DE LA RECHERCHE À L'INDUSTRIE

CEA - Saclay

Magic Numbers Off Stability

www.cea.fr

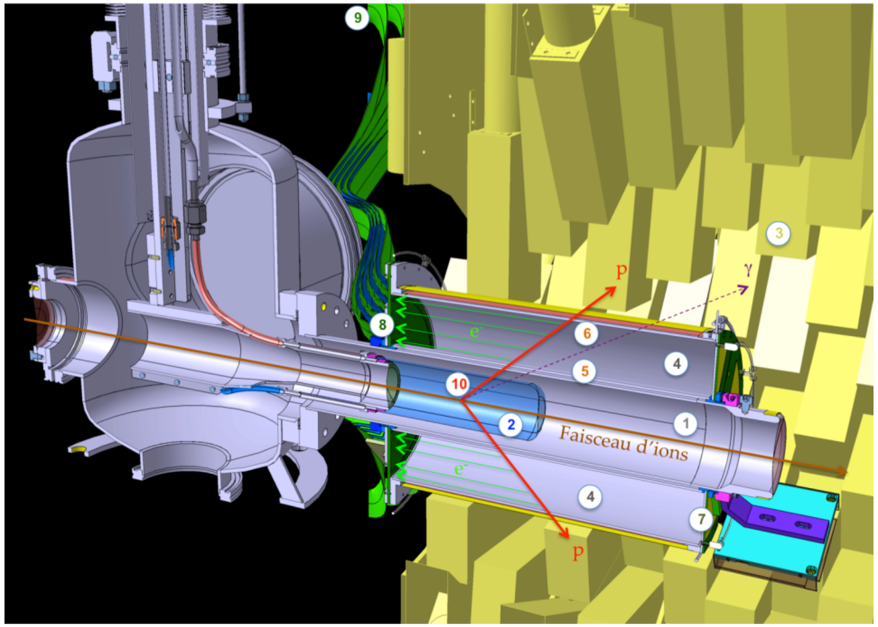
THE MINOS TPC

FOR THE SPECTROSCOPY OF THE MOST EXOTIC NUCLEI

Alain Delbart (CEA-Irfu)

DETECTORS, ELECTRONICS & COMPUTING DIVISION

SERVICE D'ELECTRONIQUE, DES DÉTECTEURS, D'INFORMATIQUE



A. Obertelli *et al.*, Eur. Phys. Jour. A **50**, 8 (2014)

http://minos.cea.fr

journée annuelle "Détecteurs gazeux" du réseau Instrumentation In2P3

Subatech, 3 septembre 2015

OUTLINE

- MINOS (MagIc Numbers Off Stability) : context and scientific cases

- The MINOS Vertex detector : history and description of the technical choices
  - ✓ TPC Vs cylindrical Tracker
  - ✓ Gas choice
  - ✓ Electric field cage : a design greatly inspired by the PANDA TPC
  - ✓ The TPC 2D imaging readout plane (RP) : a Micromegas MPGD
  - ✓ The TPC readout electronics and its connection to the RP (D. Calvet)

- The TPC validation with an ion beam and its first use in an experiment @ RIKEN

- Conclusion et perspectives

MINOS – MagIc Number Off Stability (ERC grant)
Contexte scientifique

ERC grant allocated in november 2010, for 5 years, 1,1 M€ (incl. 286 k€ Postdoc, 400 k€ invest, 85k€ exp)

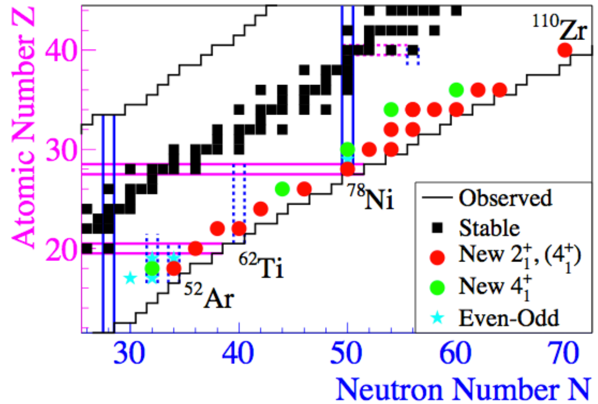
Physics motivations:

Study of the shell structure of very exotic and unstable nuclei on new generation radioactive beams

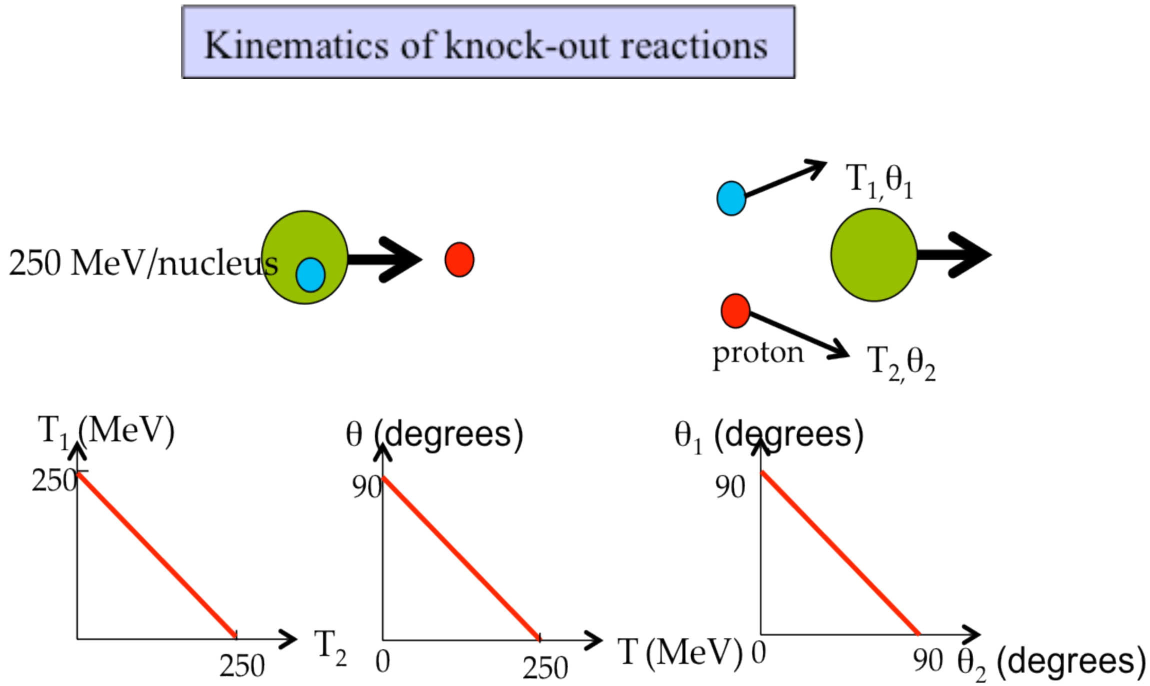
Instrumental method:

Gamma spectroscopy of knock-out reactions of radioactive nuclei impinging on a proton rich target

Innovation: Improving luminosity and preserving gamma energy resolution by coupling a thick liquid hydrogen target with a TPC to localise the vertex with 4 mm resolution and apply Doppler corrections to measured γ energies in the spectrometer (DALI2 @RIKEN or AGATA @FAIR)

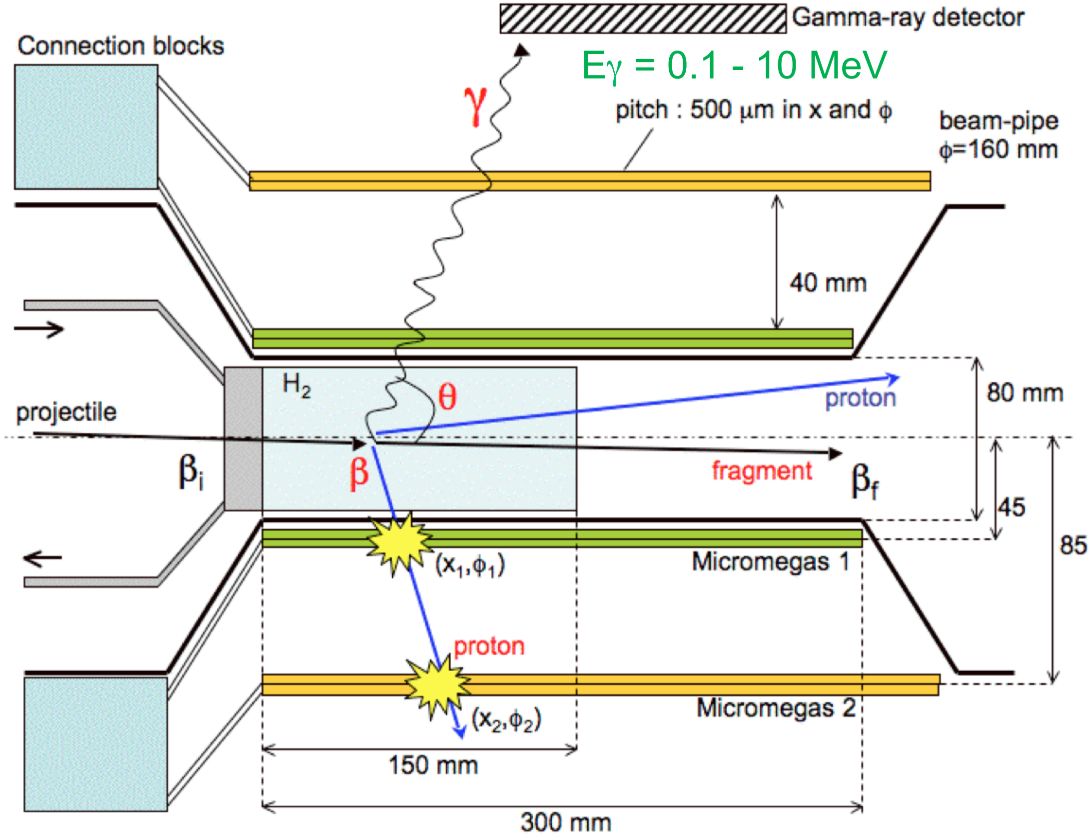


2010	ERC grant, PI: A. Obertelli
2011	simulations and design construction proposal endorsed by RIBF NP-PAC
2012	construction MOU between RIKEN Nishina Center and DSM
2013	in beam validation at HIMAC experiments approved by RIBF NP-PAC *(spokespersons: CEA-RNC-CNS-TiTech)*
2014	first two experiments at RIBF



Méthode expérimentale, preliminary design

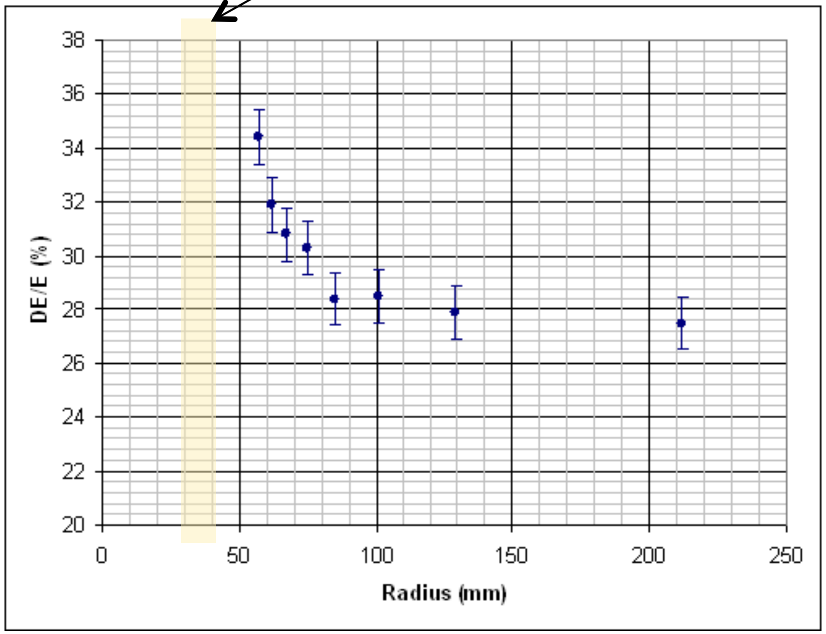
Liquid hydrogen target vs 1-cm Be target: luminosity × 5



Correction Doppler

$$E = E_\gamma \frac{(1-\beta\cos\theta)}{\sqrt{1-\beta^2}}$$

MINOS inner tracker radius

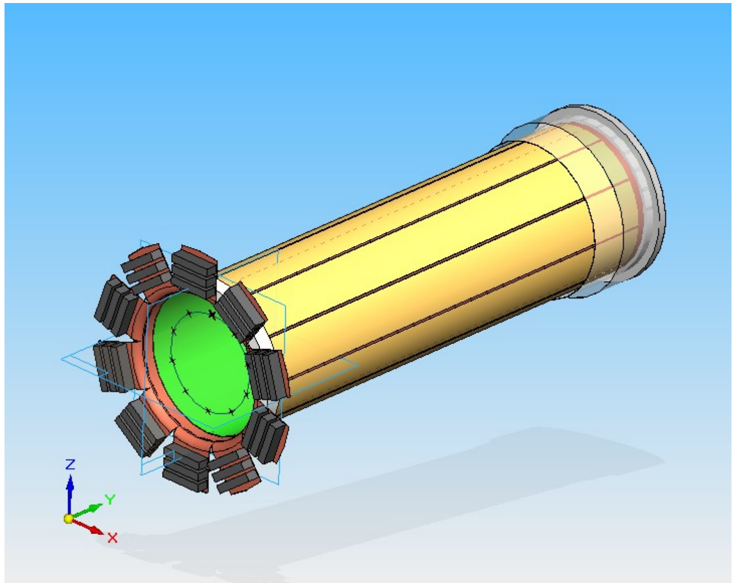


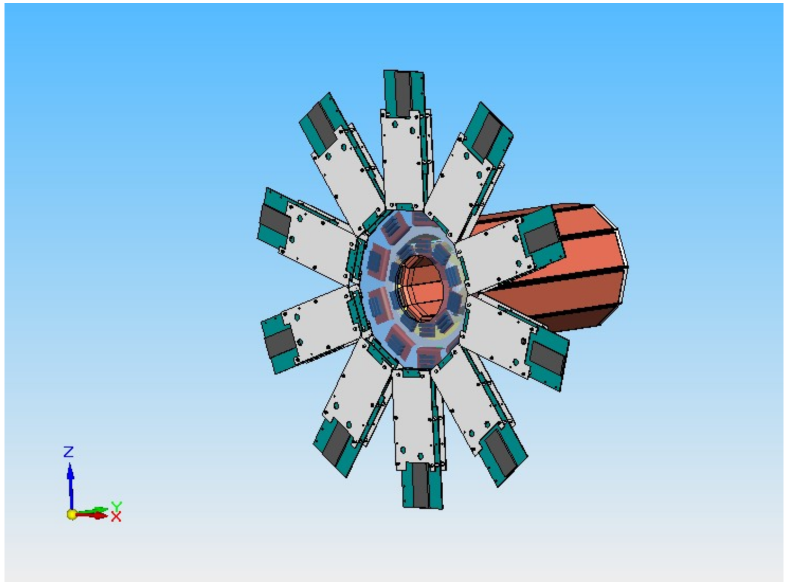
CLAS12 cylindrical prototype (2009)

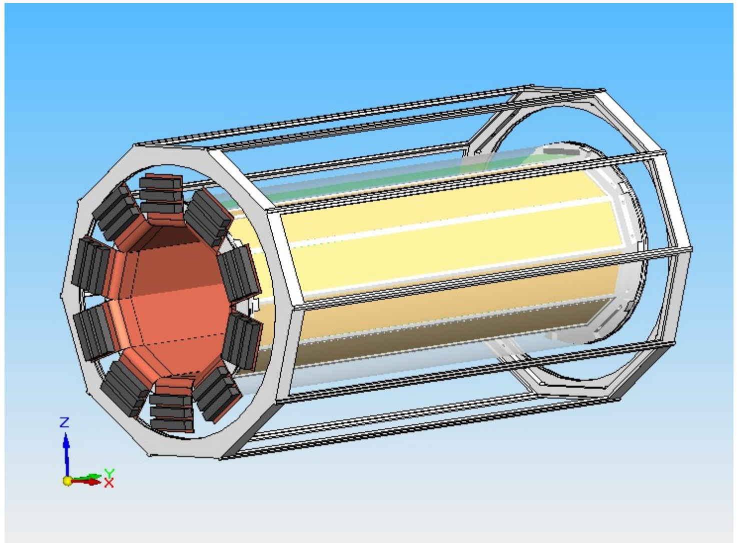
Cylindrical micromegas tracker drawbacks

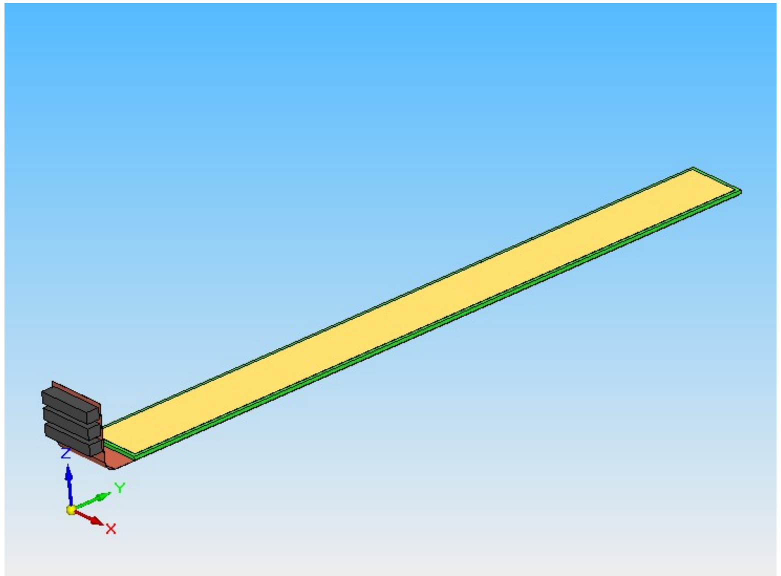
- A 2-3 orders of magnitude greater sparking probability than in TPC mode
- Feasibility for ≈30-40 mm radius of curvature ?
- 4 layers of cathodes, high capacitance strips, extraction of signals, higher radiation length, …

FIRST IDEAS FOR 2 TRACKER CYLINDERS

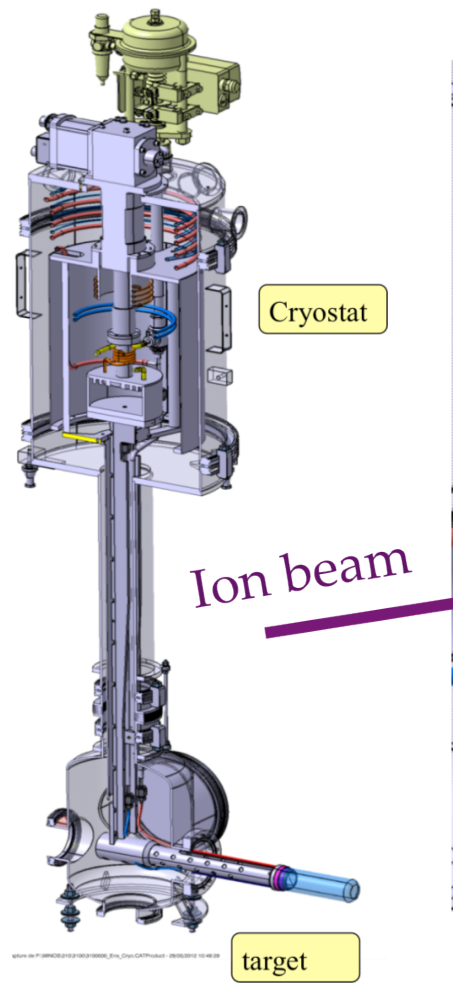




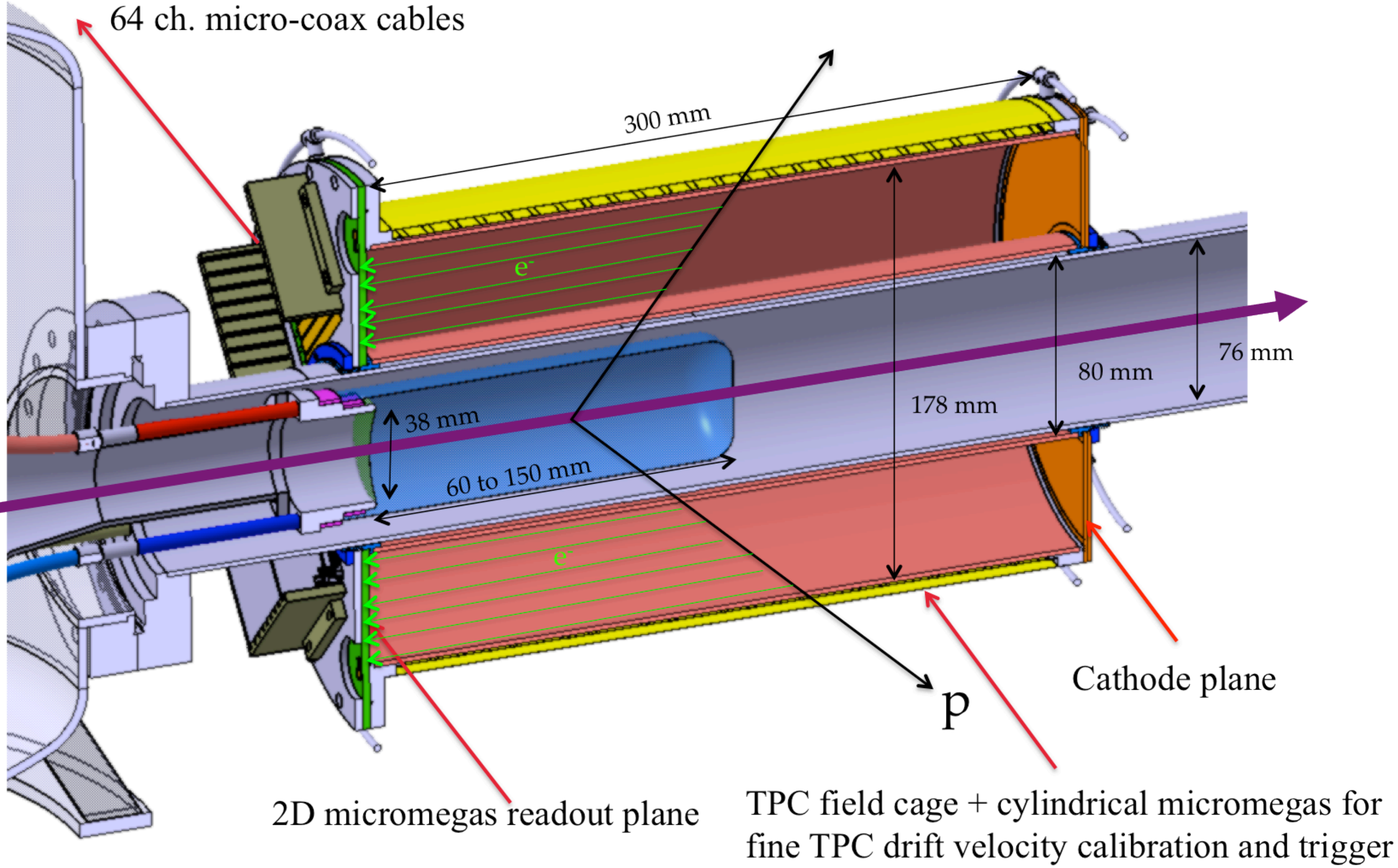




THE MICROMEGAS READOUT TPC OF MINOS



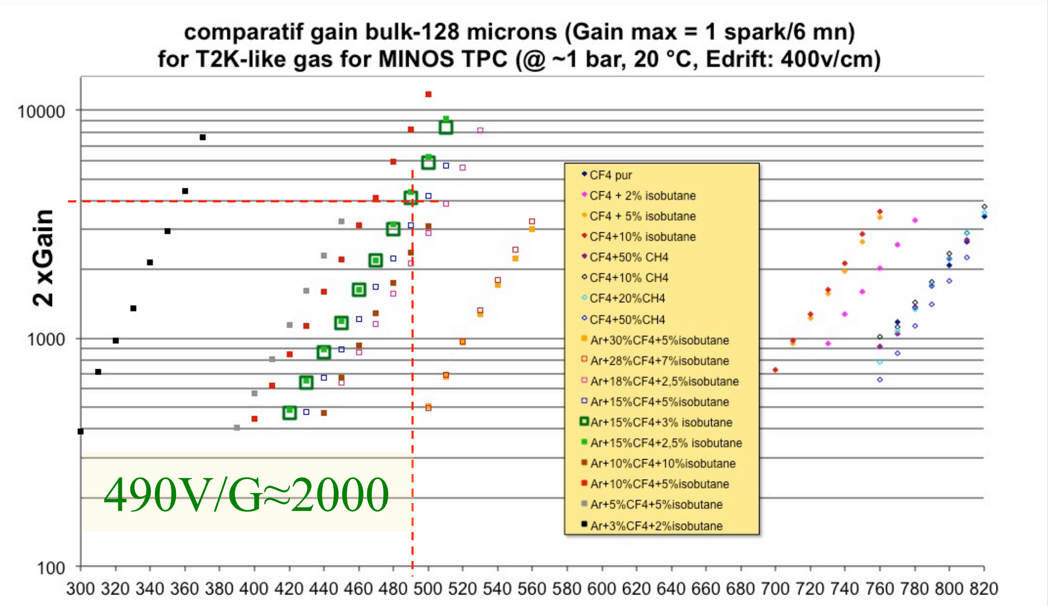
No magnetic field !

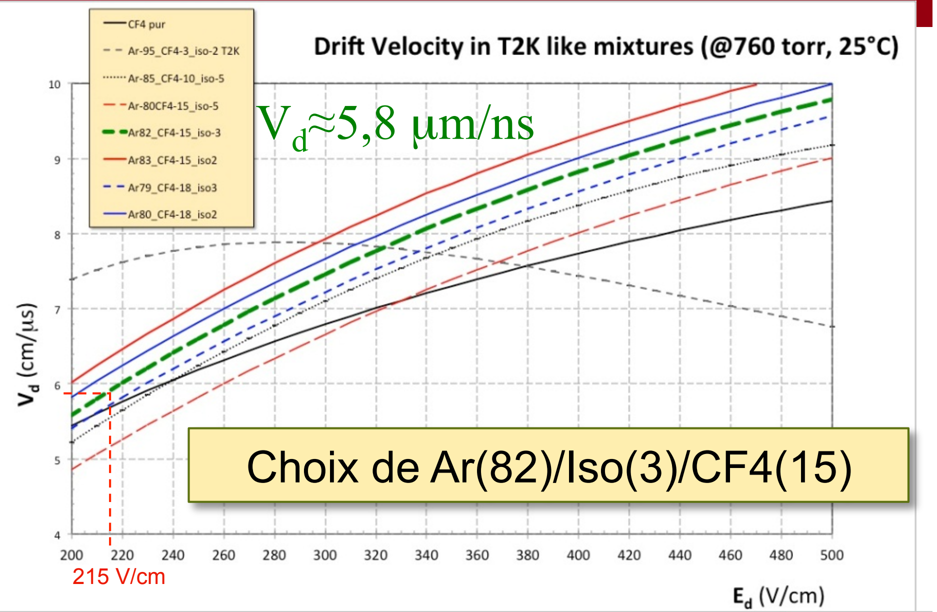


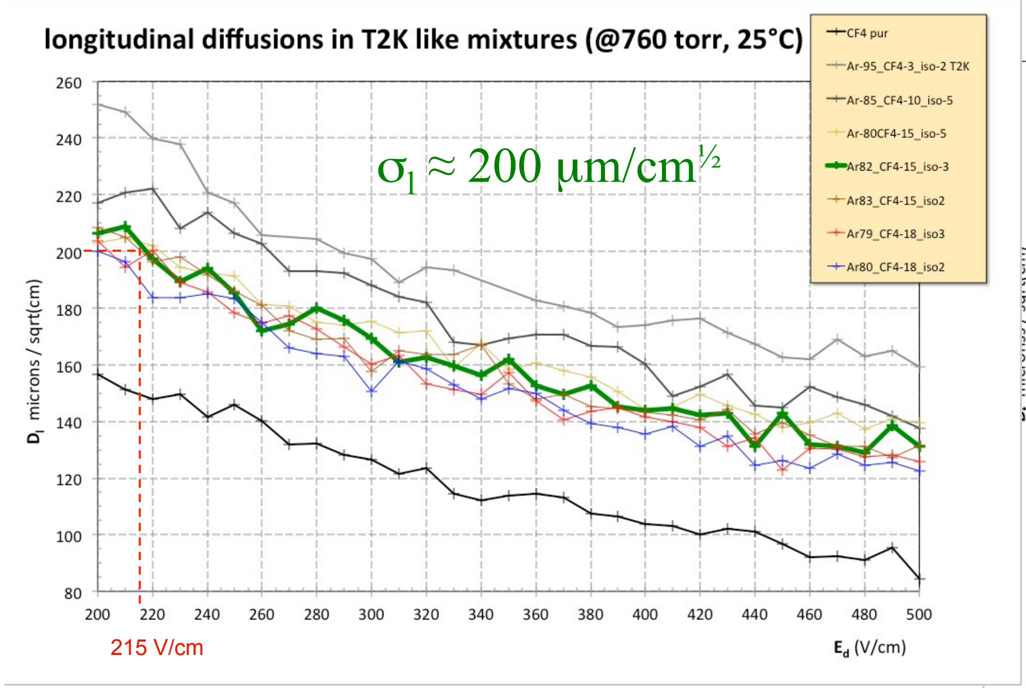
The MINOS Vertex tracker

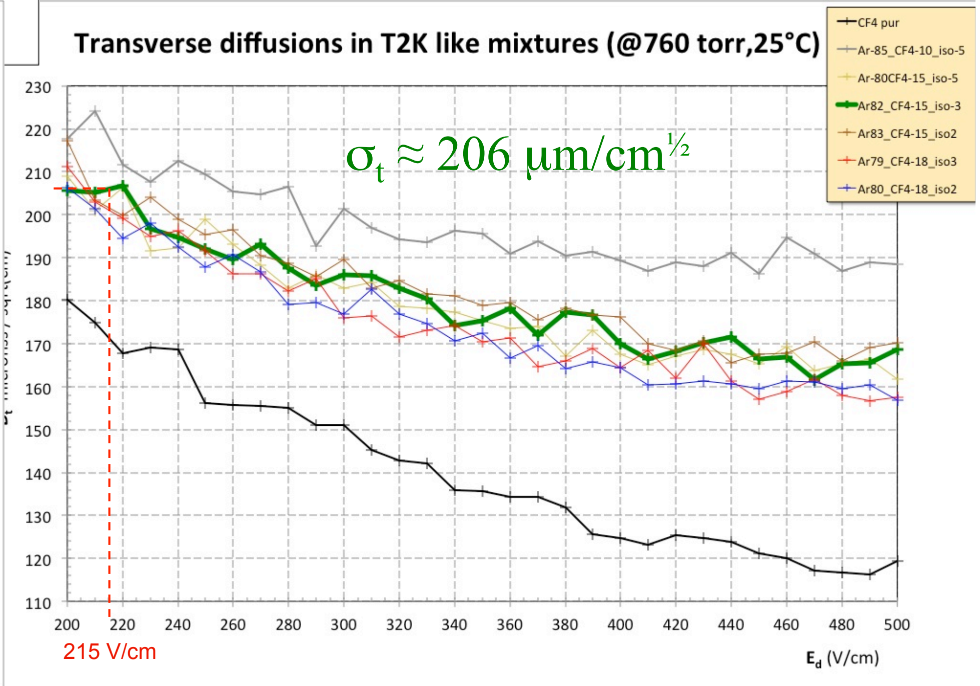
A compact cylindrical TPC readout with a bulk-micromegas pad plane and GET electronics, surrounded by a cylindrical micromegas tracker and two DSSD beam monitors (up&downstream)

TPC GAS CHOICE



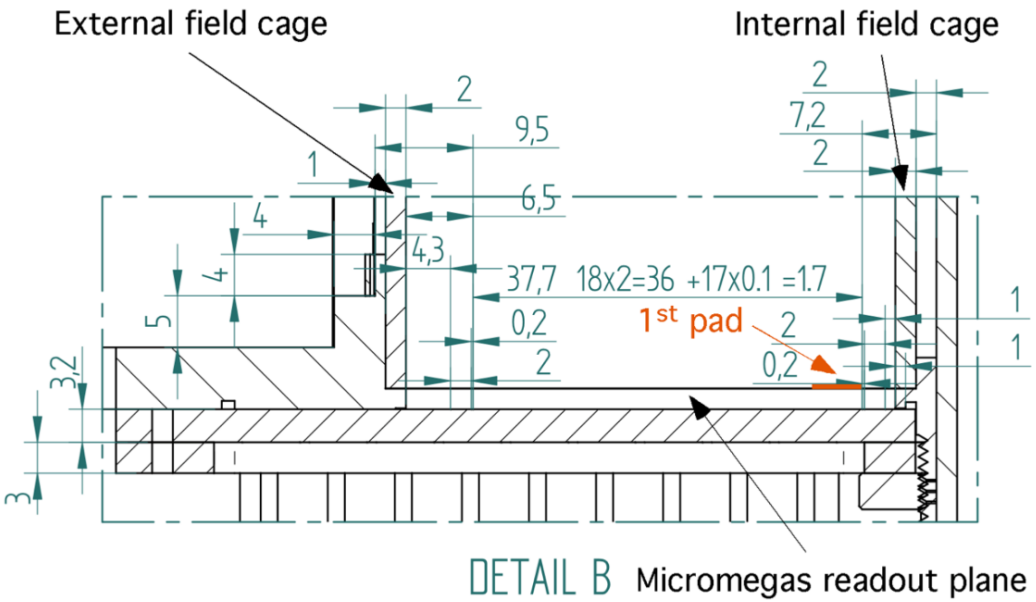


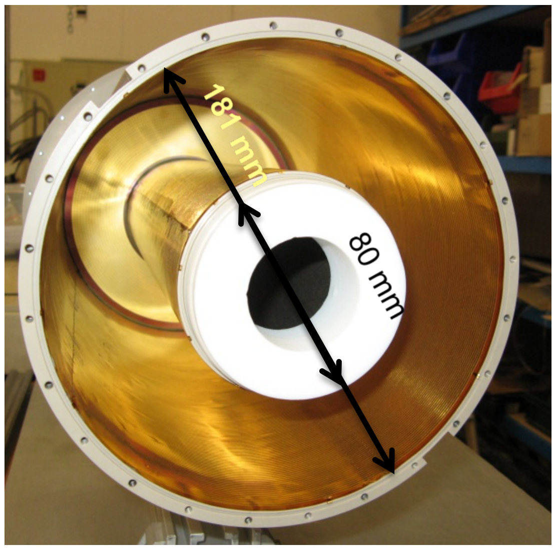




THE TPC MECHANICAL STRUCTURE

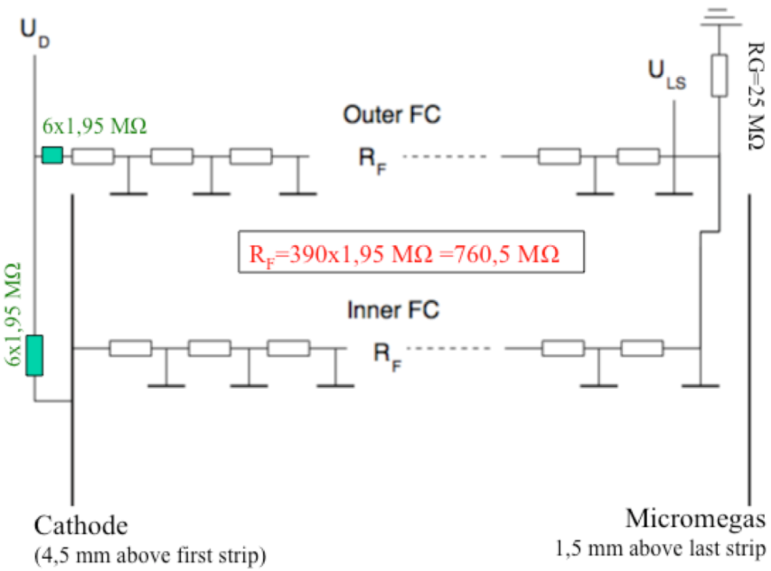
✓ A very compact and light structure made of 2 mm thick Rohacell cylinders
→ The challenge is to efficiently and accurately measure the proton tracks as soon as they exit the target (the first active pad is 7,2 mm from vacuum pipe)
✓ Solder free electrical connections between field cages and endcaps
✓ Cathode & micromegas endcaps can easily be dismounted (1 mm O-rings)
✓ Gas leaks (<0,05 l/h) are balanced with a 10 l/h gas flow to maintain H_2O & O_2 contaminations below measured 700 ppm & 40 ppm respectively
✓ 2 gas mixtures : baseline $Ar+3\%iC_4H_{10}+15\%CF_4$ & backup $Ar+3\%iC_4H_{10}$

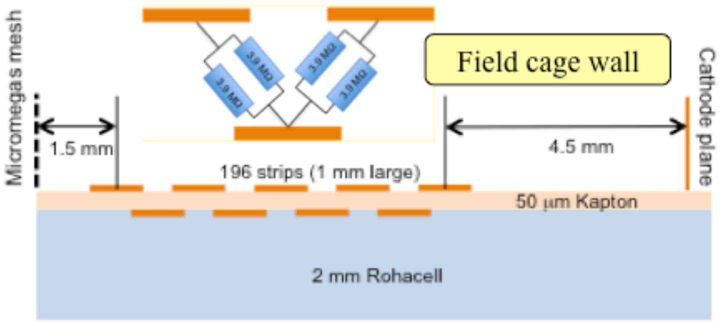




THE TPC FIELD CAGE

- ✓ The design is greatly inspired by the PANDA TPC electric field cage
- ✓ The drift field is defined by 196 + 195 strips, 1 mm large, printed with a 1,5 mm pitch on both side of a 50 µm thick gas tight kapton foil (made by CERN/TE-MPE-EM) glued on the internal & external Rohacell cylinders
- ✓ 2 x 3,9 MΩ (+/-1%) SMD805 resistors are soldered between 2 strip
- ✓ The 195 resistors between 2 adjacent strips are measured : a typical measure is 3889,8 kΩ mean value with 0,25% peak-peak dispersion
- ✓ a HV power supply is used to precisely define the last strip voltage



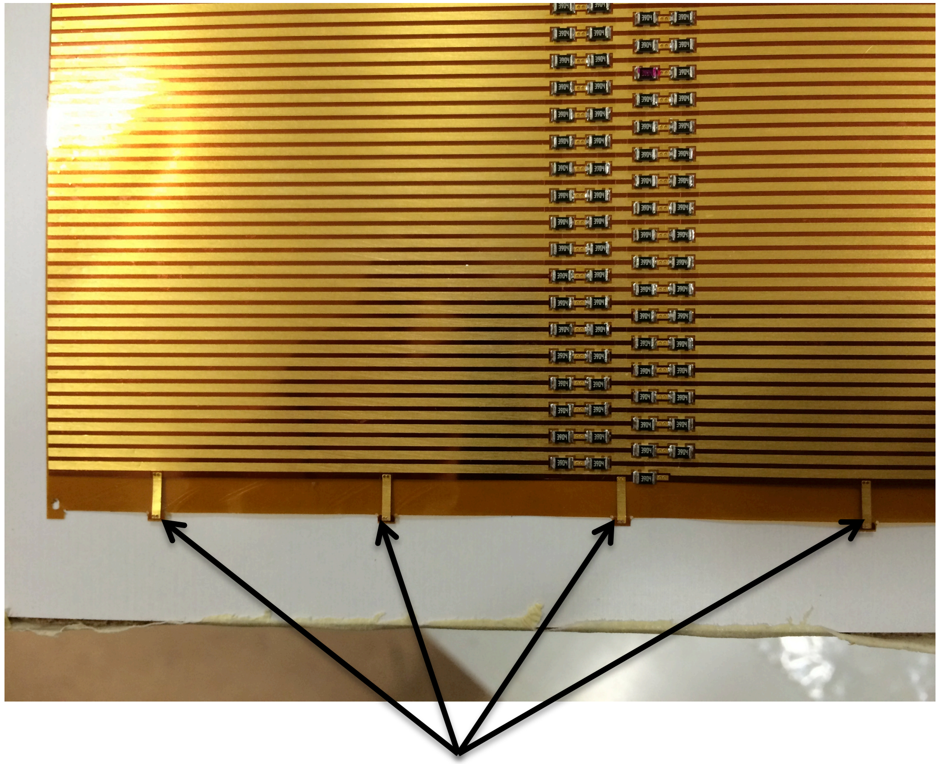


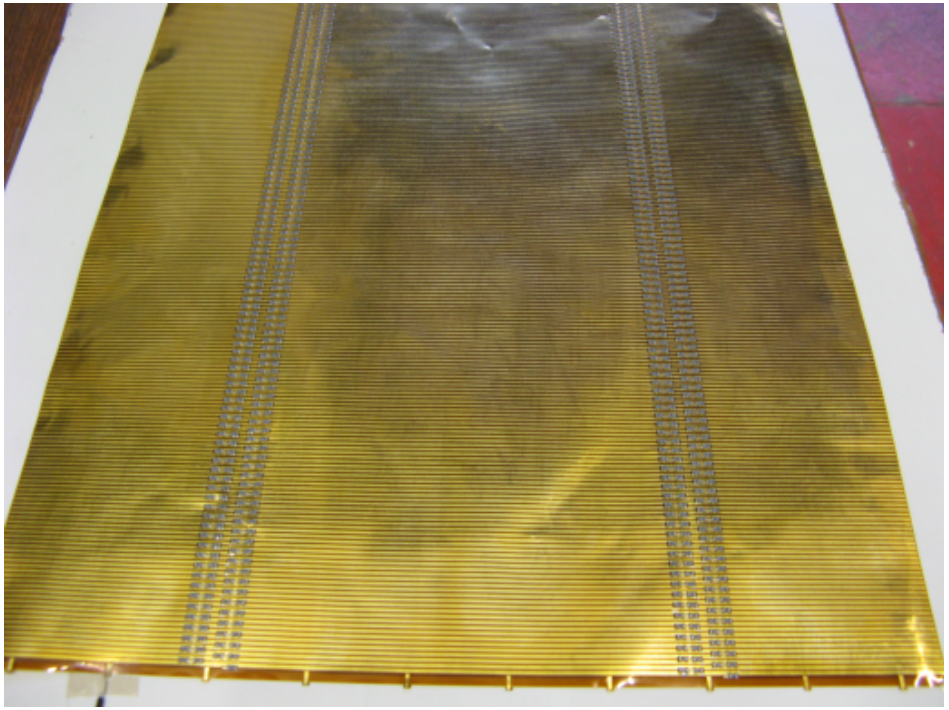
E (V/cm)	Gas	V_{drit} (cm/µs)	D_t (µm/sqrt(cm)	D_l (µm/sqrt(cm)	U_D(V)	ΔV_{strip} (V)
140	Ar+3%iso	3.67	600	348	4200	10.5
215	Ar+3%iso+15%CF4	5.8	206	200	6450	16.125

THE TPC FIELD CAGE KAPTON FOILS

External cage Kapton foil (R=90 mm)
302x561 mm^2

Internal cage Kapton foil (R=40 mm)
302x264 mm^2

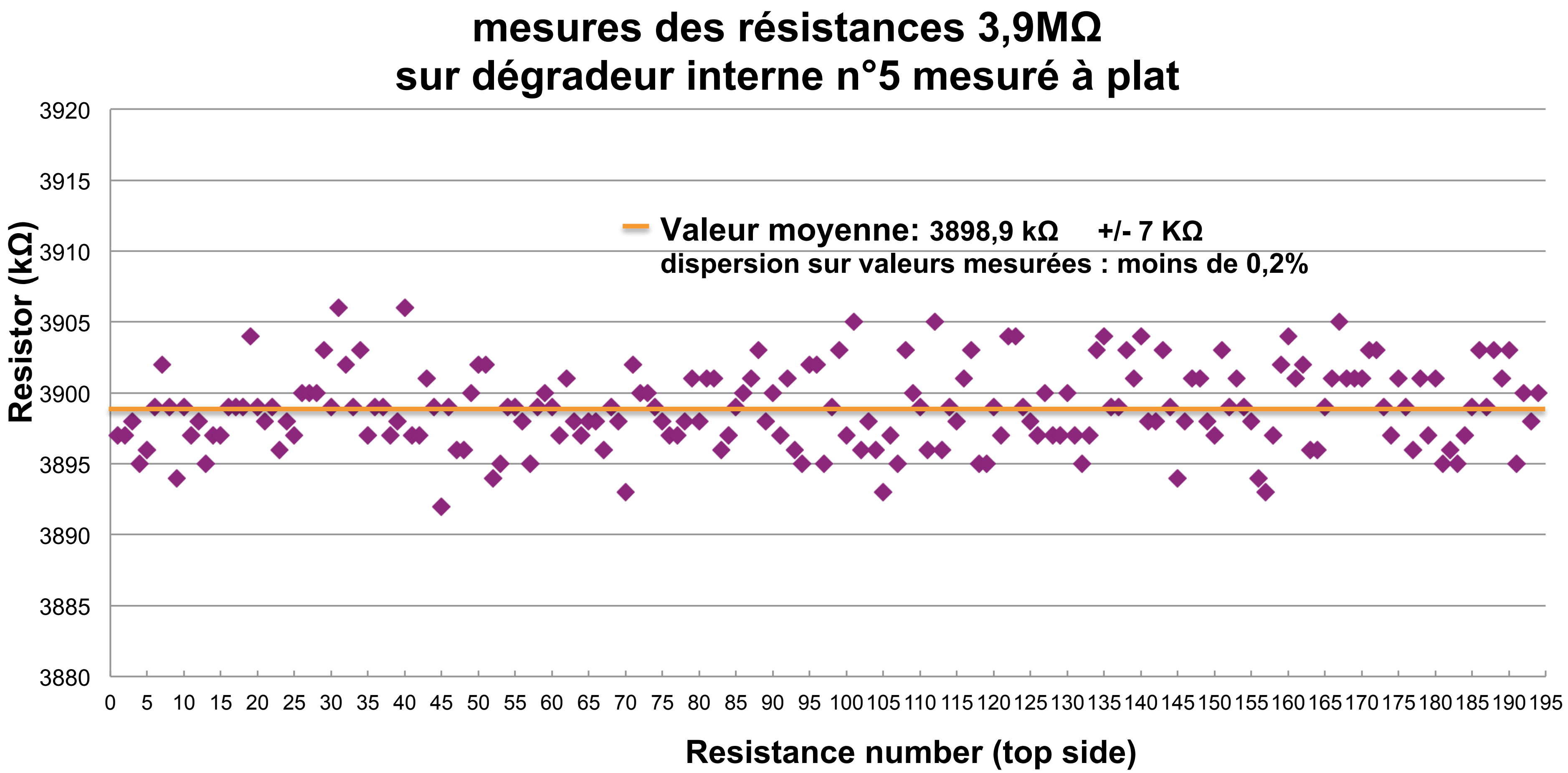




Solder-free pads for connection to cathode plane
Same pads on the Micromegas plane side

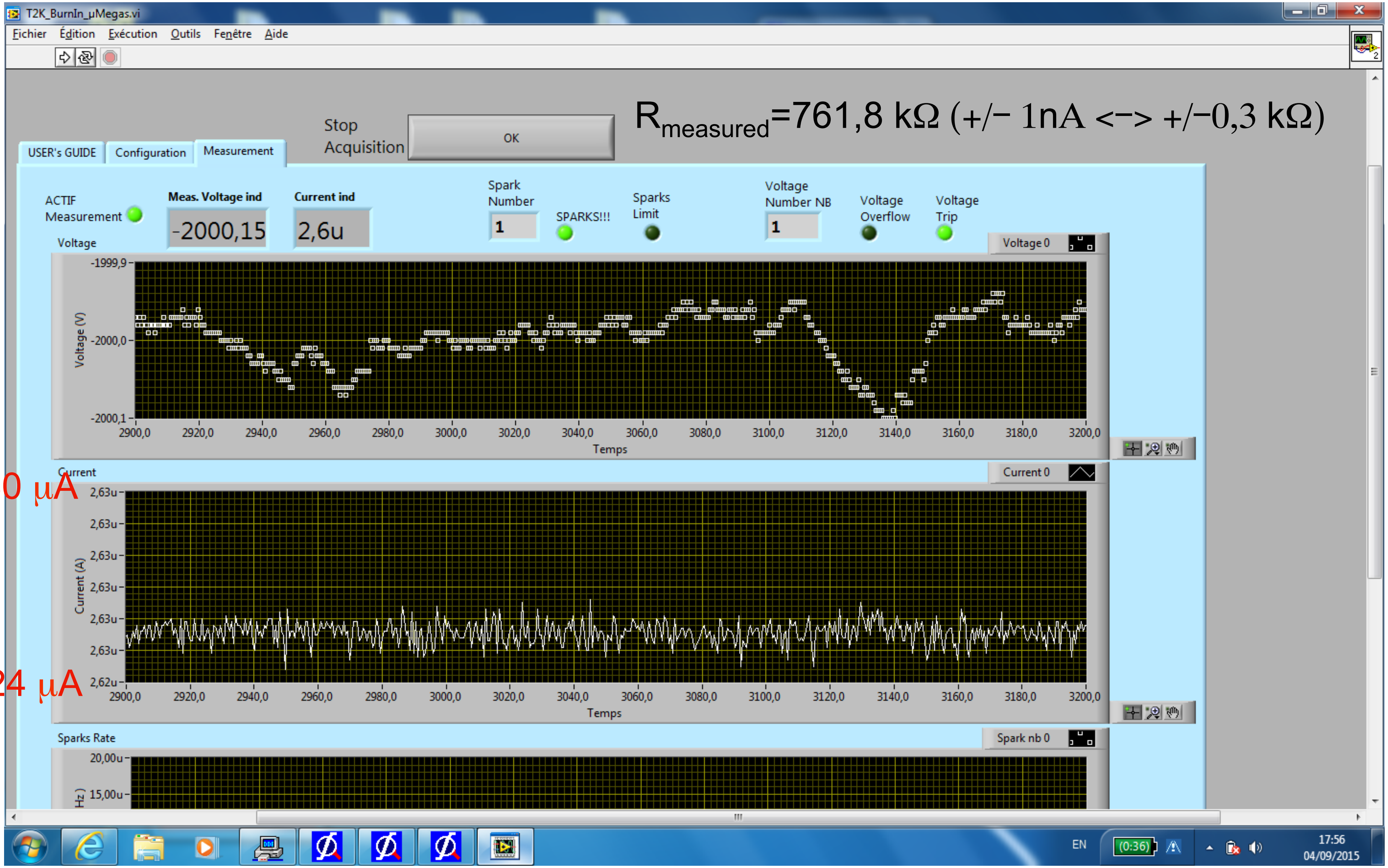
MEASUREMENT OF THE RESISTIVE CHAIN

R_{total}=760,29 kΩ (theoretical 760,50 kΩ)



THE TPC CAGE QUALITY CONTROL OF THE DRIFT CAGES

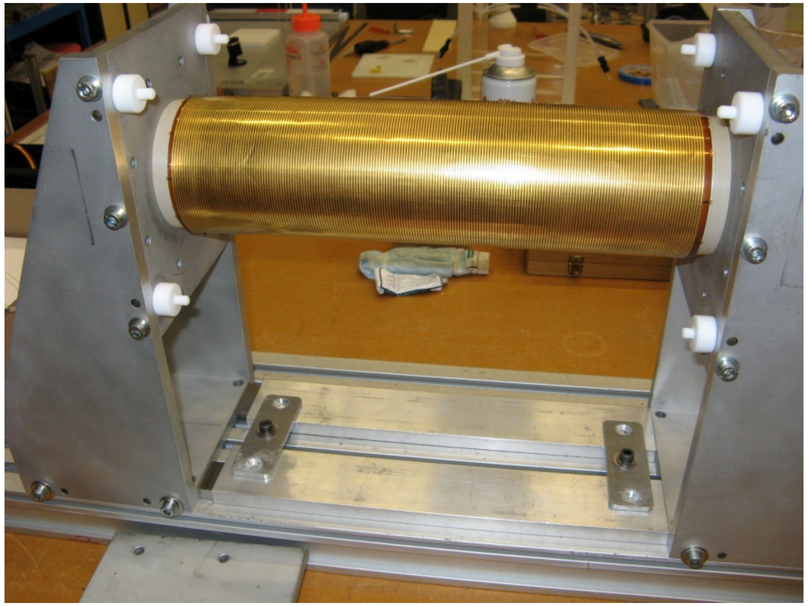
$R_{measured}$=761,8 kΩ (+/− 1nA <−> +/−0,3 kΩ)

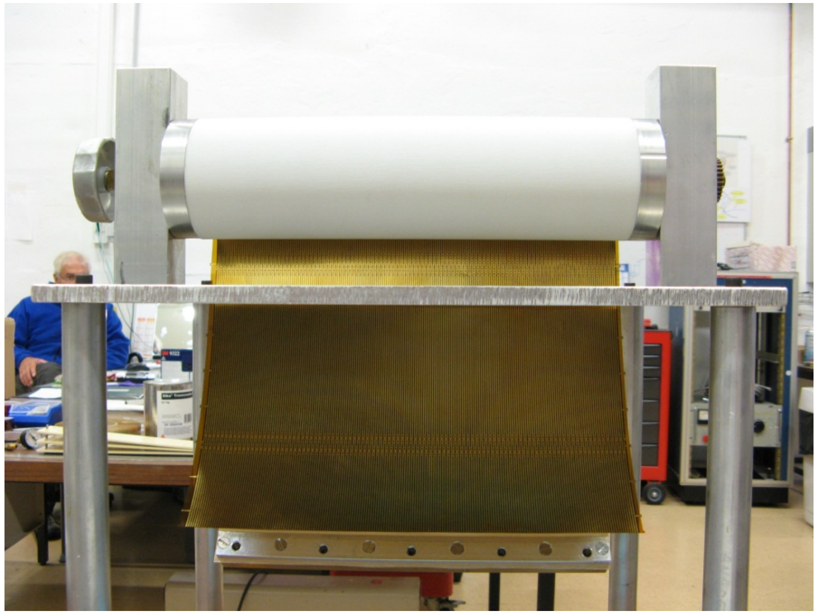


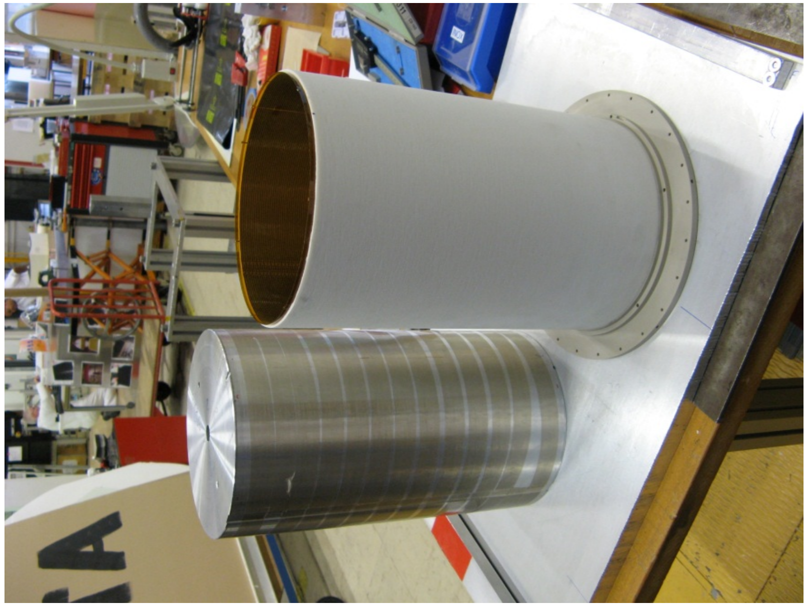
2,630 µA

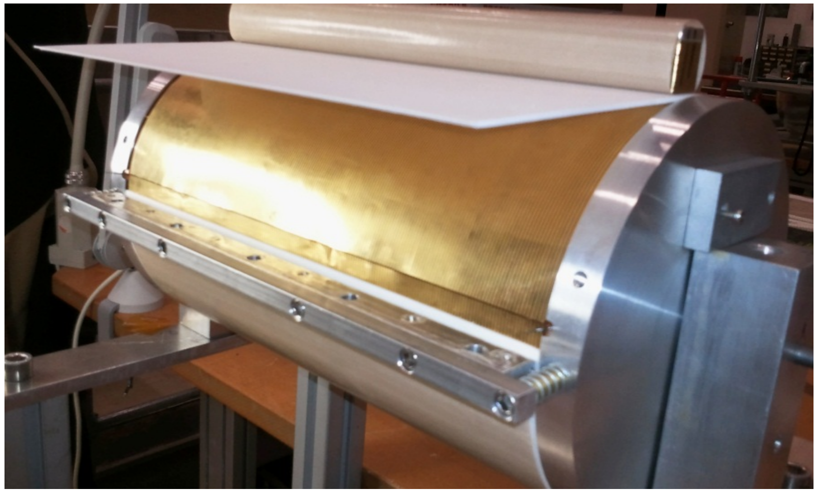
2,624 µA

THE TPC WALLS ASSEMBLY

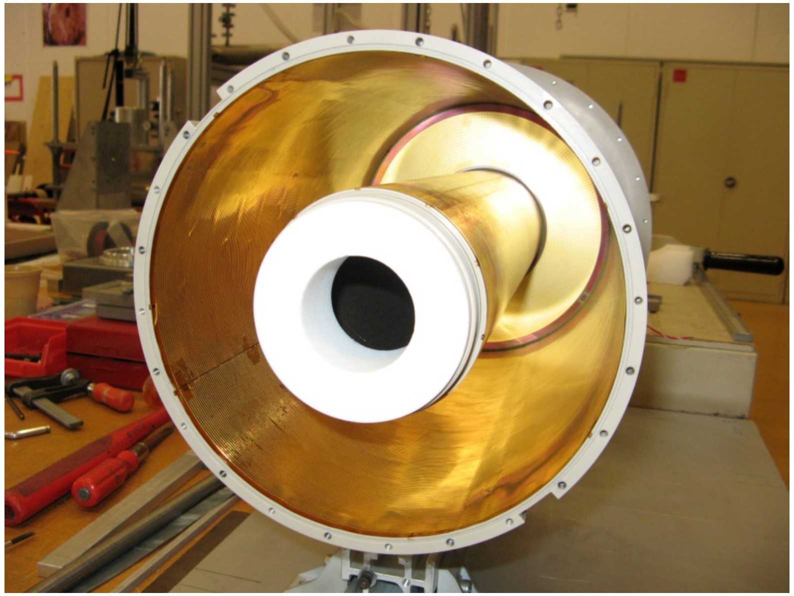


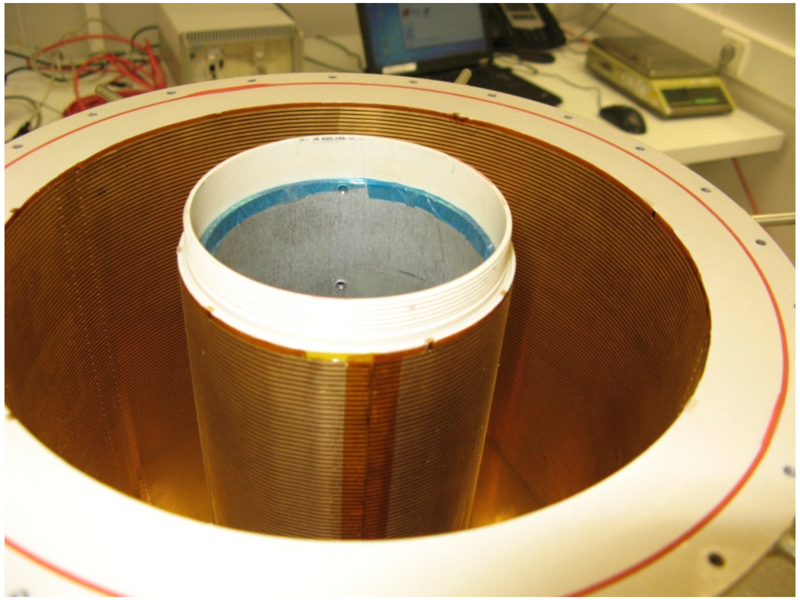


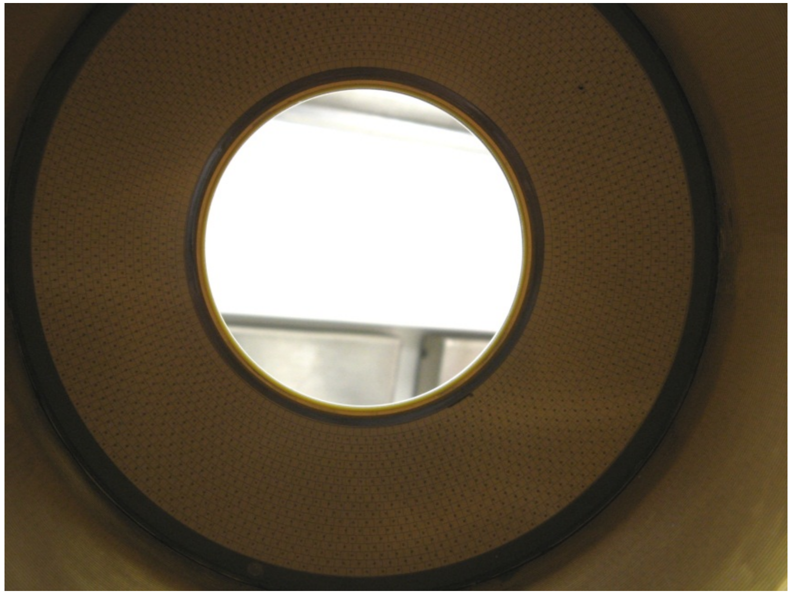


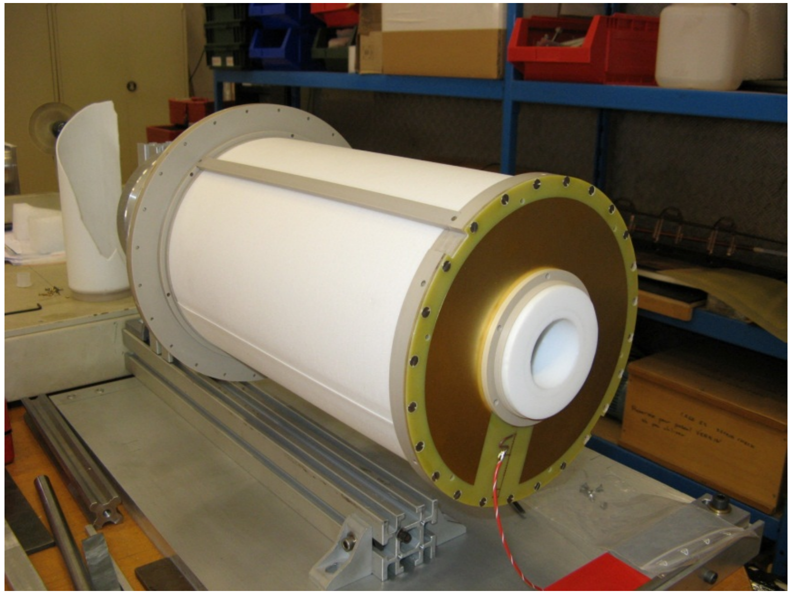


THE MINOS TPC ASSEMBLY



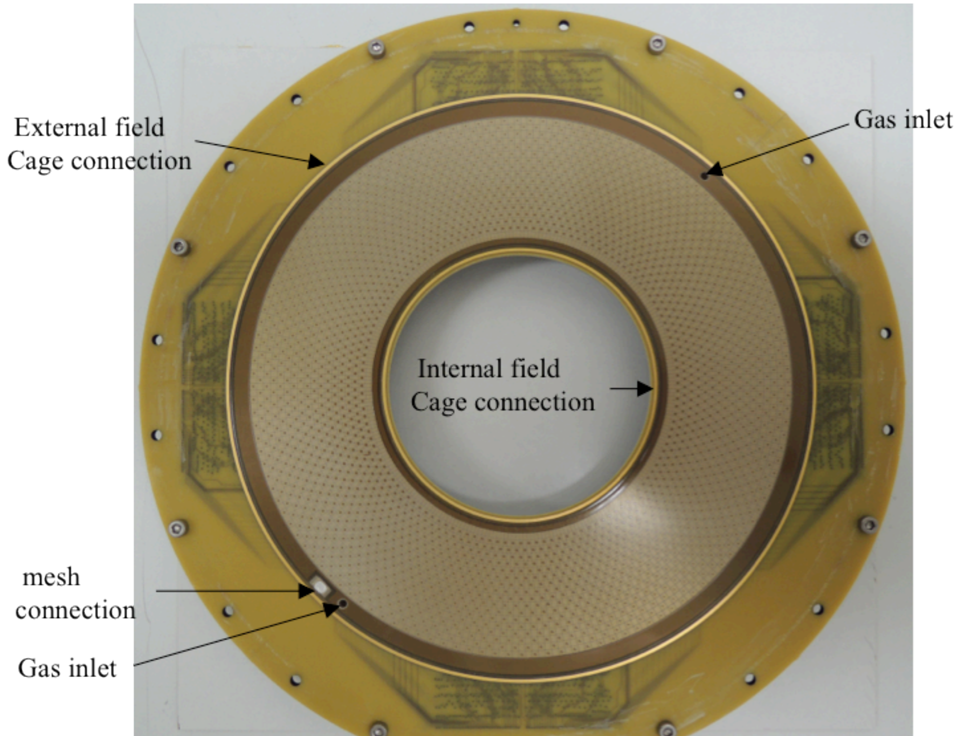




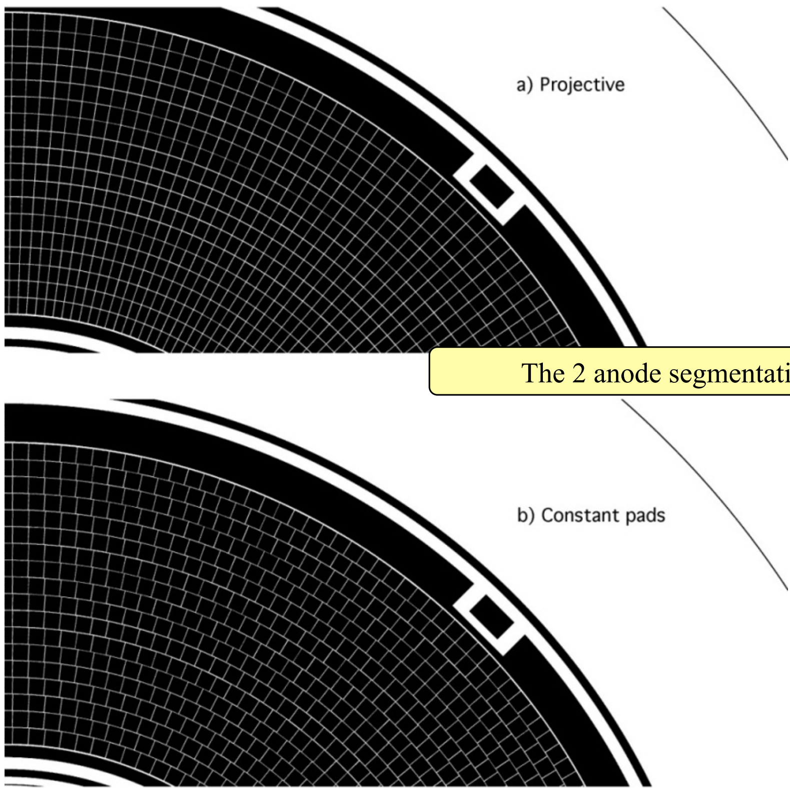


THE MICROMEGAS READOUT PLANE

- ✓ 128 µm gap bulk-micromegas, a pillar every 2 pads (made @ Irfu)
- ✓ 2 anode plane segmentations in 18 rings of 2 x 1-2 mm^2 pads
  - ✓ « projective » : 4608 pads, 256 per ring
  - ✓ « Constant pad » : 3604 x 4 mm^2 pads,
- ✓ 12 layers PCB with more than 18000 blind vias (ELTOS, Italy)

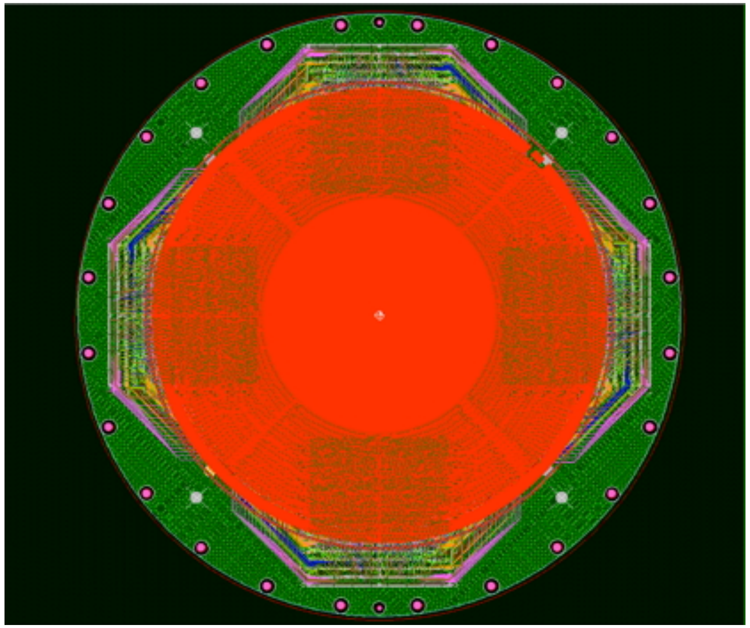


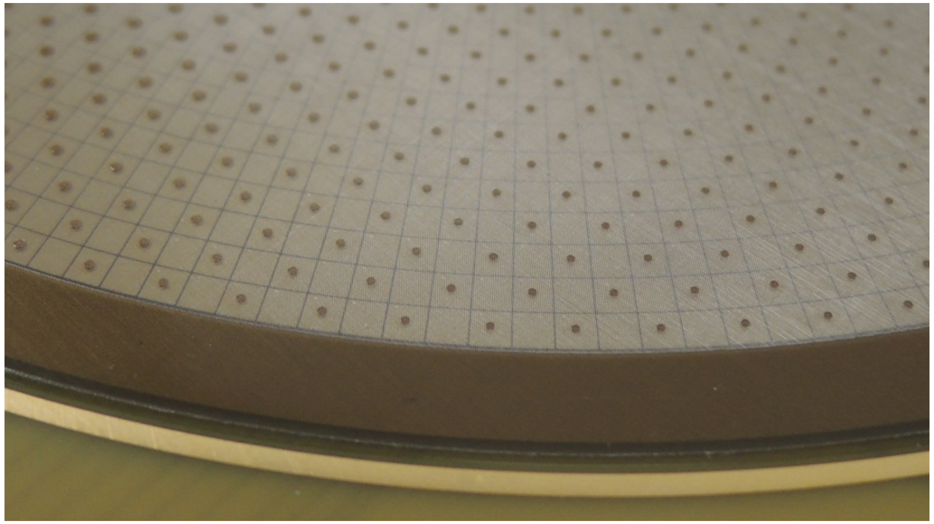
Bulk-micromegas with "Projective" anode

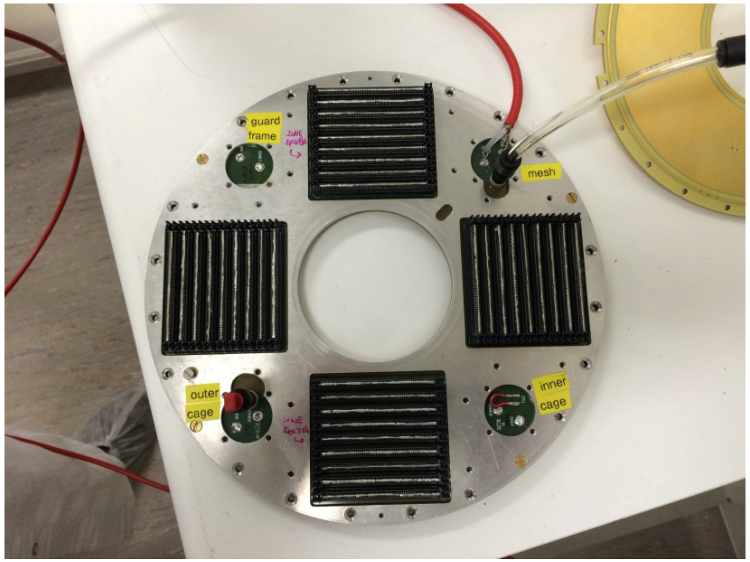


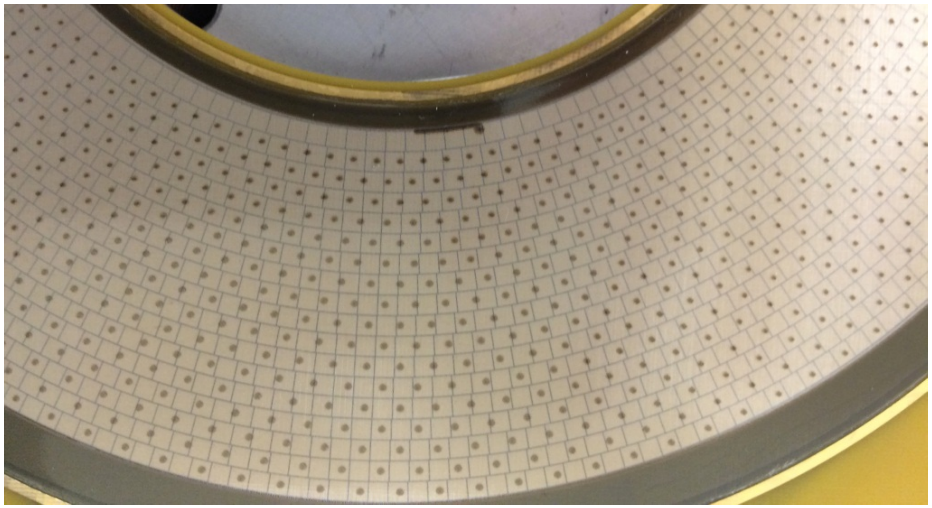
The 2 anode segmentations

THE MICROMEGAS READOUT PLANE

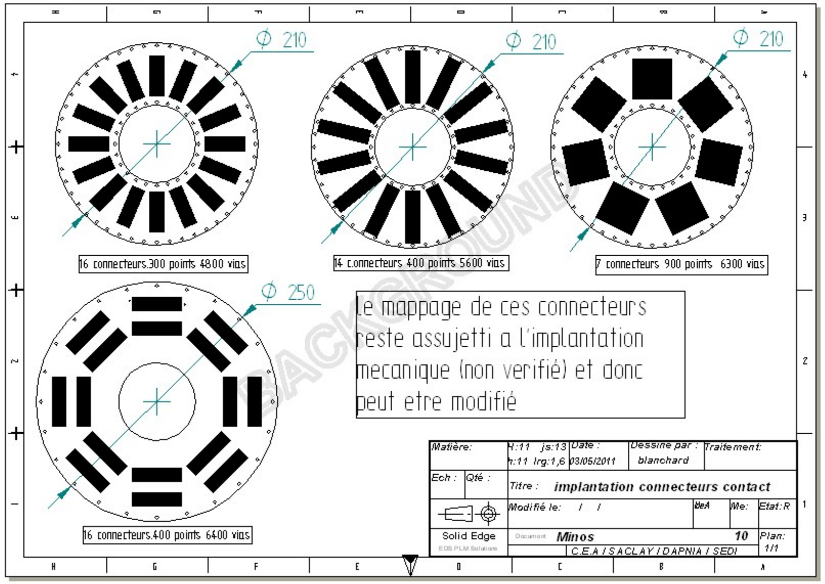


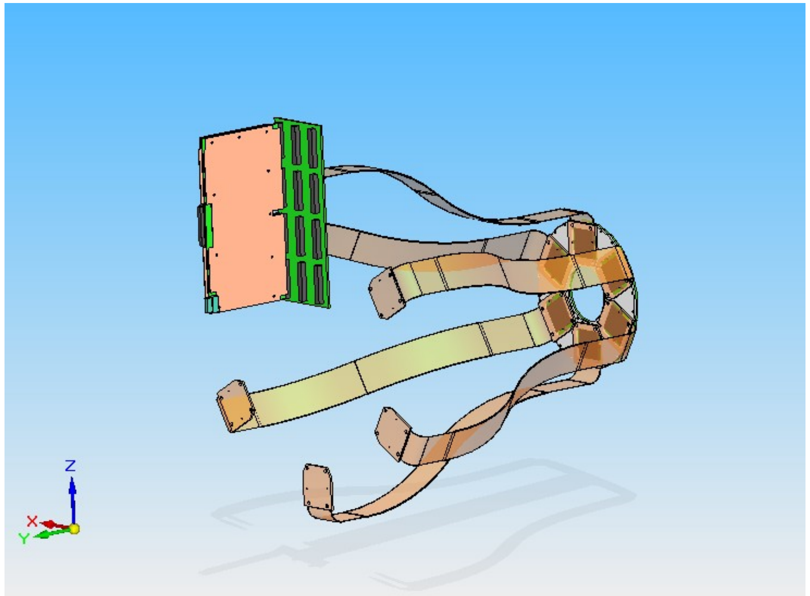


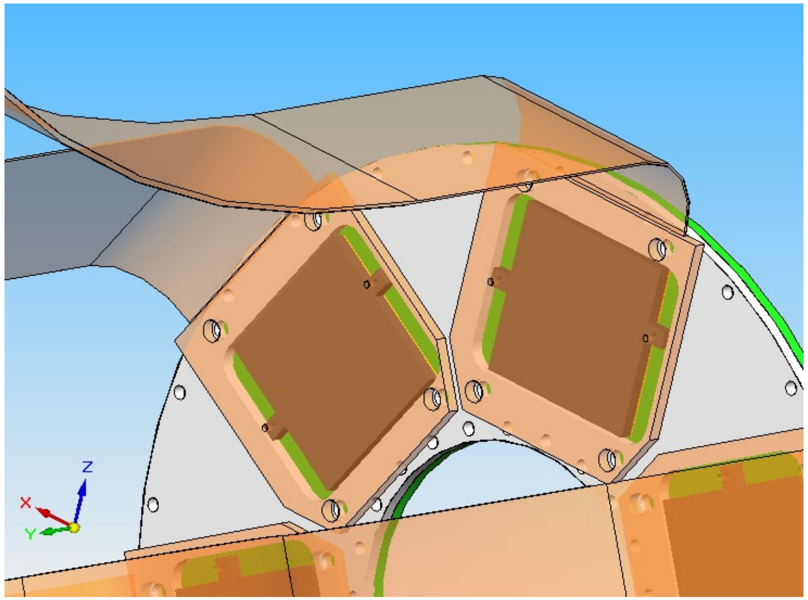


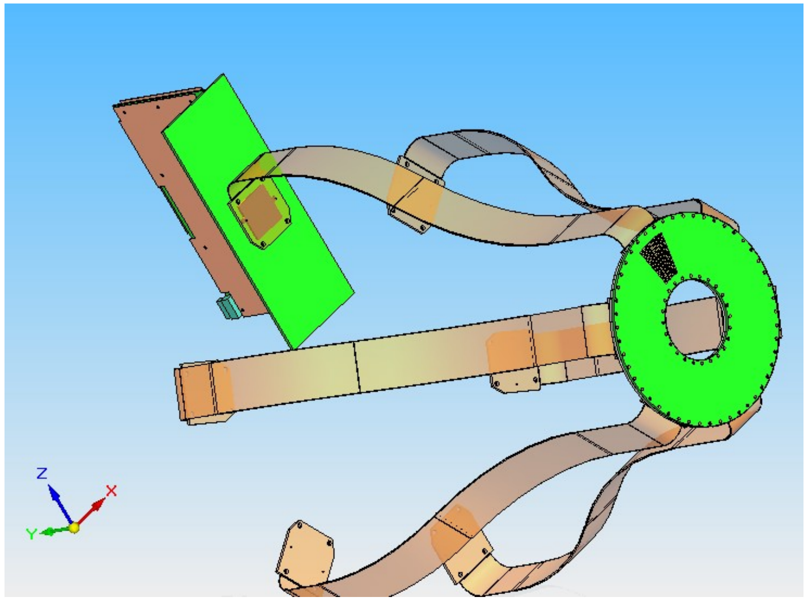


FIRST IDEAS OF FRONT-END ELECTRONICS COUPLING

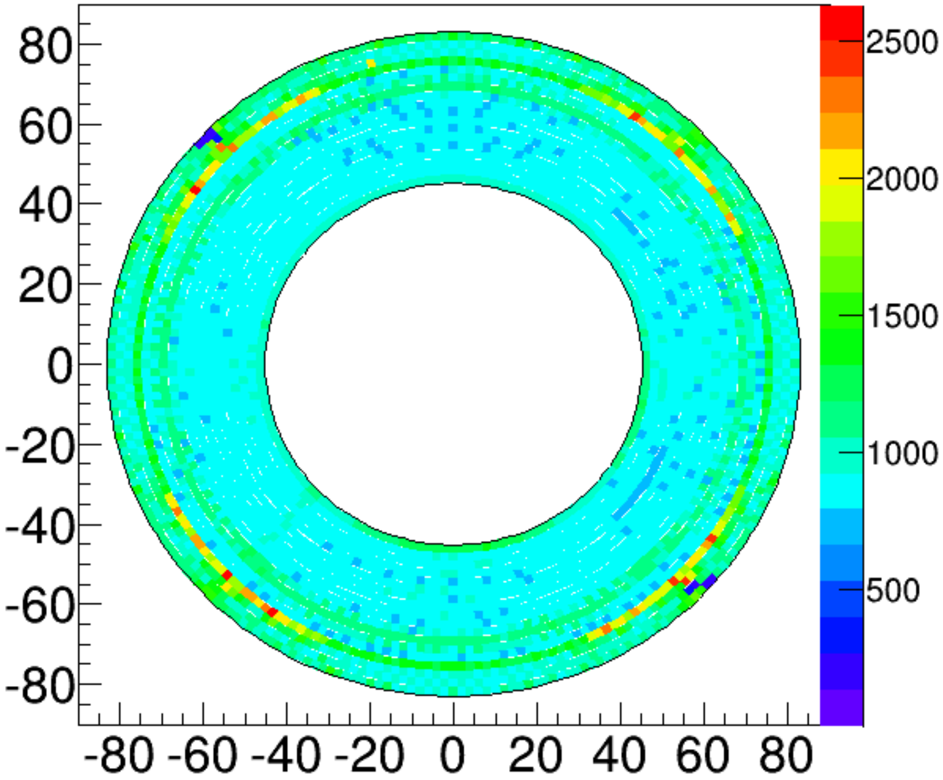








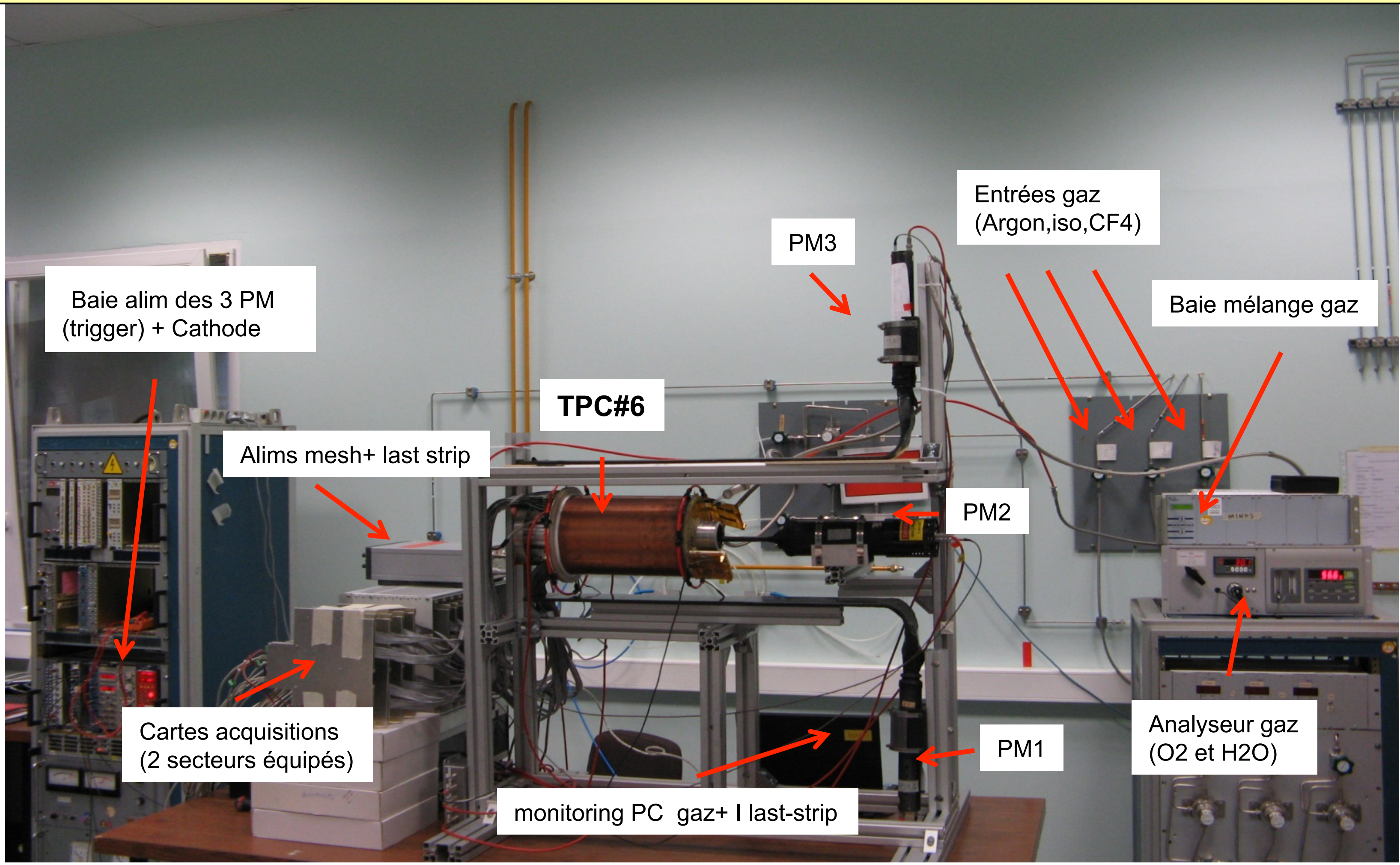
"constant pad" response to a 300 mV pulse on the micromegas mesh



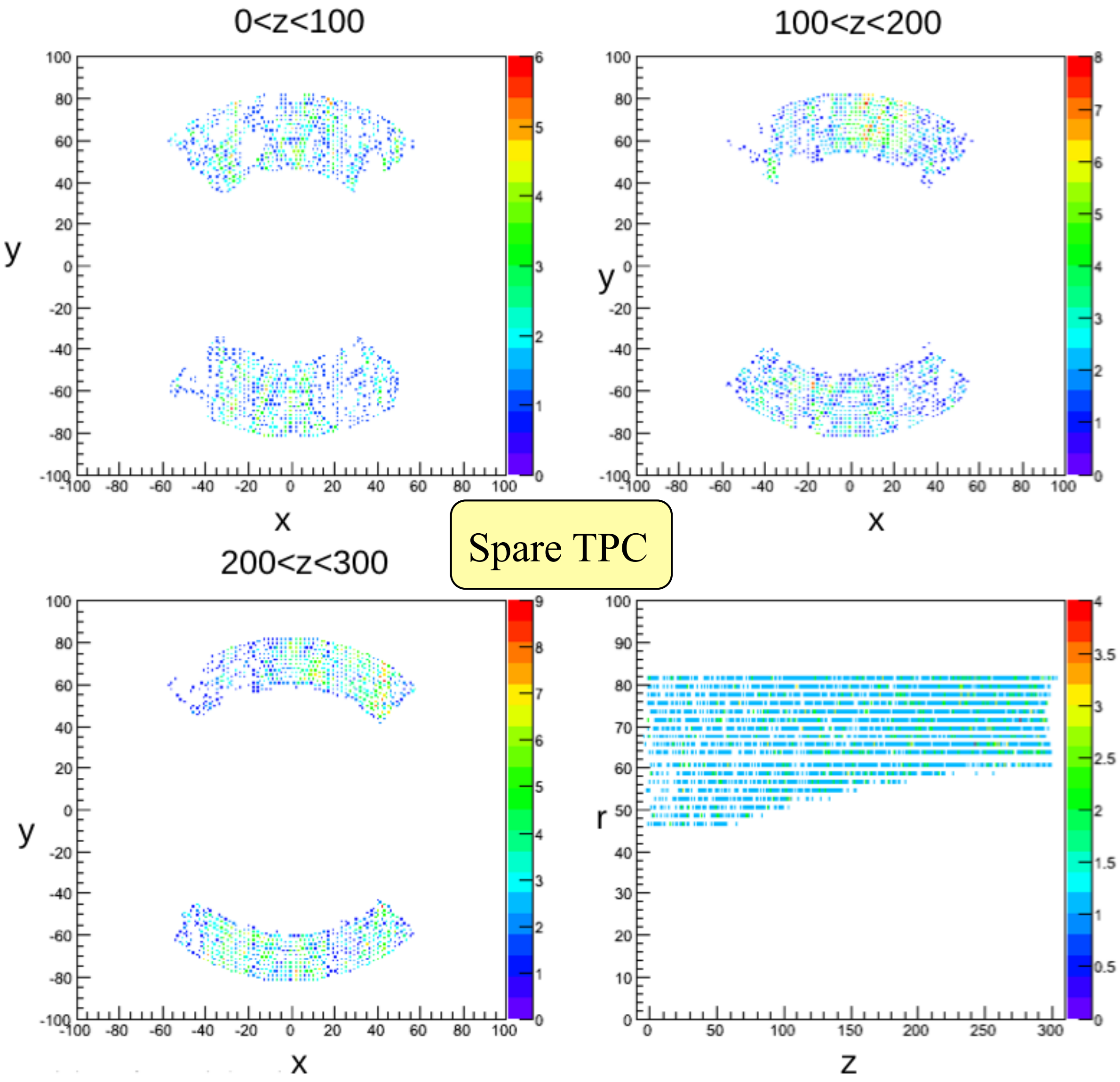
« hot » pads should be due to higher pad capacitance (PCB layout, to be confirmed)
Track reconstruction for Vertex localisation is not affected

VALIDATION IN LAB WITH COSMICS : SCINTILLATOR BASED TEST BENCH

This cosmic test bench is used to fully operate the TPC and easily detect a “global” defect of the TPC such as electric field non-uniformities.

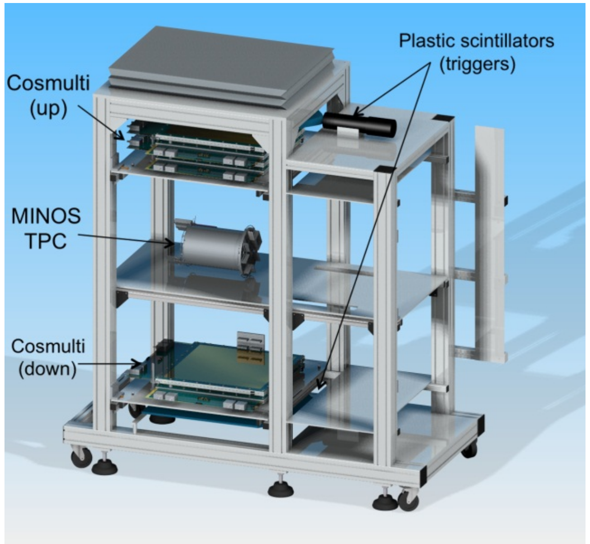


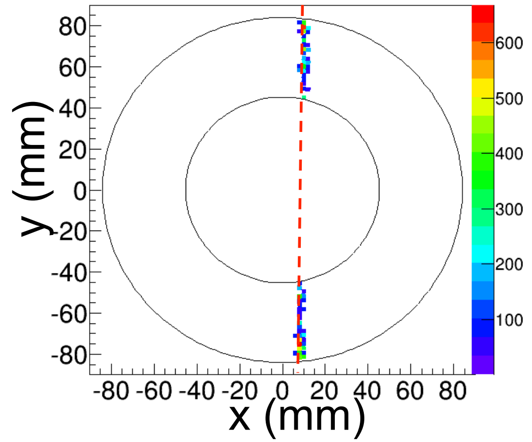
A TPC WITH A NON-UNIFORM ELECTRIC FIELD



Spare TPC

Future use of a high-resolution micromegas based cosmic test bench to localise electric field non-uniformities.

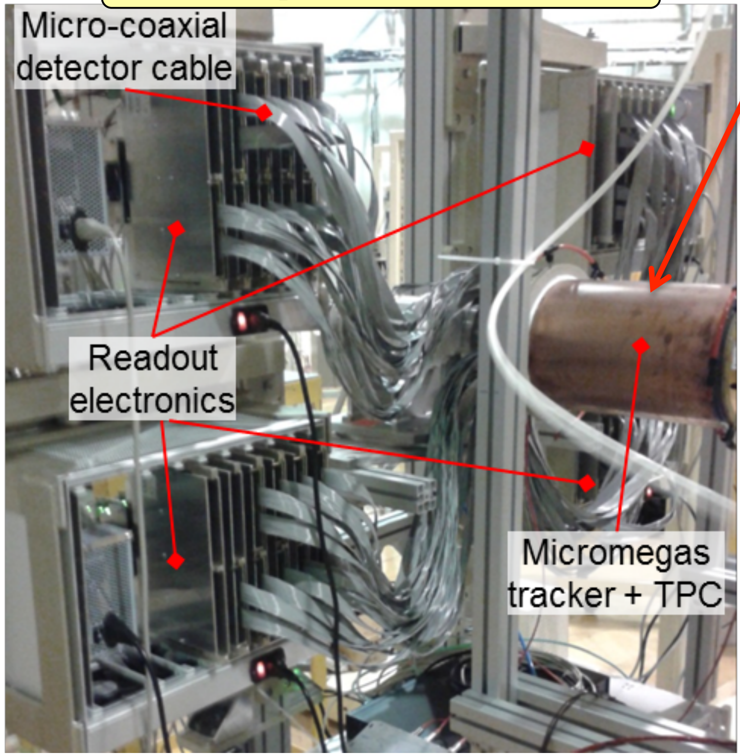


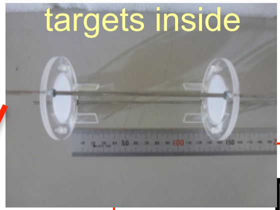


MINOS TPC TESTS WITH ION BEAM @ NIRS-HIMAC (CHIBA, JAPAN)

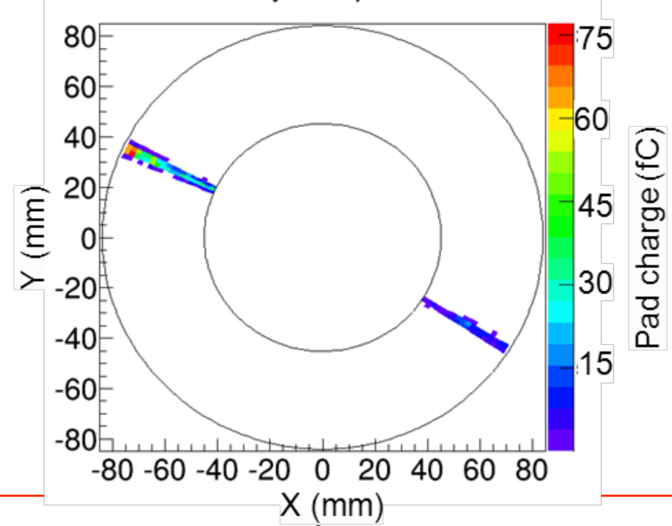
- ✓ One week Data taking in october 2013
- ✓ ^{20}Ne 180 and 350 Mev/nucleon beam
- ✓ 2 x MWDCs, 300 μm resolution, for beam tracking
- ✓ Two 0,5 mm thick CH_2 or C targets were placed 124 mm apart in place of the LH_2 target
- ✓ Use of 20 x T2K-AFTER FEC cards
- ✓ The 2 gas mixtures & anode geometries were tested

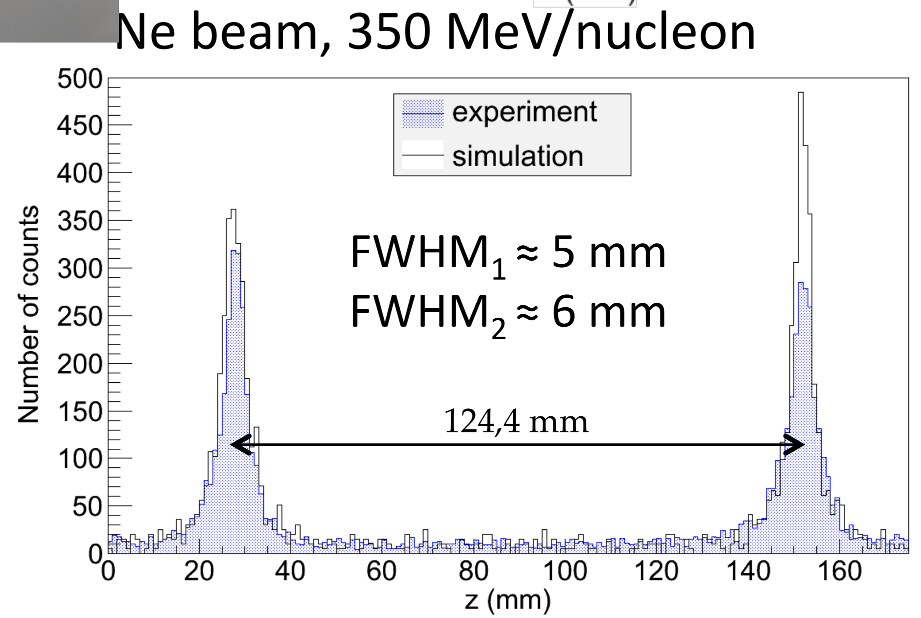
Test setup on HIMAC beam line



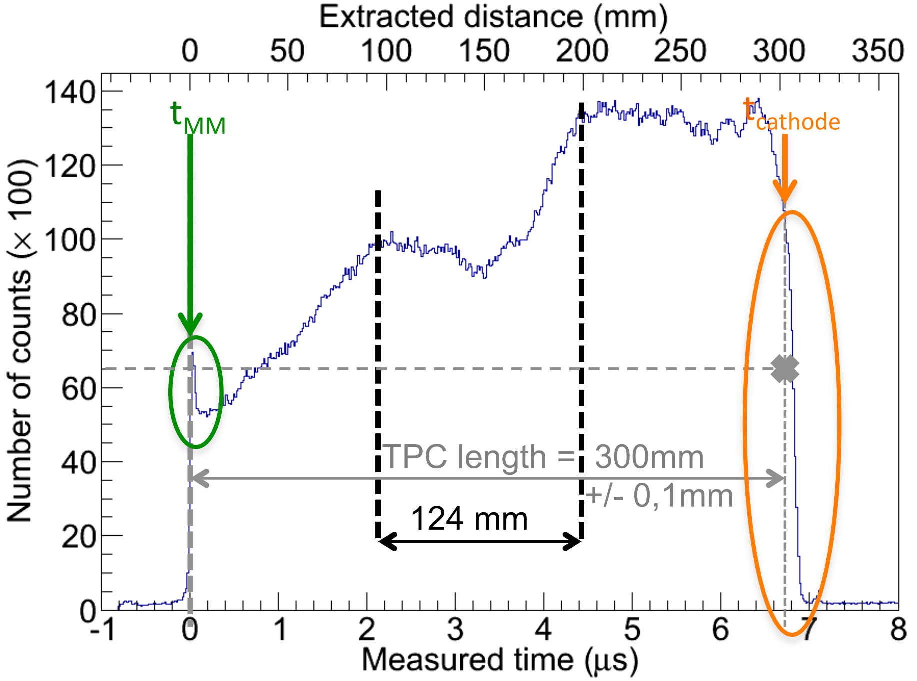


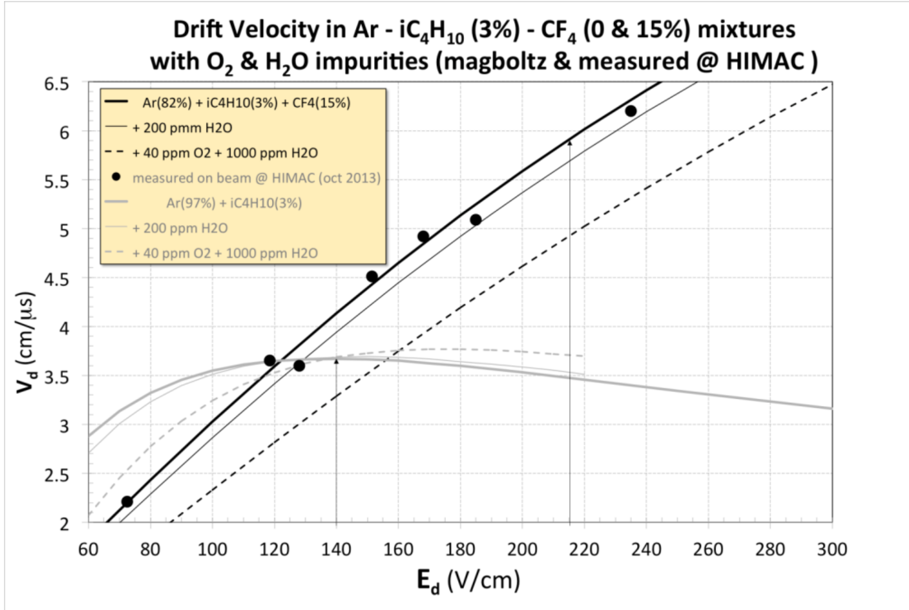
A typical (p,2p) event in the TPC

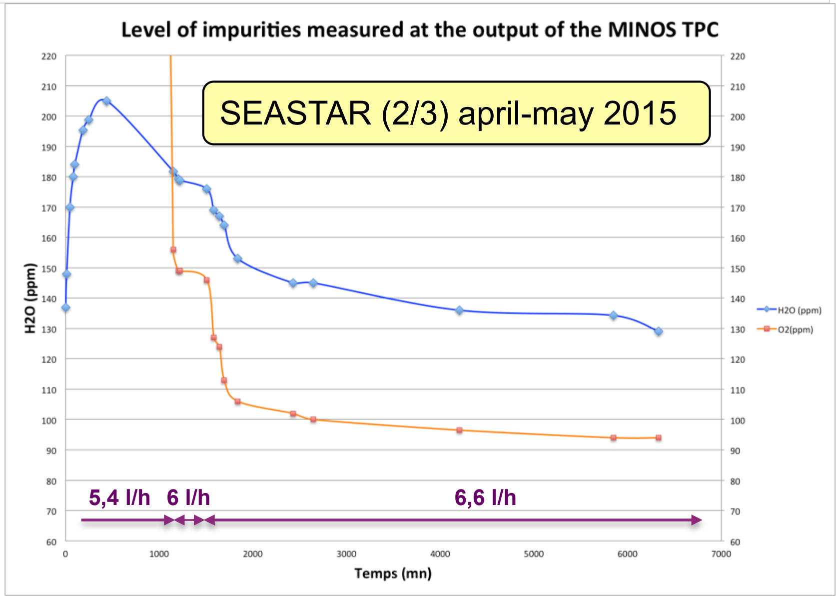




DRIFT VELOCITY MEASUREMENT







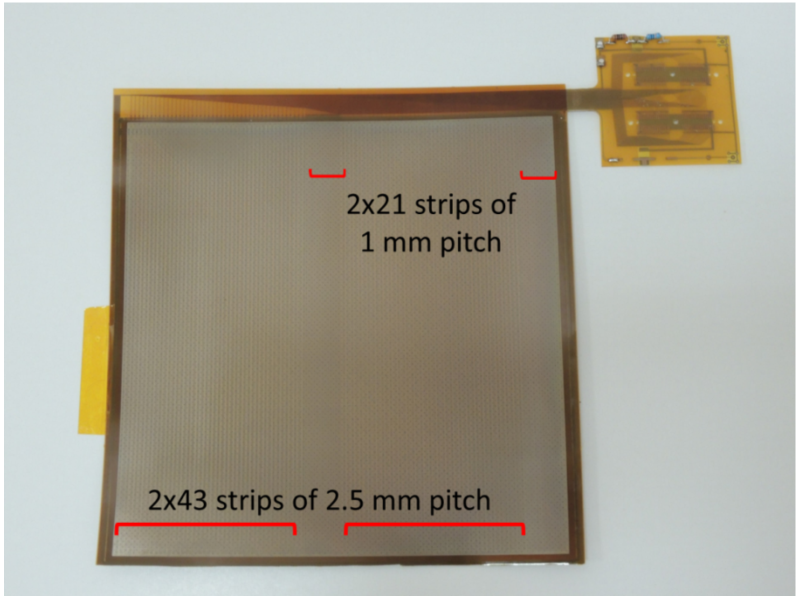
This methods is used for each run.
It is sufficient for the MINOS current required performances.
Magbolz simulations, taking into account the O_2 and H_2O measured gas contents are not always consistent with the measurement (30% vs few %).
This is under investigations : proper use and accuracy of the impurity measurement, oxysorb filter impact on gas content, … ?

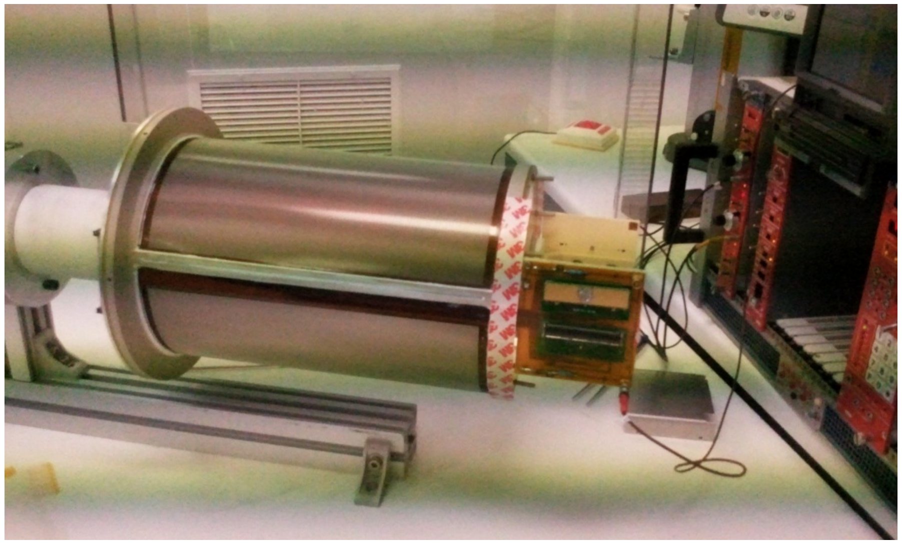
THE CYLINDRICAL EXTERNAL TRACKER FOR DRIFT VELOCITY CALIBRATION

Drift velocity TPC-independent measurement can be done by use of an external cylindrical tracker with 128 C-shape strips.
The outer side of the cathode is grounded to close the TPC Faraday cage.

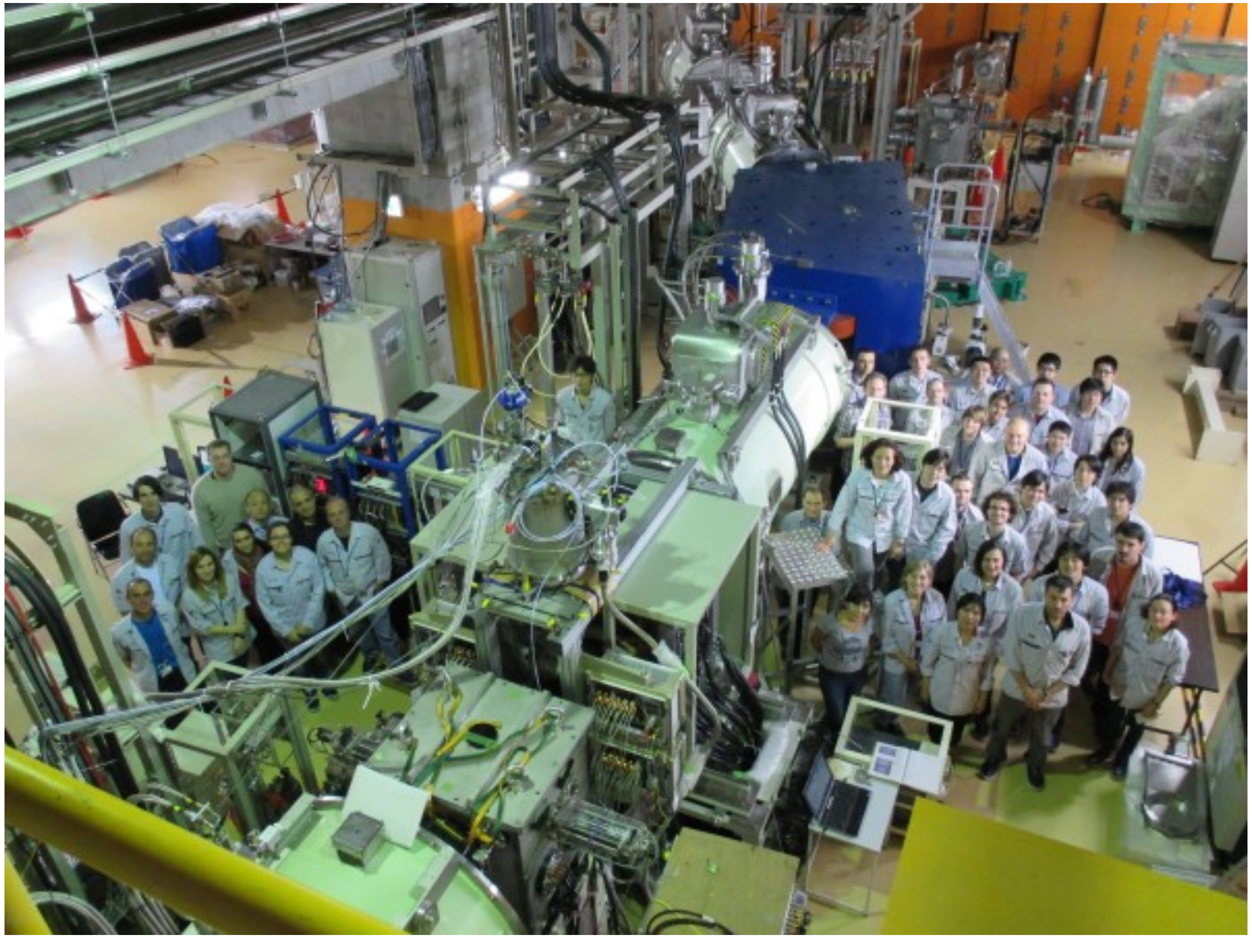
Tests and validation are on-going.

Bulk-micromegas (before curving)





- ✓ Made of 2 half cylinders of 128 µm gap bulk-micromegas + 4 mm drift space
- ✓ 200 µm thick anode PCB with 128 C-shape strips (CLAS12 tracker design)
- ✓ Cathode made of 200 µm thick Kapton covered with 5 µm copper on both sides
- ✓ Anode PCB + bulk-micromegas + cathode made by CERN/TE-MPE-EM

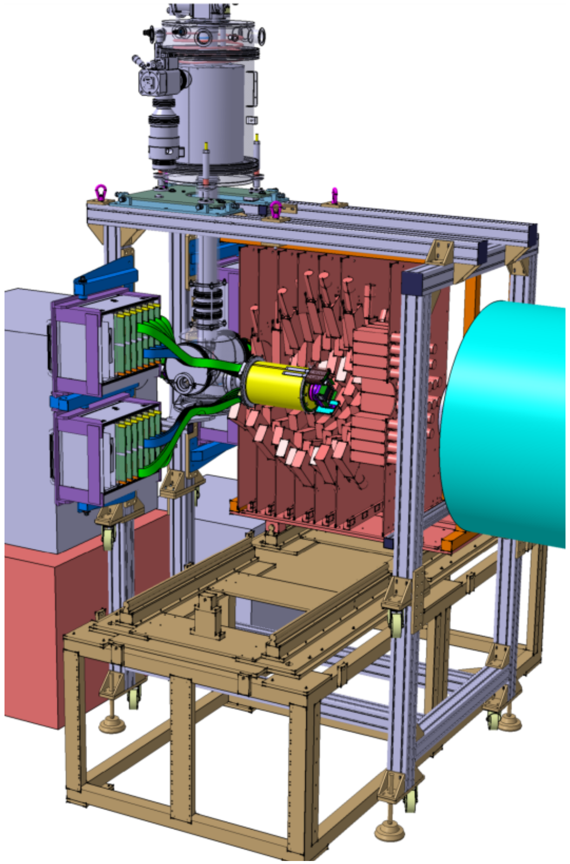


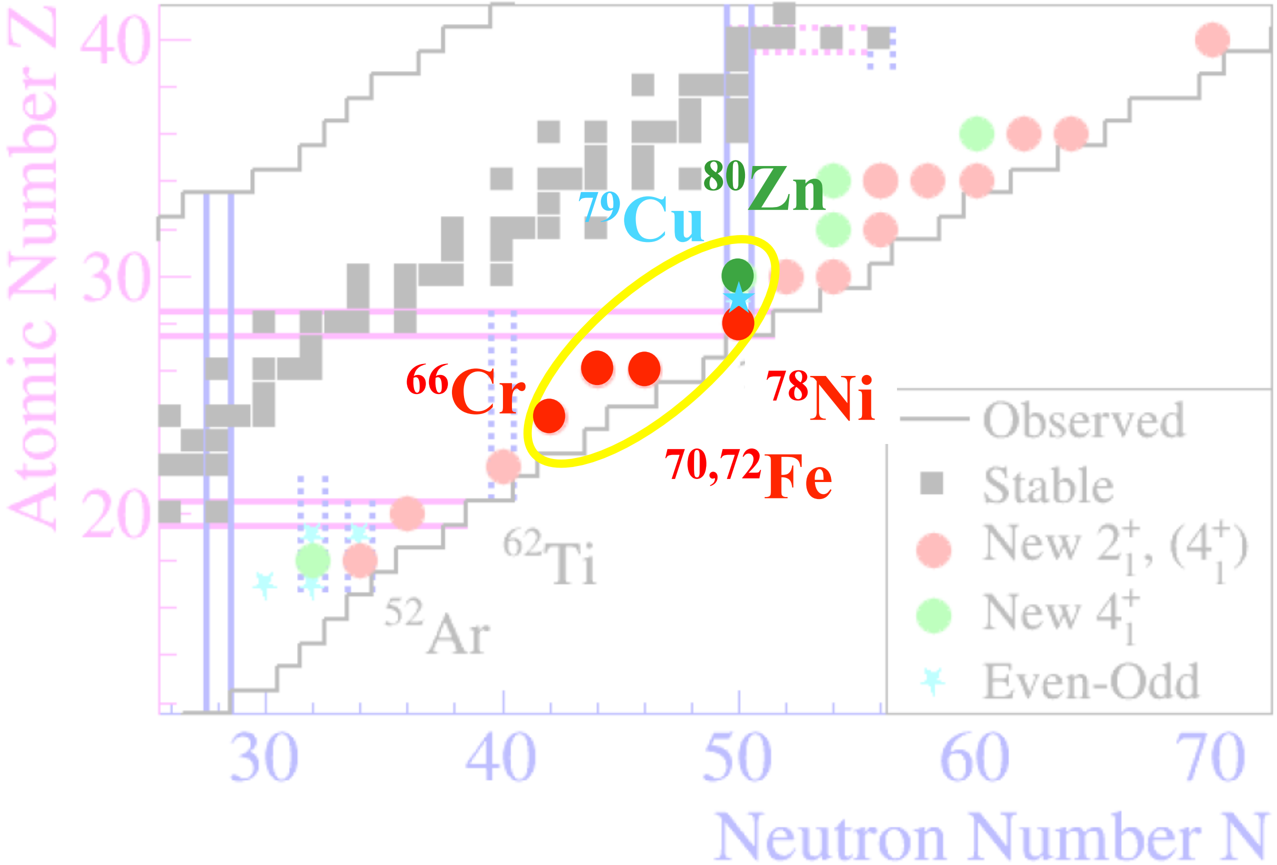
Première campagne SEASTAR (avril-mai 2014): plus de 40 collaborateurs
(Japon, France (CEA, IPHC, IPNO), Allemagne, Vietnam, Norvège, Hong-Kong, Hongrie)
SEASTAR: plus de 100 collaborateurs

SEASTAR: Shell Evolution And Search for Two-plus states At the RIBF

16 new 2^+ states & 5 new 4^+ states

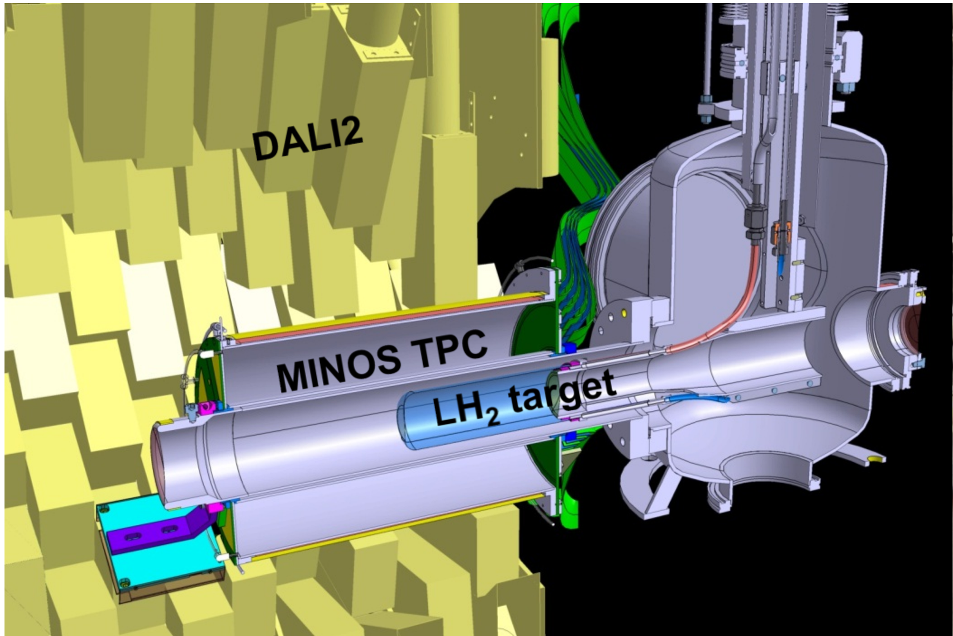
May 2014

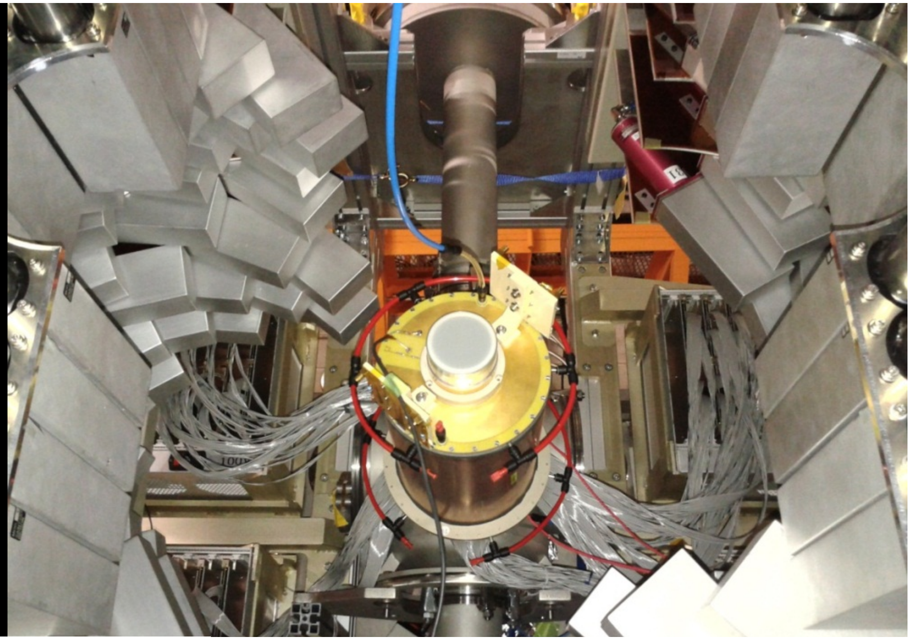


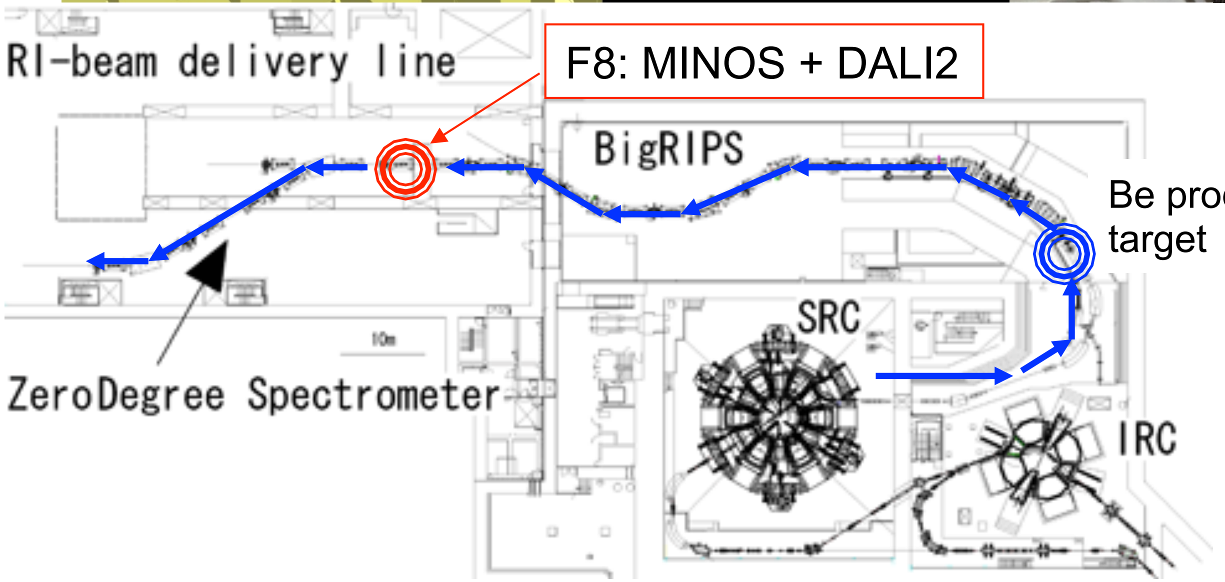


Spokespersons: P. Doornenbal (RIKEN), A. Obertelli (CEA)

FIRST SEASTAR EXPERIMENT (APRIL 2014)





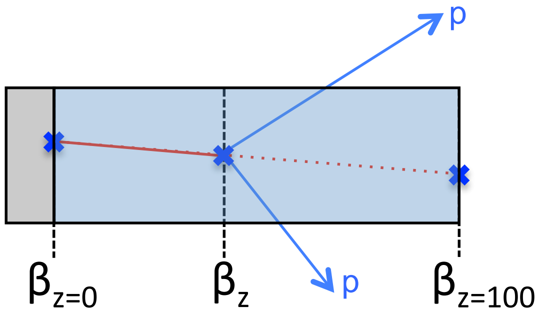


^{238}U at 345 MeV/nucleon (13 pnA)
F8 energy ≈ 250 MeV/nucleon
Total intensity on target ≈ 5000 pps
LH_2 target length = 102(1) mm

DOPPLER CORRECTION WITH MINOS @ RIKEN

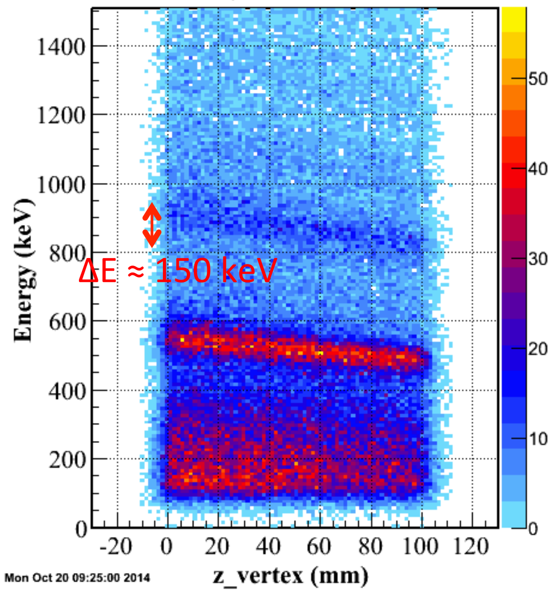
Ref: C. Santamaria

Doppler correction

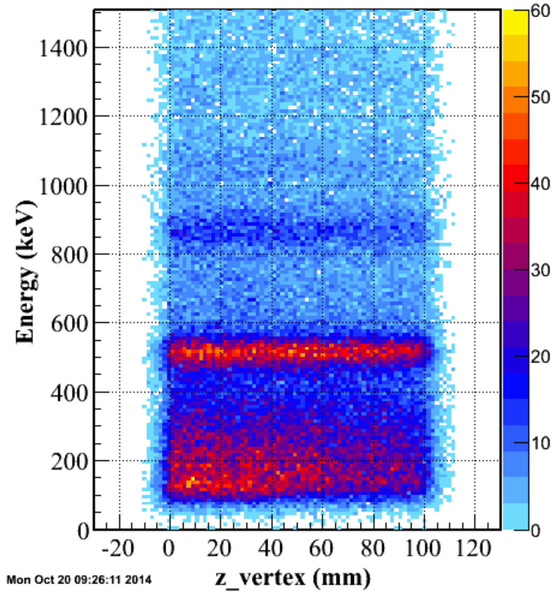


$$\beta_z = \beta_{z=0} - z\_vertex \times (\beta_{z=0} - \beta_{z=100})/L_{LH2}$$

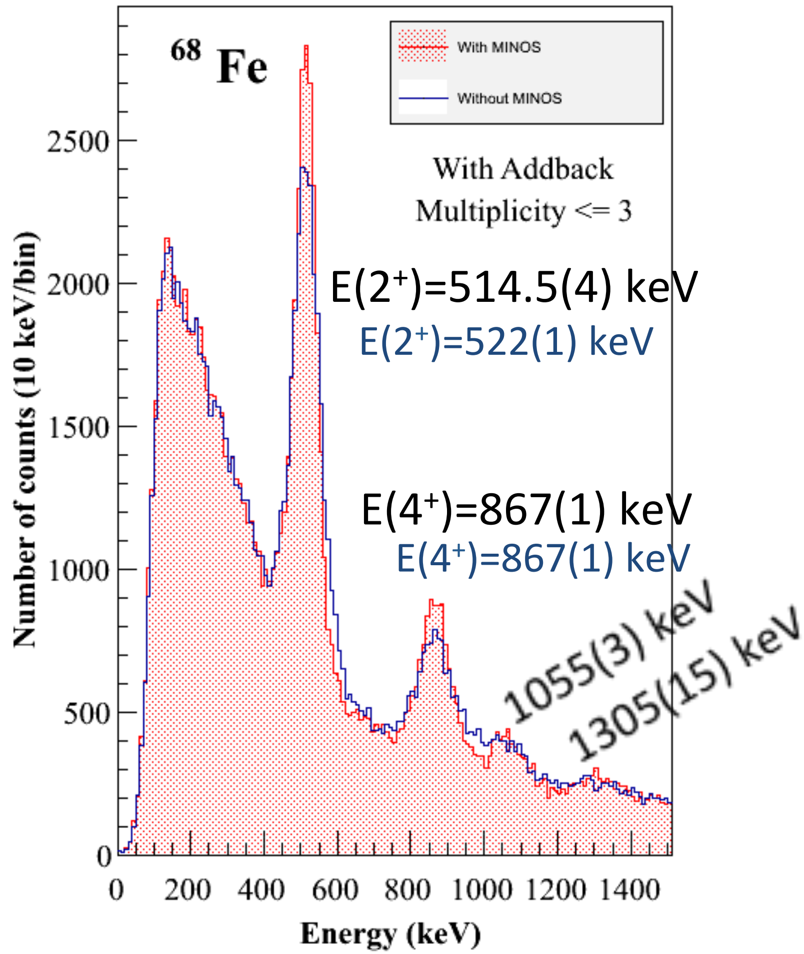
(vertex at middle of target)
w/o MINOS



vertex reconstructed
With MINOS

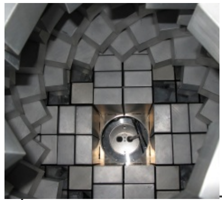


Cr settings : ^{69}Co (p,2p) ^{68}Fe



measures
tabulations

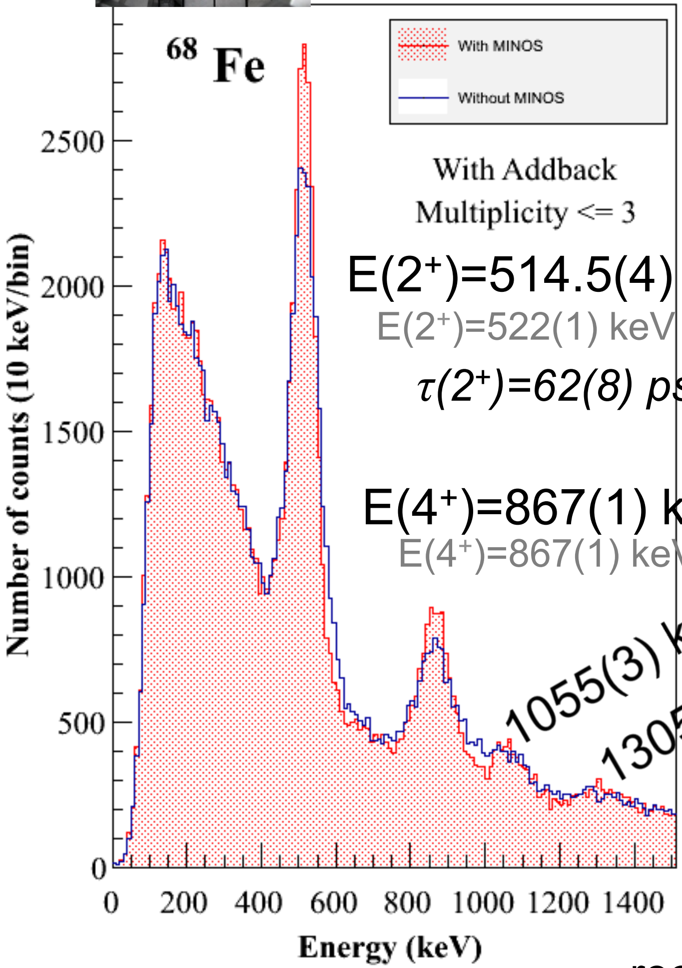
PERSPECTIVES : A BETTER GAMMA DETECTOR TOFULLY EXPLOIT THE CAPABILITIES OF MINOS



DALI2

measured

tabulated



$E(2^+)$=514.5(4) keV

$E(2^+)$=522(1) keV

$\tau(2^+)$=62(8) ps

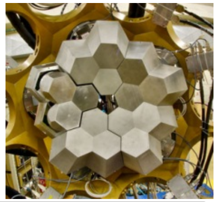
$E(4^+)$=867(1) keV

$E(4^+)$=867(1) keV

1055(3) keV

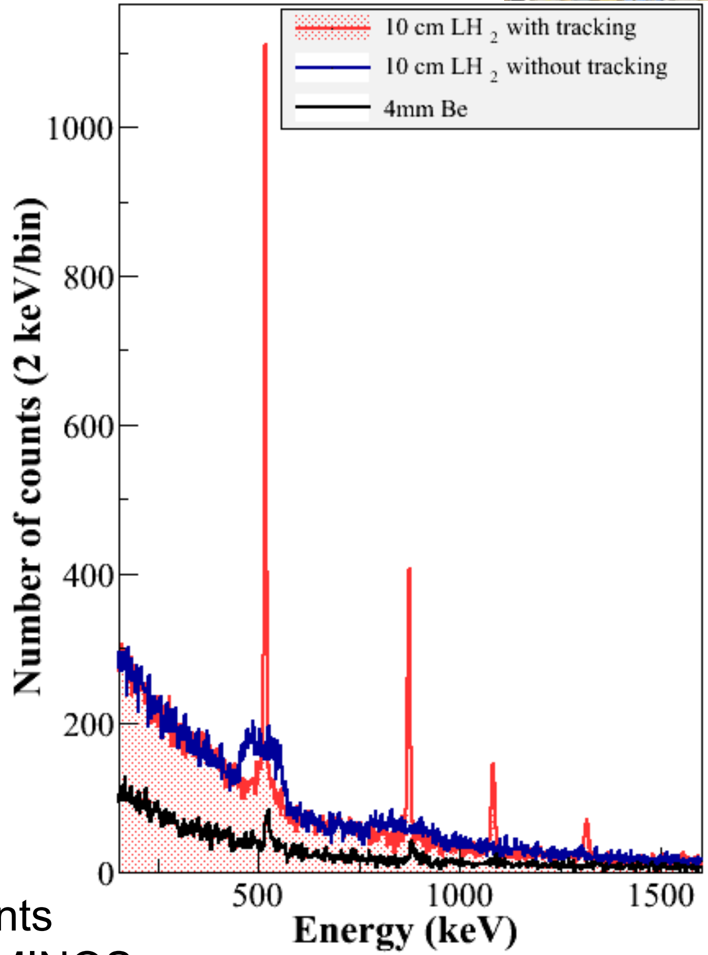
1305(15) keV

AGATA



Simulation at 300 MeV/u

With 5T+5D AGATA clusters



ONLY 2p events reconstructed by MINOS (no beam tracking used)

CONCLUSION AND PERSPECTIVES

- The MINOS instrument was designed, constructed and validated in 3 years and it is fully operational in physics experiments since april 2014. It was used in three 10 days campaigns. 2 experiments per year at the RIKEN/RIBF ion beam facility are scheduled for the 2015-2018 period.

- Developments are still needed beyond the ERC program :
  - ✓ To add a cylindrical micromegas tracker on the outer shell for drift velocity calibration.
  - ✓ To understand the non-uniformity of the spare TPC to build a new one
  - ✓ To add two upstream and downstream DSSDs for ion beam precise localisation (SEASTAR experiments)

- To fully exploit the MINOS sensitivity, a new generation gamma detector is required, such as AGATA (for experiments at RIKEN or FAIR).

THE CEA TEAM (2015)

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SPhN


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Thèse (2012-15)


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embauchée 2012


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E. Pollacco

SEDI

Détecteur


A. Delbart


A. Peyaud


A. Giganon


G. Prono


C. Lahonde

Electronique / DAQ


D. Calvet


F. Chateau


S. Anvar

CC et mécanique

SACM


J.-Y. Rousse


D. Loiseau

SIS


C. Peron


D. Leboeuf

Cible

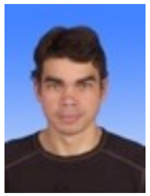

J.-M. Gheller


G. Authelet

'experts' IRFU Hors MINOS


E. Delagnes


P. Chesny


D. Attié


P. Colas

MINOS development and local teams

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Physics collaborations

Di-neutron correlations Uesaka, Sasano, Zenihiro, Yoneda, Sato, Otsu, Shimizu, Baba, Isobe, Sako, Stul, Panin (RNC), **Kubota**, Dozono, Ota, Kobayashi M., Kiyokawa (CNS), **Corsi**, Obertelli, Santamaria, Pollacco, Lapoux, Gillibert, Calvet, Delbart, Gheller, Authelet, Roussé (CEA), Kobayashi N., Koyama, Miyazaki (Tokyo Univ.), Kobayashi T., Hasegawa, Sumikama (Tohoku Univ.), Nakamura, Kondo, Togano, Shikata, Tsubota, Saito, Ozaki (Tokyo Tech), Yasuda, Sakaguchi, Shindo, Tabata, Ohkura, Nishio (Kyushu Univ.), Nakatsuka (Kyoto Univ.),Yukie, Kawakami, Kanaya (Miyazaki Univ.), Marques, Gibelin, Orr (LPC Caen), Flavigny (IPNO), Yang, Feng (Peking Univ.), Caesar, Paschalis (TUD), Reichert (TUM), Kim (Ehwa Womans University)

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SEASTAR N. Alamanos, G. de Angelis, N. Aoi, H. Baba, C. Barbieri, C. Bertulani, A. Corsi, F. Delaunay, Z. Dombradi, **P. Doornenbal**, T. Duguet, S. Franchoo, J. Gibelin, A. Gillibert, S. Go, M. Gorska, A. Gottardo, S. Grévy, J.D. Holt, E. Ideguchi, T. Isobe, A. Jungclaus, N. Kobayashi, T. Kobayashi, Y. Kondo, W. Korten, Y. Kubota, I. Kuti, V. Lapoux, S. Leblond, J. Lee, S. Lenzi, H. Liu, G. Lorusso, C. Louchart, R. Lozeva, F.M. Marques, I. Matea, K. Matsui, Y. Matsuda, M. Matsushita, J. Menendez, D. Mengoni, S. Michimasa, T. Miyazaki, S. Momiyama, P. Morfouace, T. Motobayashi, T. nakamura, D. Napoli, F. Naqvi, M. Niikura, **A. Obertelli**, N. Orr, S. Ota, H. Otsu, T. Otsuka, N. Pietralla, Z. Podolyak, E.C. Pollacco, G. Potel, G. Randisi, F. Recchia, E. Sahin, H. Sakurai, C. Santamaria, M. Sasano, A. Schwenk, Y. Shiga, Y. Shimuzu, S. Shimoura, J. Simonis, P.A. Soderstrom, S. Sohler, V. Soma, I. Stefan, D. Steppenbeck, T. Sumikama, H. Suzuki, M. Tanaka, R. Taniuchi, K.N. Tuan, T. Uesaka, J. Valiente Dobon, Zs. Vajta, D. Verney, H. Wang, V. Werner, Zh. Xu, R. Yokoyama, K. Yoneda