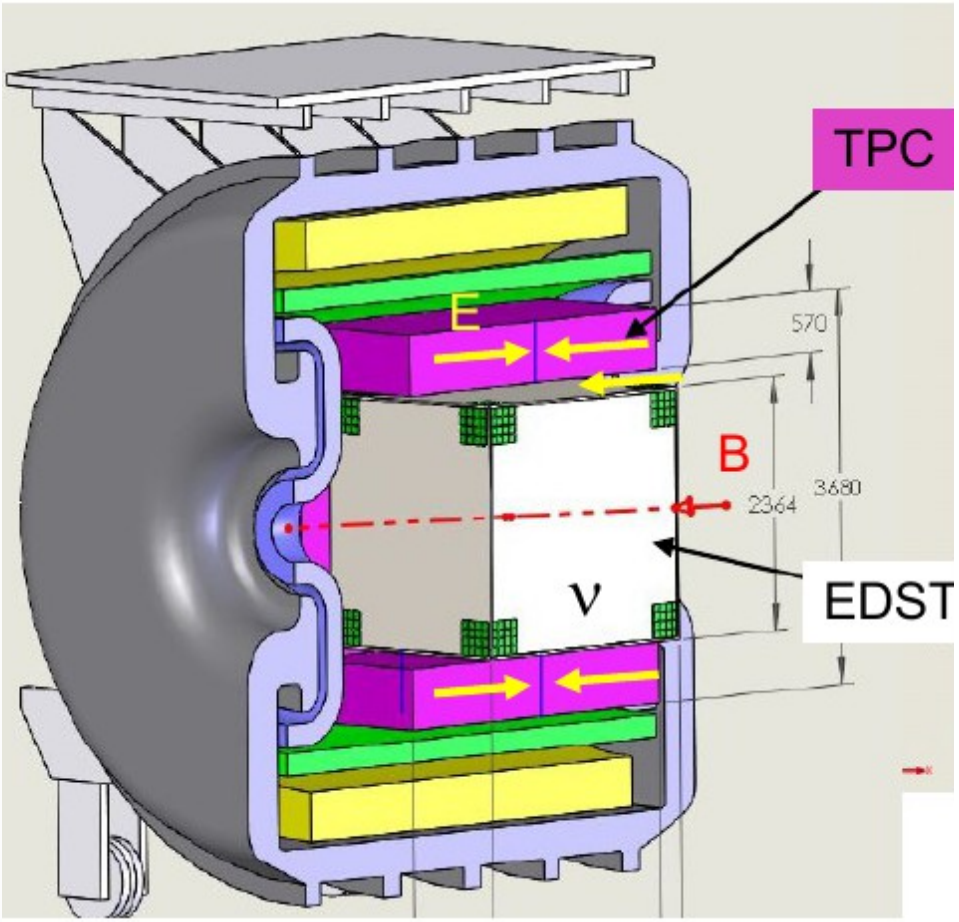
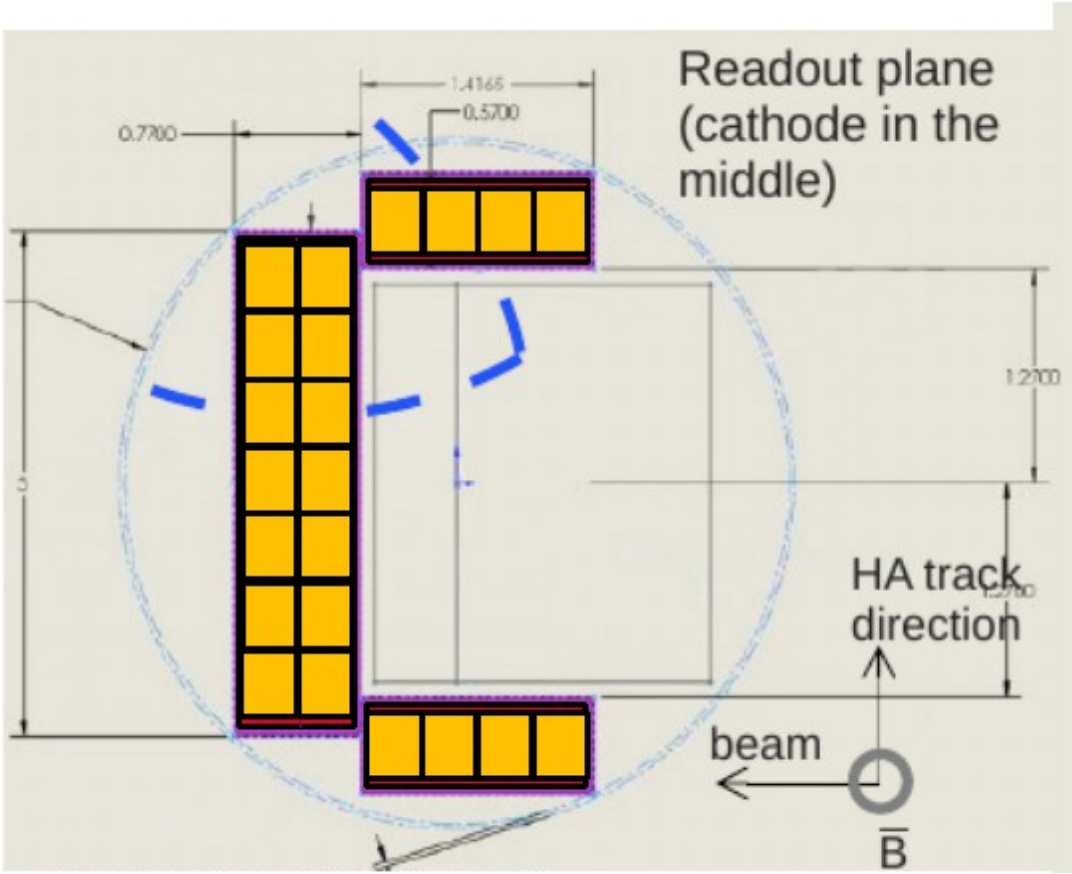
Time Projection Chambers for SAND

S.Bolognesi, A.Delbart, G.Eurin, P.Granger (IRFU, CEA)

SAND DUNE meeting – 30 July 2020

SAND TPCs





- **Momentum reconstruction:**

  Momentum resolution ~5-10% space point resolution depends on magnetic field and pad granularity

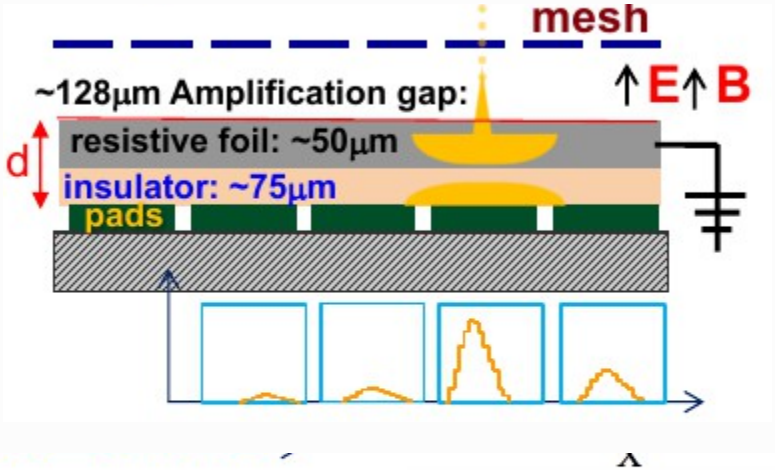
  Momentum scale ~2% depends on uniformity of Bfield, Efield, alignment → can be calibrated with K

- **Particle identification through dE/dx:**

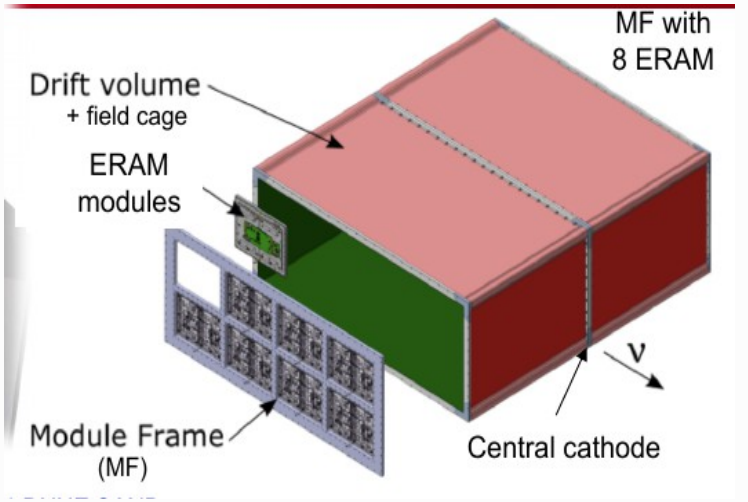
  Energy resolution ~10% (~45% more ionization for electrons than muon/pions)

A detector which we know how to build and stable!

The detector: resistive bulk Micromegas



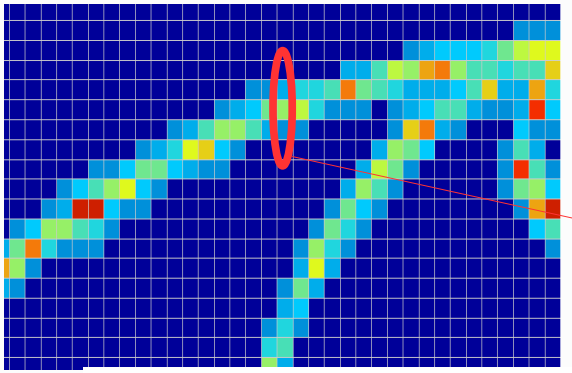
ND280 upgrade TPC

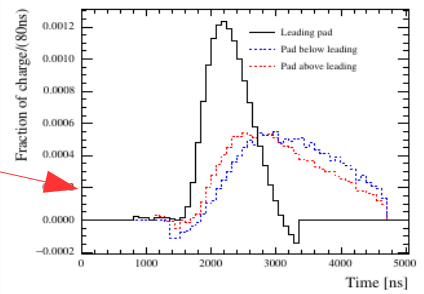


- **Charge spreading over multiple pads**

$$\sigma_r = \sqrt{\frac{2t}{RC}} \qquad \begin{cases} t \approx shaping\ time\ (few\ 100\ ns) \\ RC_{[ns/mm^2]} = \dfrac{180\ R_{[M\Omega/\blacksquare]}}{d_{[\mu m]}/175} \end{cases}$$

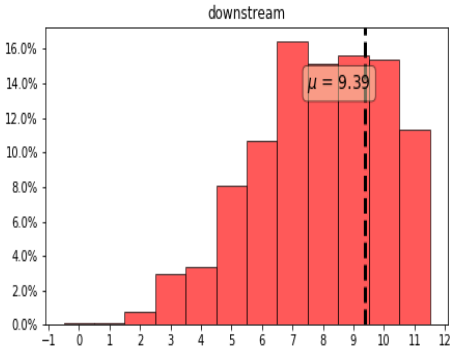
- **Test beam signal and event display**

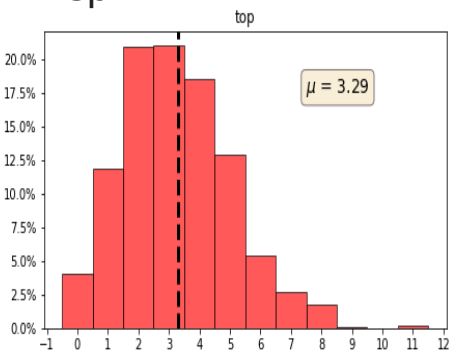


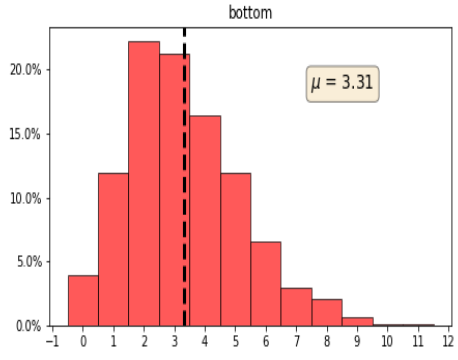


- Study on-going for **SAND: optimization of pad granularity / resistivity** → optimization of resolution with SAND occupancy

Number of tracks per DUNE spill







Electronics

Parameter	2x T2K/ HA-TPC 3	2+1 DUNE SAND
Overall x × y × z (m)	2.0 × 0.8 × 1.8	1,41 x 0,47 x 2,3 0,77 x 3 x 2,3
Drift distance (cm)	90	
Magnetic Field (T)	0.2	
Electric field (V/cm)	275	
Gas Ar-CF_4-iC_4H_{10} (%)	95 - 3 - 2	
Drift Velocity $cm/\mu s$	7.8	
Transverse diffusion ($\mu m/\sqrt{cm}$)	265	
Micromegas gain	1000	
Micromegas dim. z×y (mm)	340x420 (32)	340x420 (44)
Pad z × y (mm)	10 × 11	10x11
N pads	36864	50688
el. noise (ENC)	800	
S/N	100	
Sampling frequency (MHz)	25	
N time samples	511	

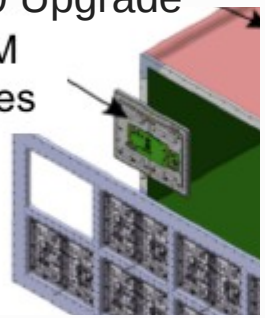
First estimates for SAND:

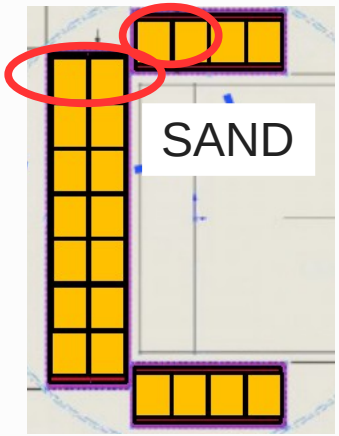
downstream TPC: 200x77cm2
→ 2x14 ERAM (42x34 cm2)

top/bottom TPCs: 2x57x141cm2
→ 2x2x4 ERAM (42x34 cm2)

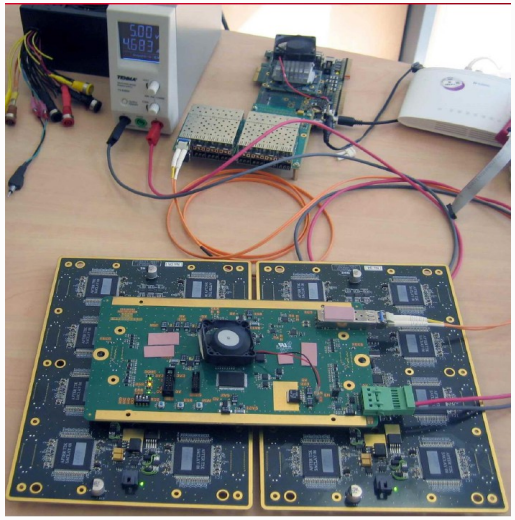
1152 channel/ERAM
→ 50688 channels
→ ~1000 ASICs

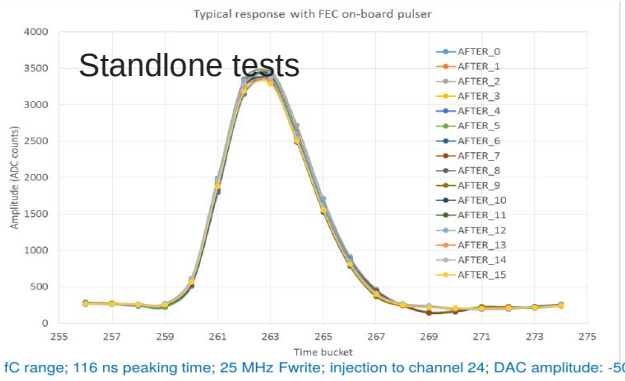
ND280 Upgrade ERAM modules



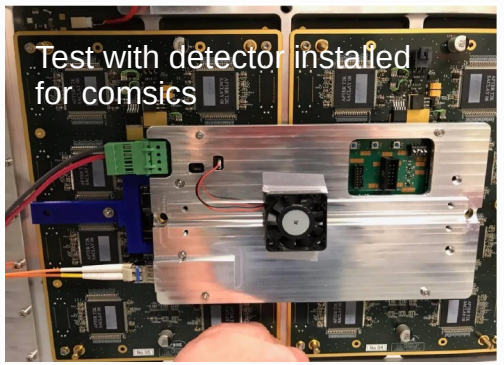


2 ERAM ND280 Upgrade:
2x8 ASICs
2 Front-End Card x 1 Front-End Mezzanine Card





120 fC range; 116 ns peaking time; 25 MHz Fwrite; injection to channel 24; DAC amplitude: -500 units



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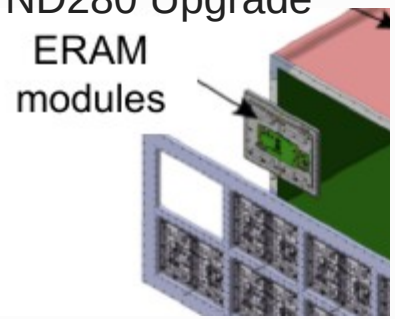

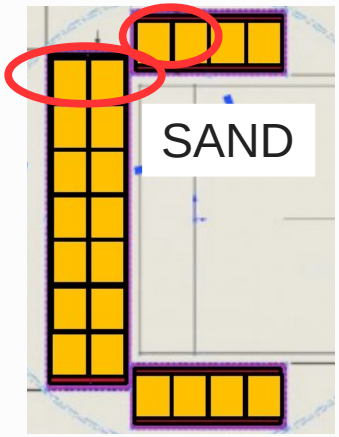

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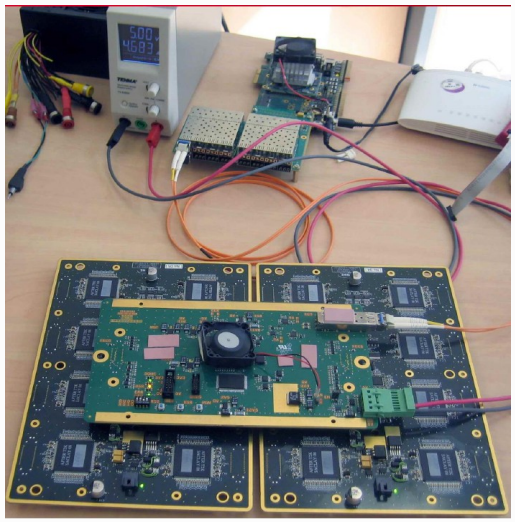
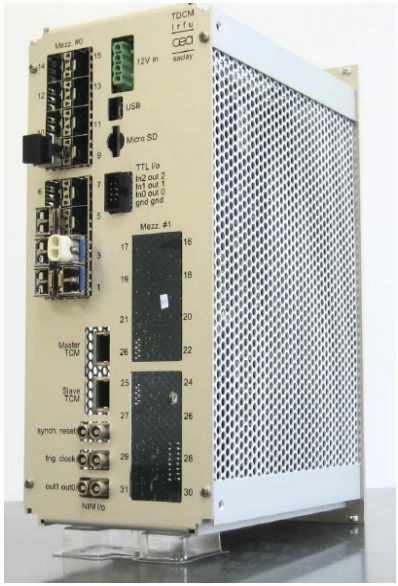
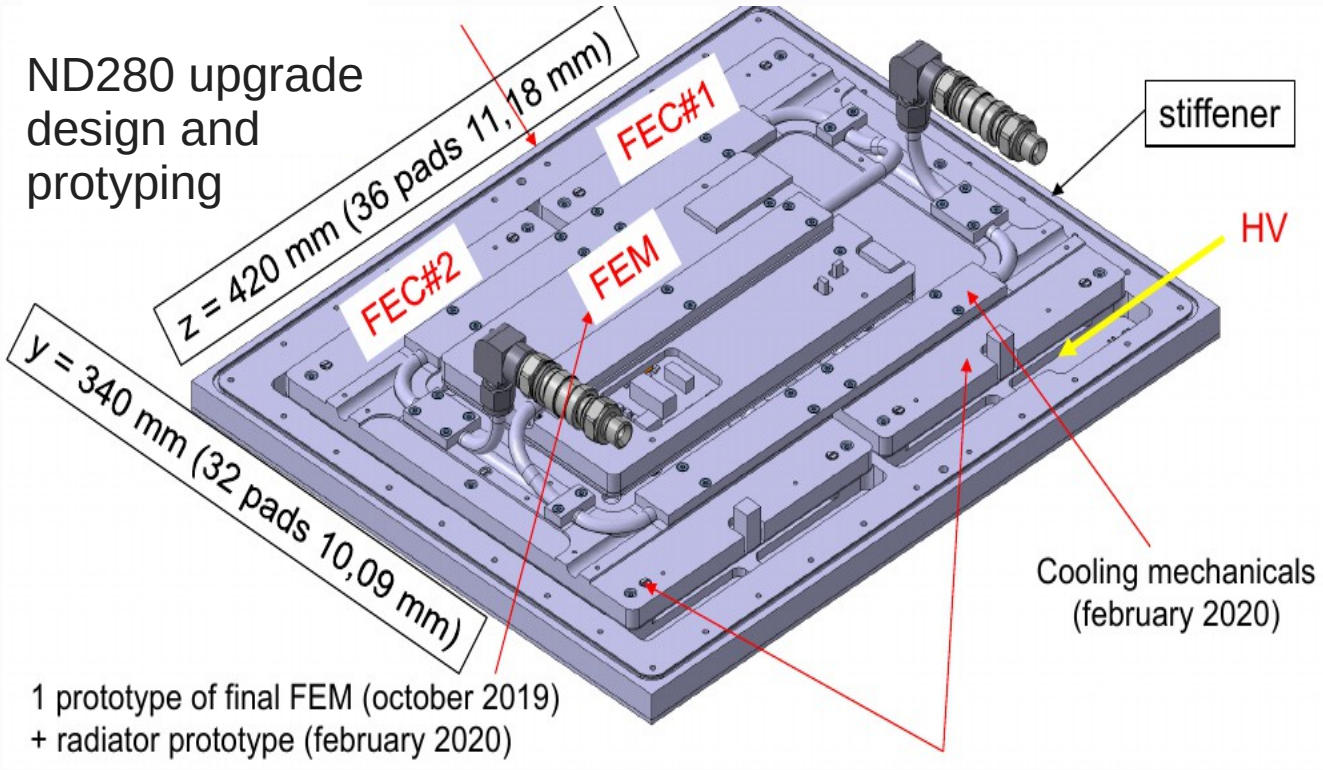


Back-End: 1 TDCM per ND280 upgrade TPC



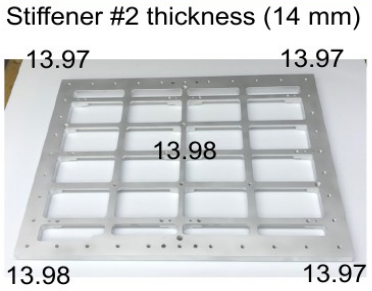
Mechanics/ cooling

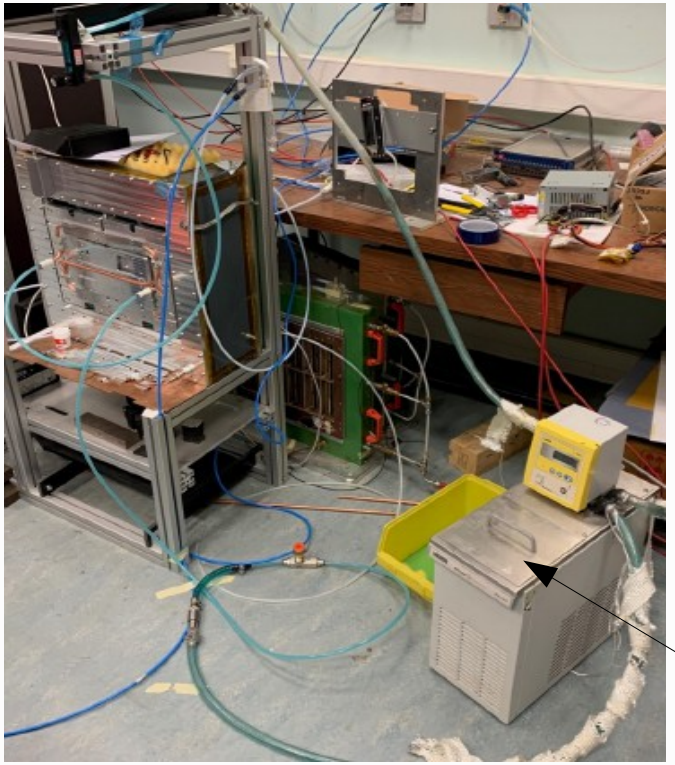
ND280 upgrade design and protyping



1 prototype of final FEM (october 2019)
+ radiator prototype (february 2020)

Full test of procedures

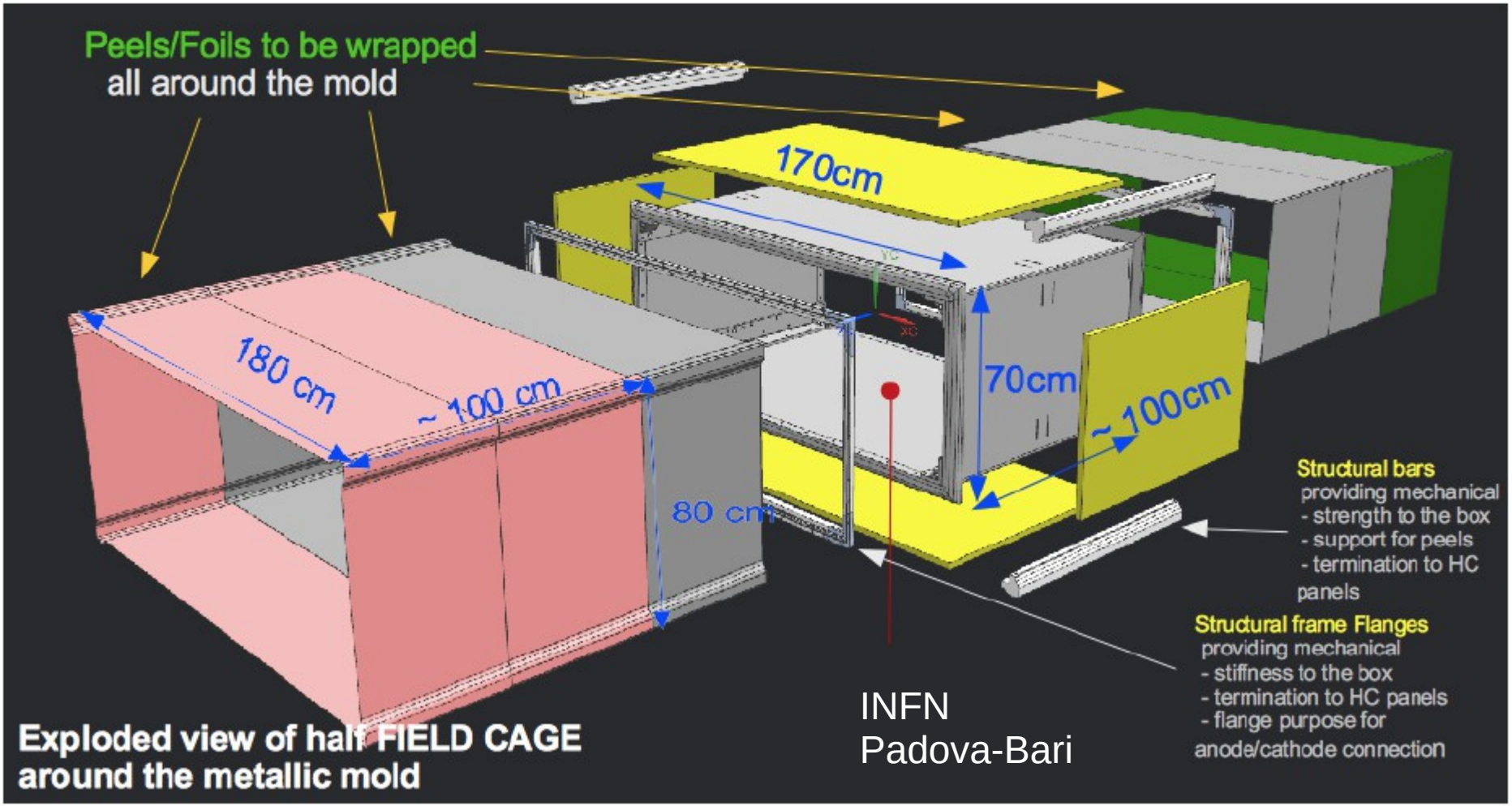




Cooling tests with new chiller at Saclay
re-usable for SAND tests

ND280 upgrade field cage

To keep $^{\Delta E}/_{E} \leq 10^{-4}$ confined at <1cm from FC walls, the TPC cage requirements are :
Cathode flatness better than 0.1mm, Micromegas plane flatness better than 0.2 mm,
Cathode/Anode planes parallel to within 0.2mm, Field Cage walls flatness better tham 0.3mm
Voltage divider resistors matched within rms ~ 0.1%



Prototyping

Protoypes for ND280 upgrade

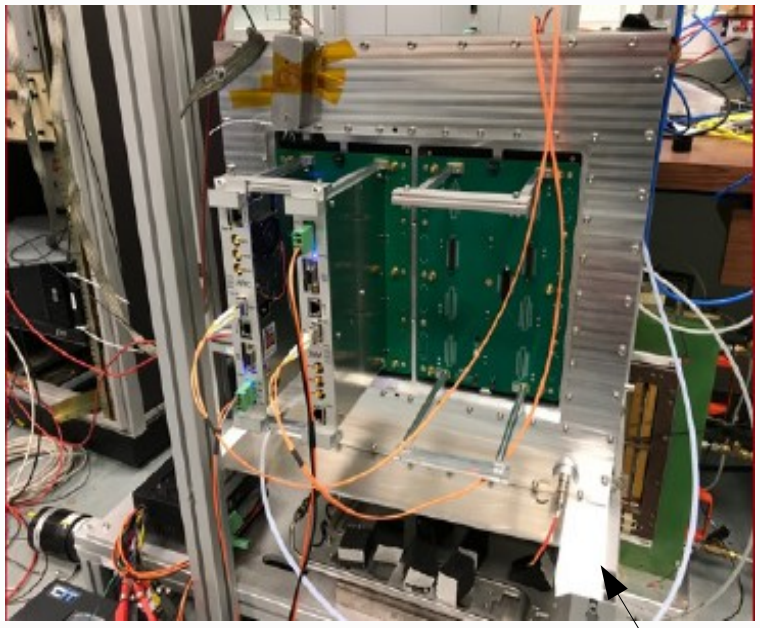
- *test beam at CERN 2018*: first prototype with large pads and resistive MM
- *test beam at DESY 2019:* optimized pad size and resistivity (with magnetic field)
- planned *test beam at DESY 2020* (with field cage prototype, final electronics and ERAM design)
- *multiple detector protypes* tested on dedicated **cosmic test bench at Saclay**
- **CERN platform** for *field cage tests and final TPC test with comsics*

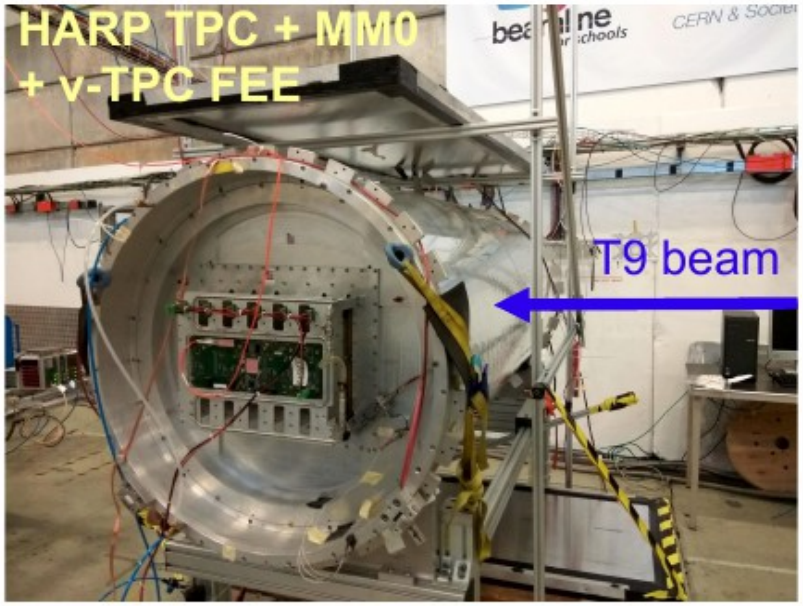
A lot of expertise developed and infrastructure built

SAND dedicated prototyping (30k financement secured):

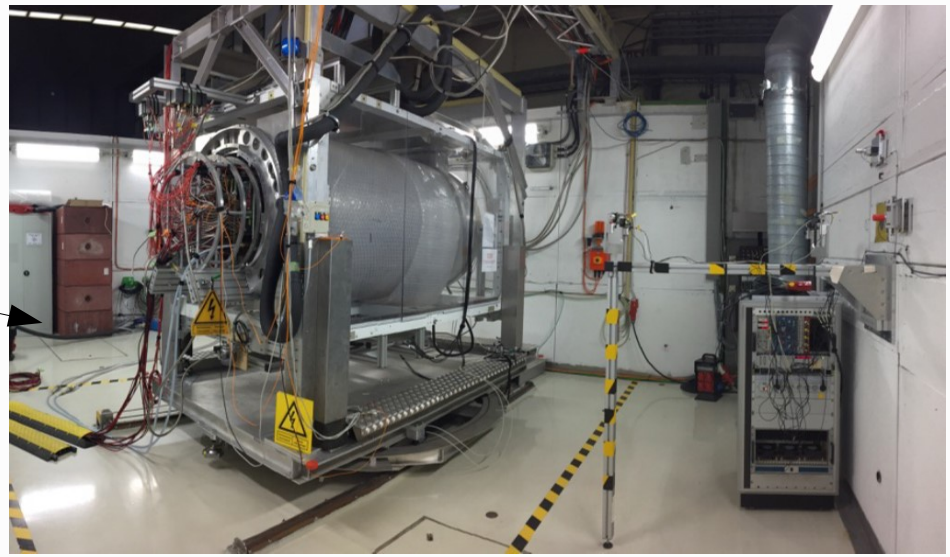
- new pad size and RC values: resistivity of DLC foil + glue thickness
- can be installed in Saclay cosmic bench (PMTs for trigger, gas, cooling, electronics, DAQ, … and even analysis code!)

Extensive tests on-going for ND280 upgrade



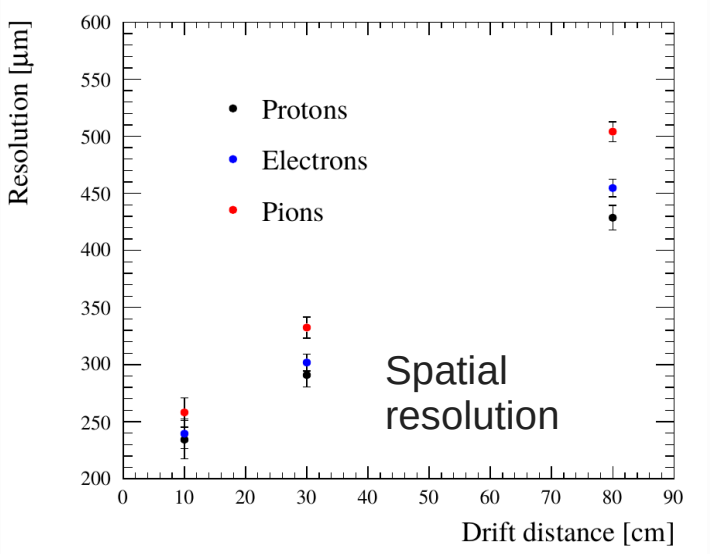


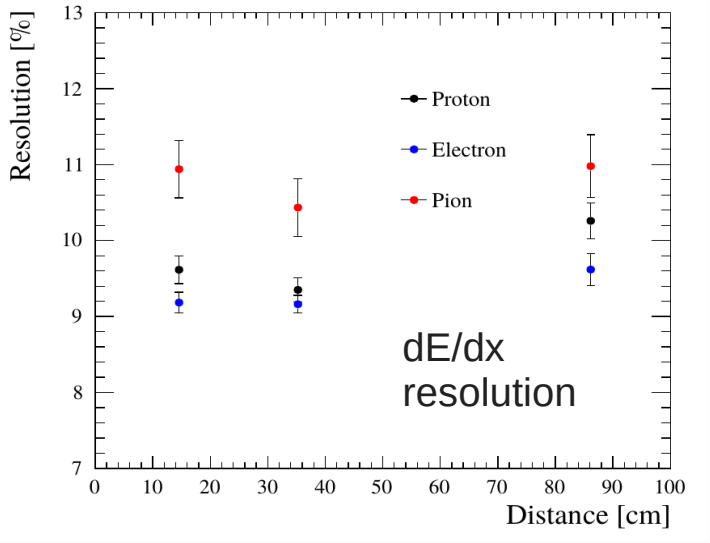
- **Cosmic test bench @ IRFU Saclay → available for SAND R&D**
- Test beam at CERN in 2018
- Test beam at DESY, with magnetic field, in 2019
- Test beam at DESY planned in 2020 with field cage prototype, complete ERAM (detector, mechanics, electronics, cooling)
- Installation at ND280 in summer 2022



Performances

Results from **preliminary prototype at CERN in 2018**: pad 9.8x7mm² with large R and 200microns glue

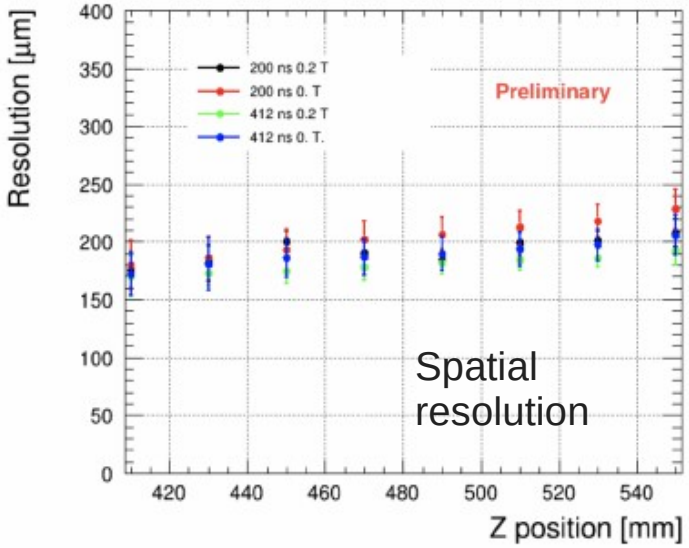


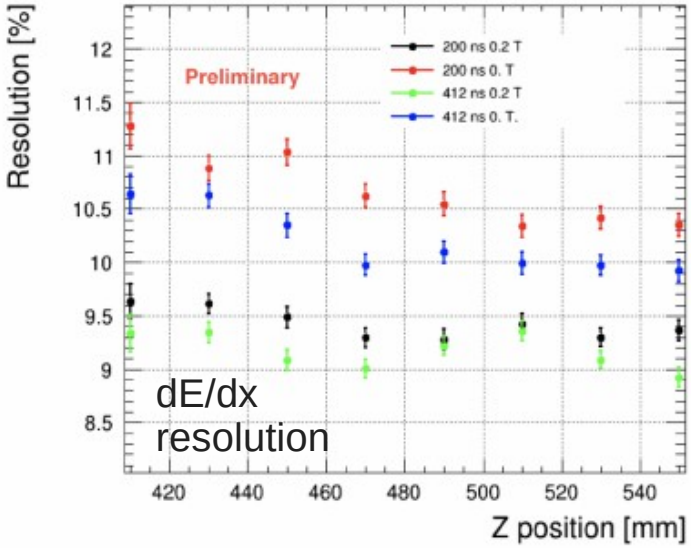


Nucl.Instrum.Meth.A 957 (2020) 163286

Even better results at **DESY in 2019 with final pad design** (10x11mm²) **and improved RC:**
R~0,25 Mohm/sq and 75 microns glue → RC~50 ns/mm²

preliminary spatial resolution factor 3-4 better than present T2K TPCs

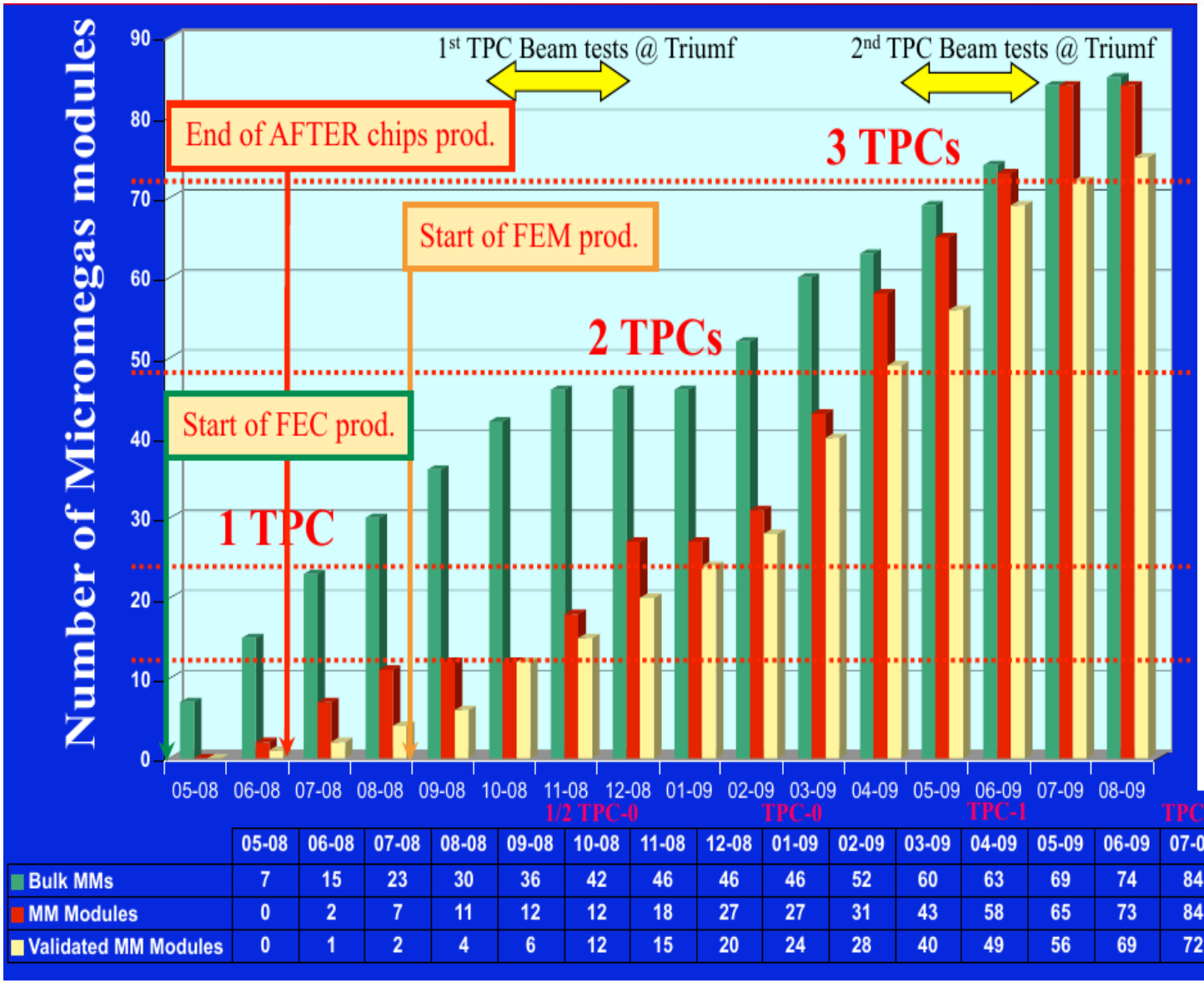




arXiv:2005.05695

T2K TPC: a success story

The decision on technology must consider the **prospects for production**



	05-08	06-08	07-08	08-08	09-08	10-08	11-08	12-08	01-09	02-09	03-09	04-09	05-09	06-09	07-09	08-09
Bulk MMs	7	15	23	30	36	42	46	46	46	52	60	63	69	74	84	85
MM Modules	0	2	7	11	12	12	18	27	27	31	43	58	65	73	84	84
Validated MM Modules	0	1	2	4	6	12	15	20	24	28	40	49	56	69	72	75

Final percentage of good modules/produced:
Micromegas (82/89) 92%
FEC (499/514) 97%
FEM (84/93) 90%

12 **dead MM channels** over 124272 channels (0.01%)

10 years of operation with only 1 FEM failure and 2HV filters to repair

Production for ND280 upgrade

- The Resistive Micromegas (ERAM) is also a **bulk-micromegas: mature technology, mastered by CERN, IRFU & some PCB industrials**

- ERAM integrates a new element: DLC foil to provide the resistivity for the charge spreading. ND280 upgrade (production of 32 modules) will **secure the path for production for SAND (DLC procurements, production yield, ...)**

ERAM design almost validated for production : only RC optimization through the choice of glue thickness needs to be fixed after last prototype tests by this fall

→ **series production of ERAM detector & its Front-End Electronics (FEC & FEM) planned to start at the end of the year**

SAND TPC cost estimate

Including only hardware (no manpower, travels, common funds, technical coordination, ...)

Chips	230 keuros
Front-End + Back-End	215 keuros
Field cage	1.000 keuros
Services (HV, LV, gas system)	350 keuros
Cooling	165 keuros
Detectors ERAM	300 keuros
Total	**2260 keuros**

Interest of IRFU to design a new chip

Highly depends on final design: interesting R&D on resistive field cage (as in ArgonCube)

Except for the cage, these are pretty accurate estimates (excluding only shipping and integration of TPC in KLOE)

Summary

The expertise and infrastructures developed for ND280 vertical TPCs and ND280-Upgrade horizontal TPCs are a phenomenal advantage in the path to build SAND TPCs

Studies on-going to adapt the design: some financing (30k euros) secured to produce **prototypes to install on Saclay comsics test-bench**

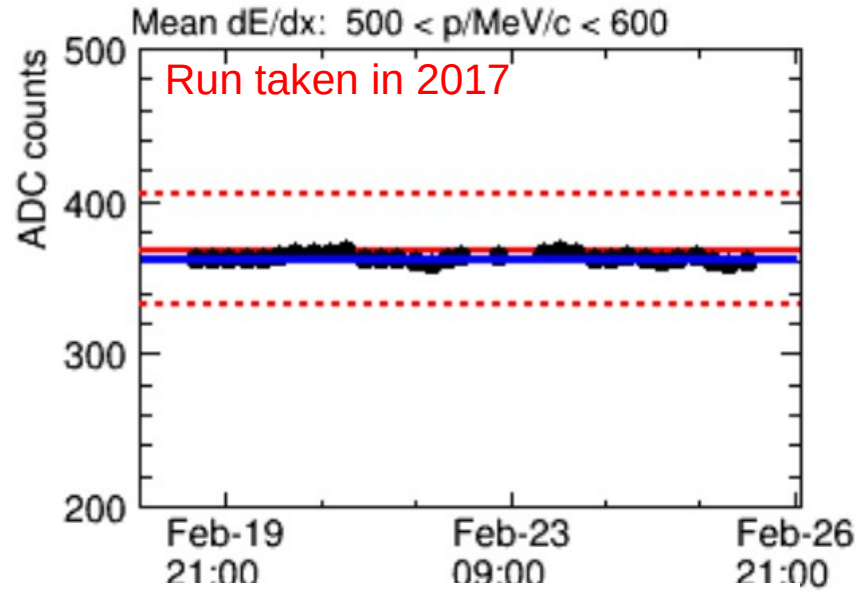
Clear path to design and build ERAM, electronics, mechanics, infrastructures (gas, cooling, ...)

Preliminary cost estimates available. Discussion on-going on the financing:

- design of SAND at day-0? → spending profile
- looking forward to collaborators

Astonishing stability/reliability in 10 years

Mean dE/dx from cosmics



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