NSTRUMENTING PUMA

A TOOL TO MAP THE NUCLEAR SURFACE

Emanuel Pollacco for the PUMA collaboration
CEA Saclay

GDS Jan 2019

Collaboration

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TECHNISCHE UNIVERSITÄT DARMSTADT

RIKEN NISHINA CENTER

CERN

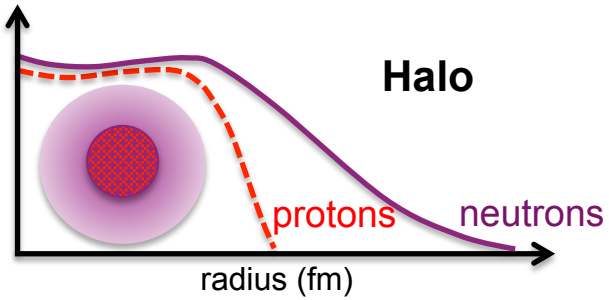
IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

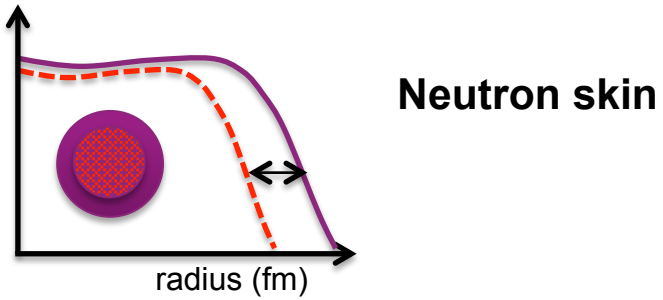
RCNP Research Center for Nuclear Physics

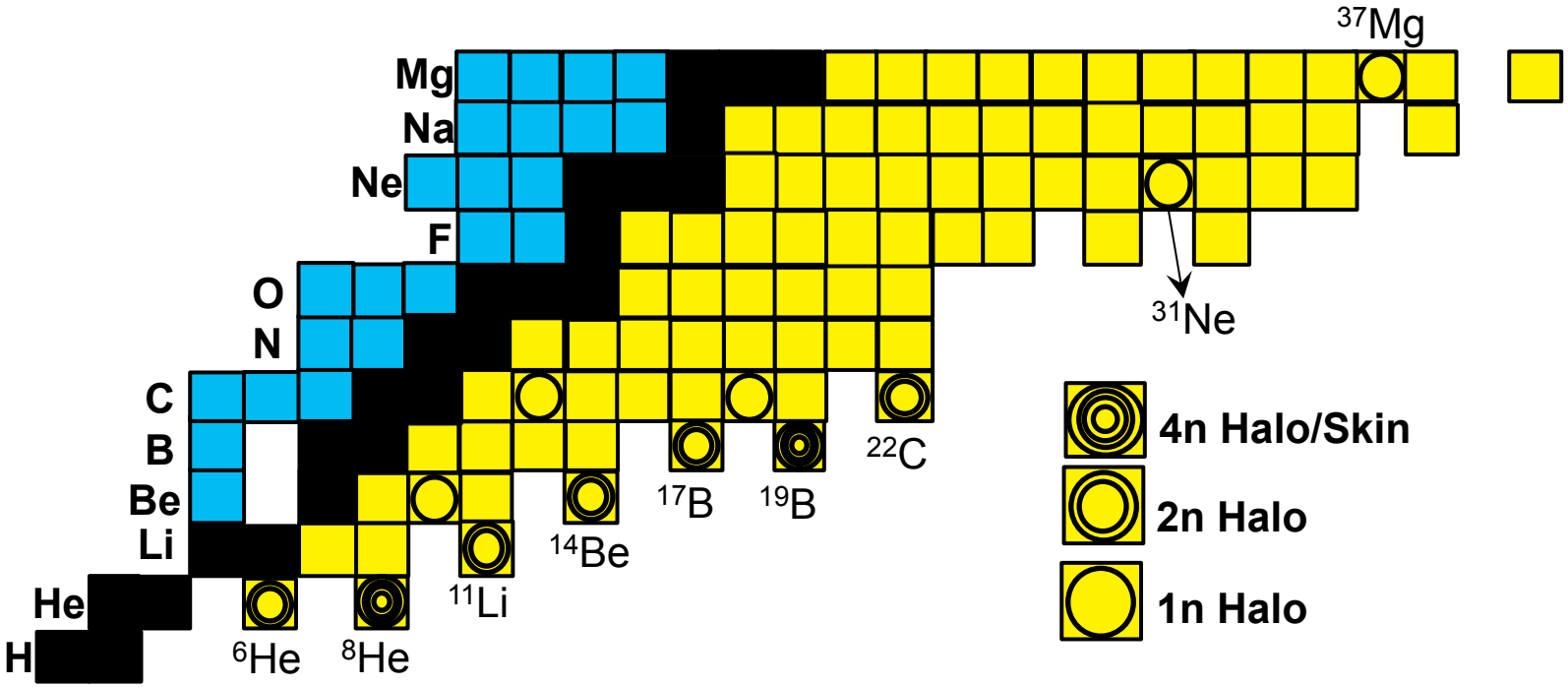
IPHC Institut Pluridisciplinaire Hubert Curien STRASBOURG

WHAT DOES THE SURFACE LOOK LIKE?

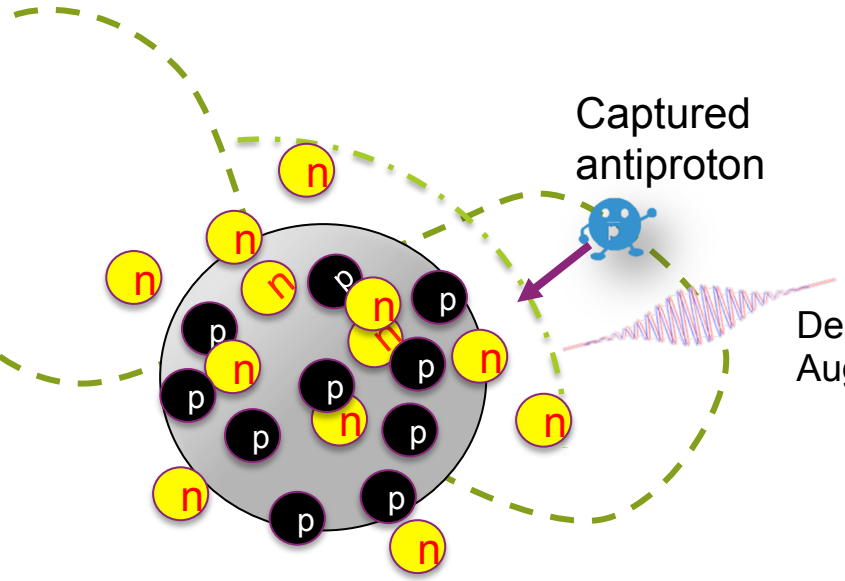
X-section for annihilation very high.

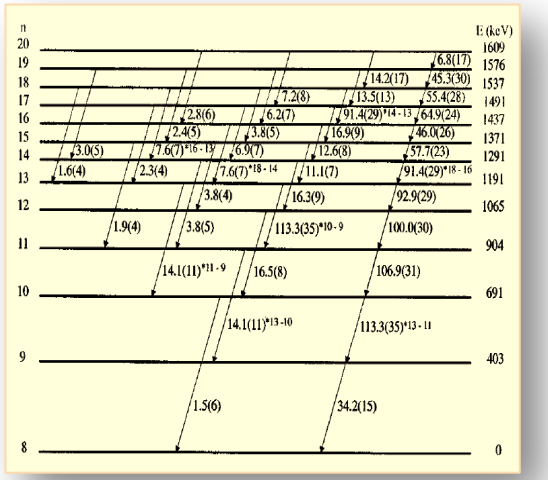


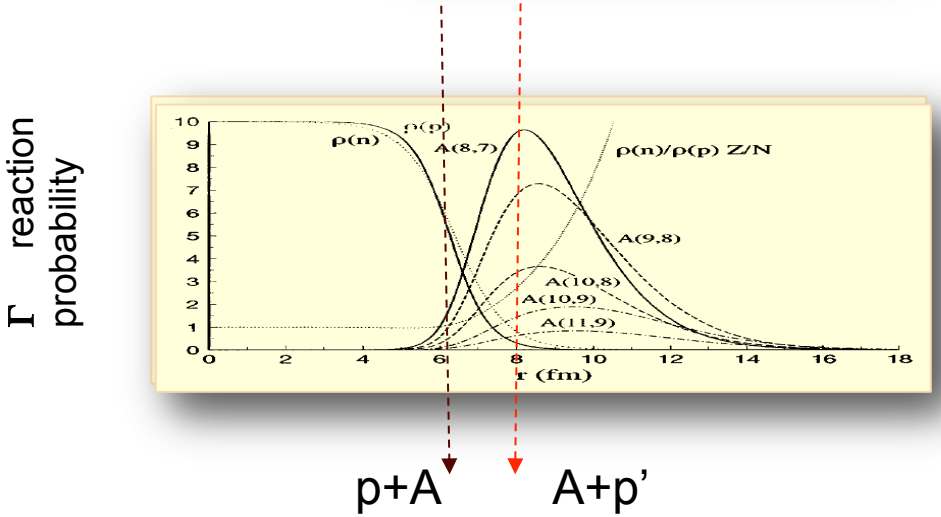




Antiproton annihilation as a probe for nuclear tails

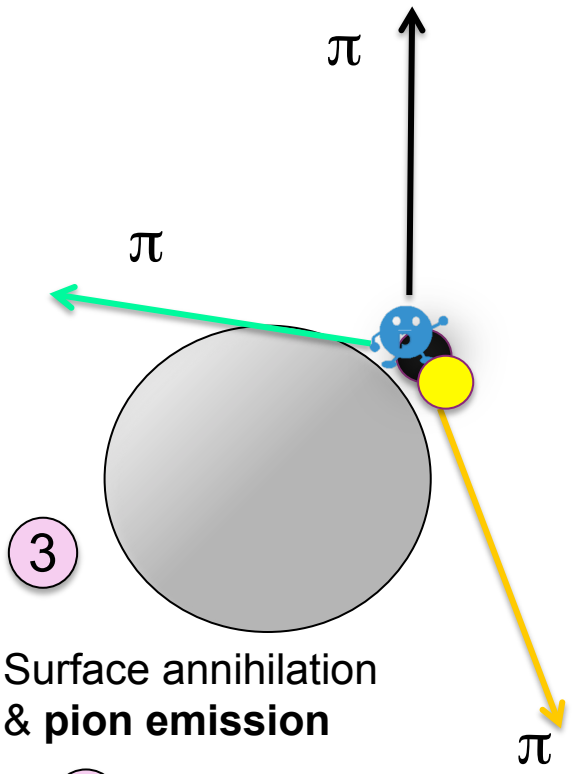






Microscopic calculations based on realistic N-Nbar interactions are required

Antiproton annihilation as a probe for nuclear tails



Surface annihilation
& **pion emission**

4

Cascade & **residue production**, decay

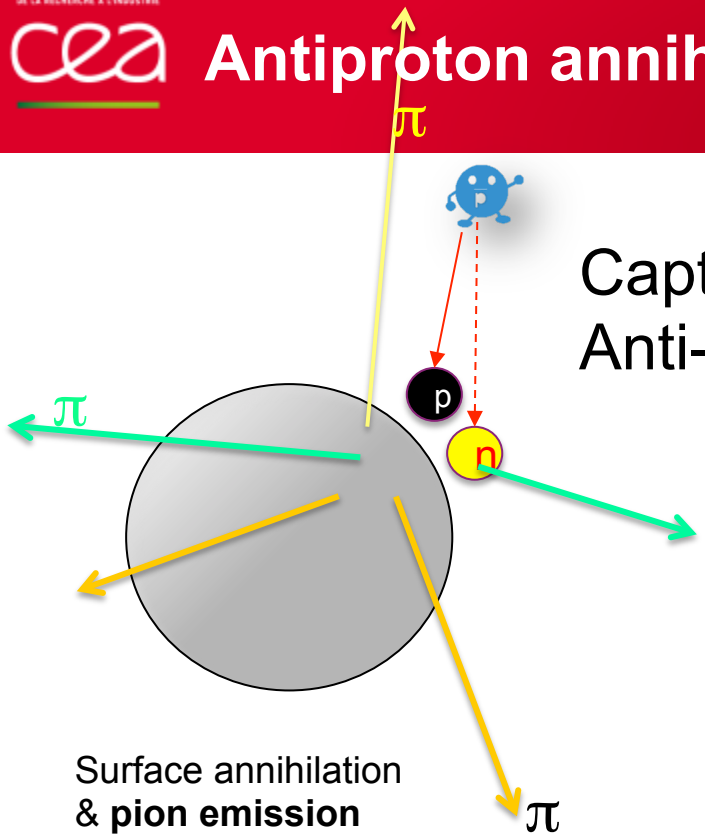
Net electric charge conservation

- **-1**: neutron annihilation
- **0**: proton annihilation

Antiproton-proton, $\overline{p}p$	
Pion final state	Branching ratio
$\pi^0\pi^0$	0.00028
$\pi^0\pi^0\pi^0$	0.0076
$\pi^0\pi^0\pi^0\pi^0$	0.03
$\pi^+\pi^-$	0.0032
$\pi^+\pi^-\pi^0$	0.069
$\pi^+\pi^-\pi^0\pi^0$	0.093
$\pi^+\pi^-\pi^0\pi^0\pi^0$	0.233
$\pi^+\pi^-\pi^0\pi^0\pi^0\pi^0$	0.028
$\pi^+\pi^-\pi^+\pi^-$	0.069
$\pi^+\pi^-\pi^+\pi^-\pi^0$	0.196
$\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0$	0.166
$\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0\pi^0$	0.042
$\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$	0.021
$\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\pi^0$	0.019

Antiproton-neutron, $\overline{p}n$	
Pion final state	Branching ratio
$\pi^-\pi^0$	0.0075
$\pi^- k\pi^0$ $(k > 1)$	0.169
$\pi^-\pi^-\pi^+$	0.023
$\pi^-\pi^-\pi^+\pi^0$	0.17
$\pi^-\pi^-\pi^+ k\pi^0$ $(k > 1)$	0.397
$\pi^-\pi^-\pi^-\pi^+\pi^+$	0.042
$\pi^-\pi^-\pi^-\pi^+\pi^+\pi^0$	0.12
$\pi^-\pi^-\pi^-\pi^+\pi^+ k\pi^0$ $(k > 1)$	0.066
$\pi^-\pi^-\pi^-\pi^-\pi^+\pi^+\pi^+ k\pi^0$ $(k \geq 0)$	0.0035

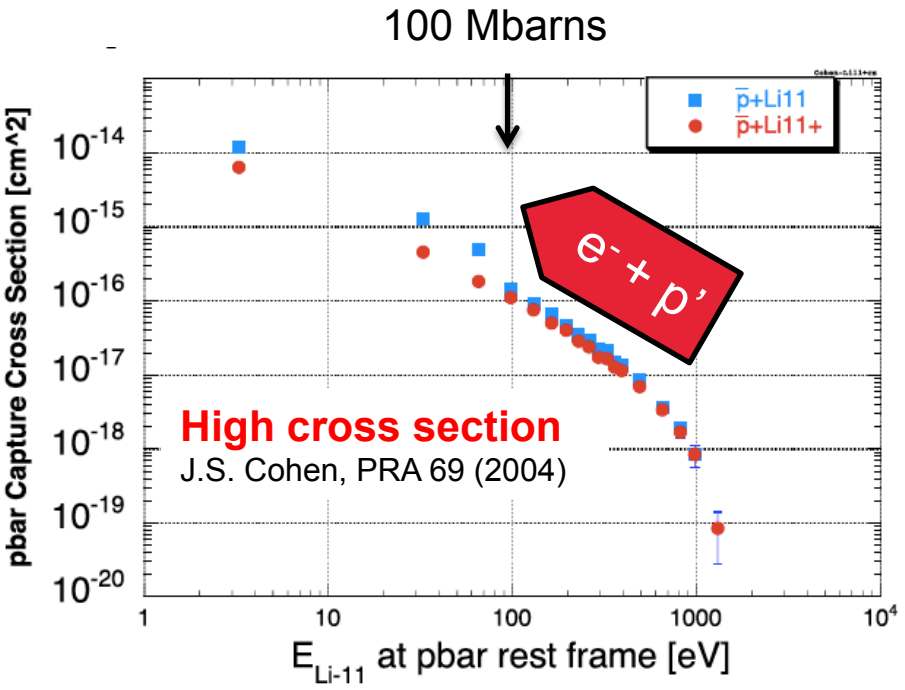
Antiproton annihilation as a probe for nuclear tails



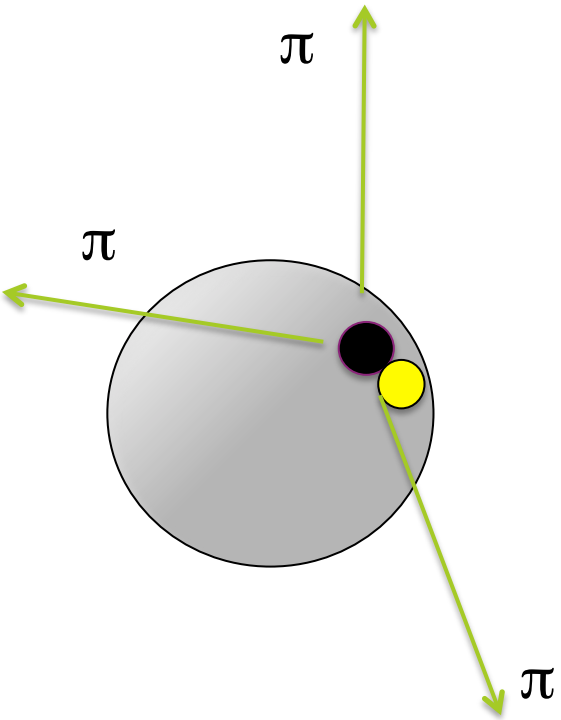
Captured
Anti-proton

Surface annihilation
& **pion emission**
➔ **n/p annhaliation**
➔ **Residual Interactions**

Cascade **X-Ray** & **Residue production**,
Decay ie γ, e n, p, α, fragments
Hypernuclei Λ



Antiproton annihilation as a probe for nuclear tails



Surface annihilation
& **pion emission**

- Sensitive to **neutron-proton density ratio at surface**

$$\frac{N_n}{N_p} \overset{\text{theory}}{\longleftrightarrow} \left.\frac{\rho_n}{\rho_p}\right|_{surface}$$

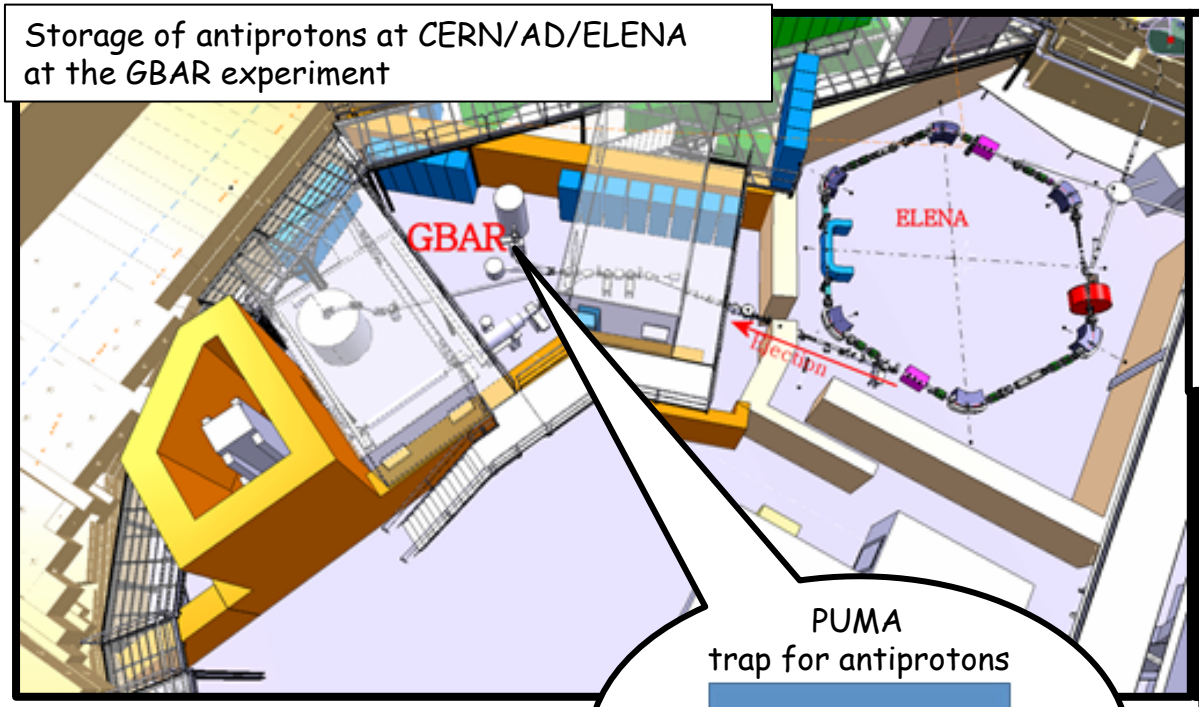
Extracted from data

- (Brookhaven, LEAR @ CERN)
  Bugg et al., PRL 31, 475 (1973)
  A.Trzcinska et al., PRL 87, 082501 (2001)

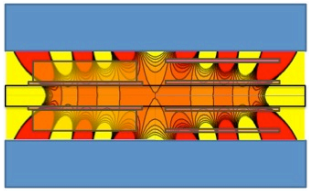
PUMA: Pbar Unstable Matter Annihilation

Bringing the antiprotons from AD (CERN) to ISOLDE (and other RIB facilities)

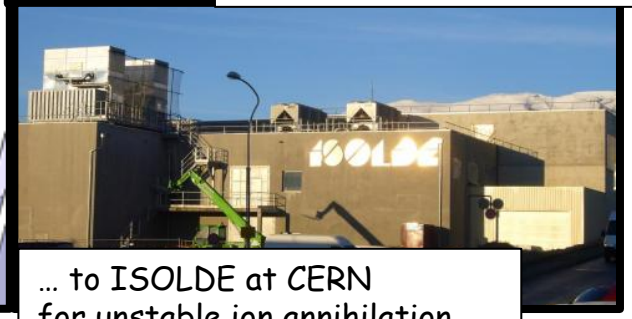
Storage of antiprotons at CERN/AD/ELENA
at the GBAR experiment



PUMA
trap for antiprotons



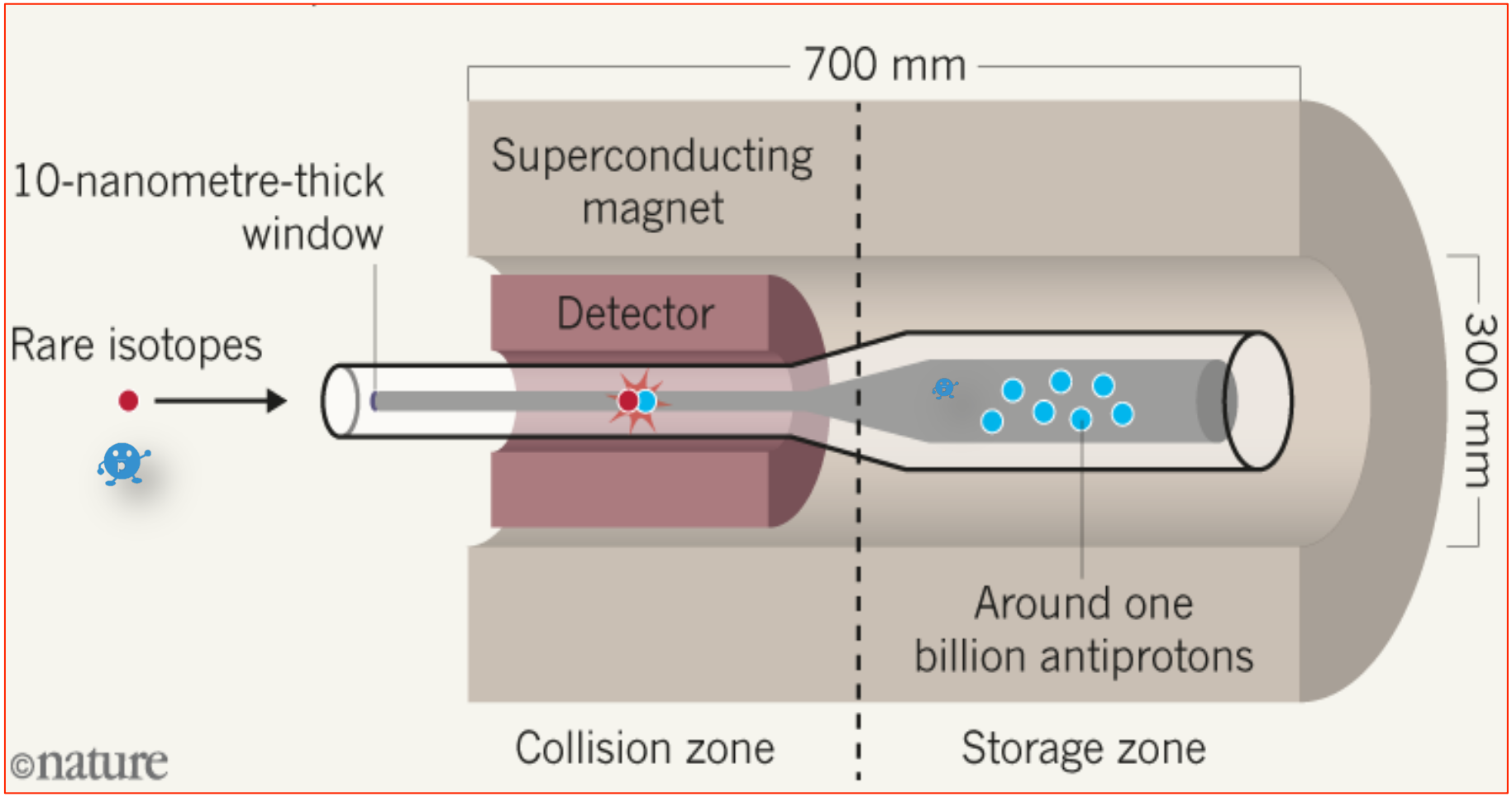
Transport the antiprotons…



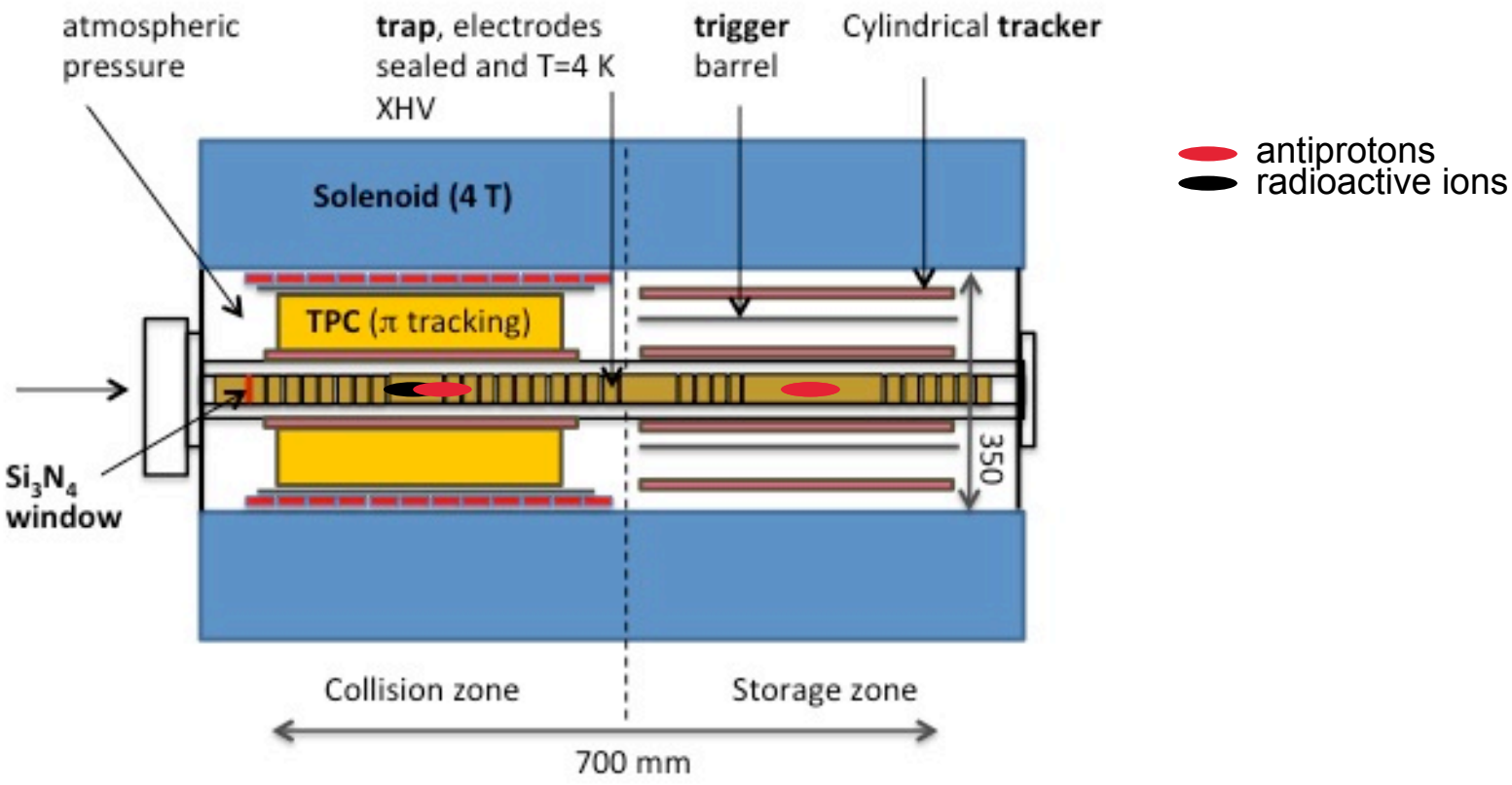
… to ISOLDE at CERN
for unstable ion annihilation.

A BOTTLE OF ANTI-MATTER

Penning Trap

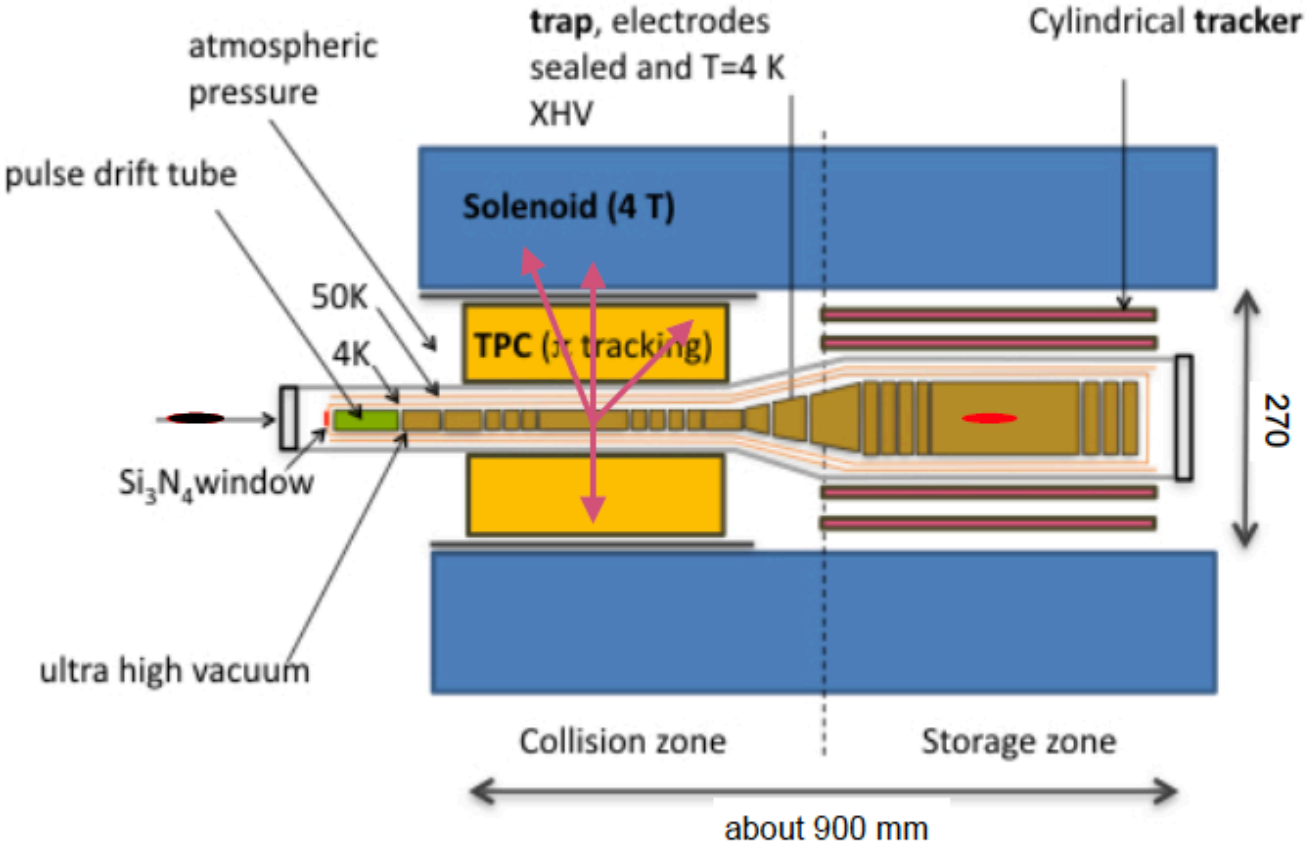


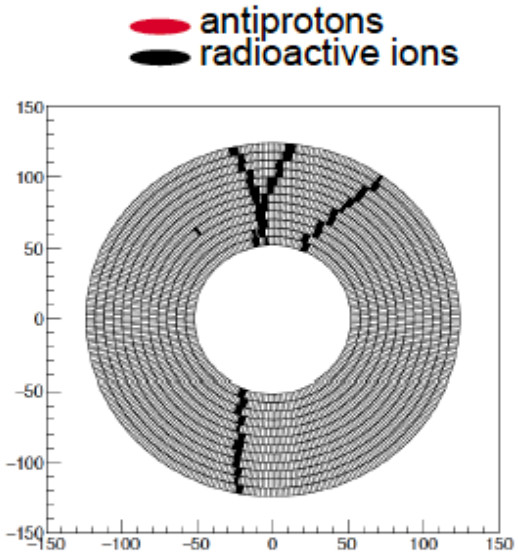
The PUMA device



- Store a large number of antiproton ($<10^8$) for a long time
  ⇒ **sealed cryogenic (4 K) trap for extreme vacuum (10^{-16} mbar)**
- Transport ions through a **nanometric window**
- Reconstruct net charge of annihilation via pion detection

PUMA: a magnetic bottle for antiprotons

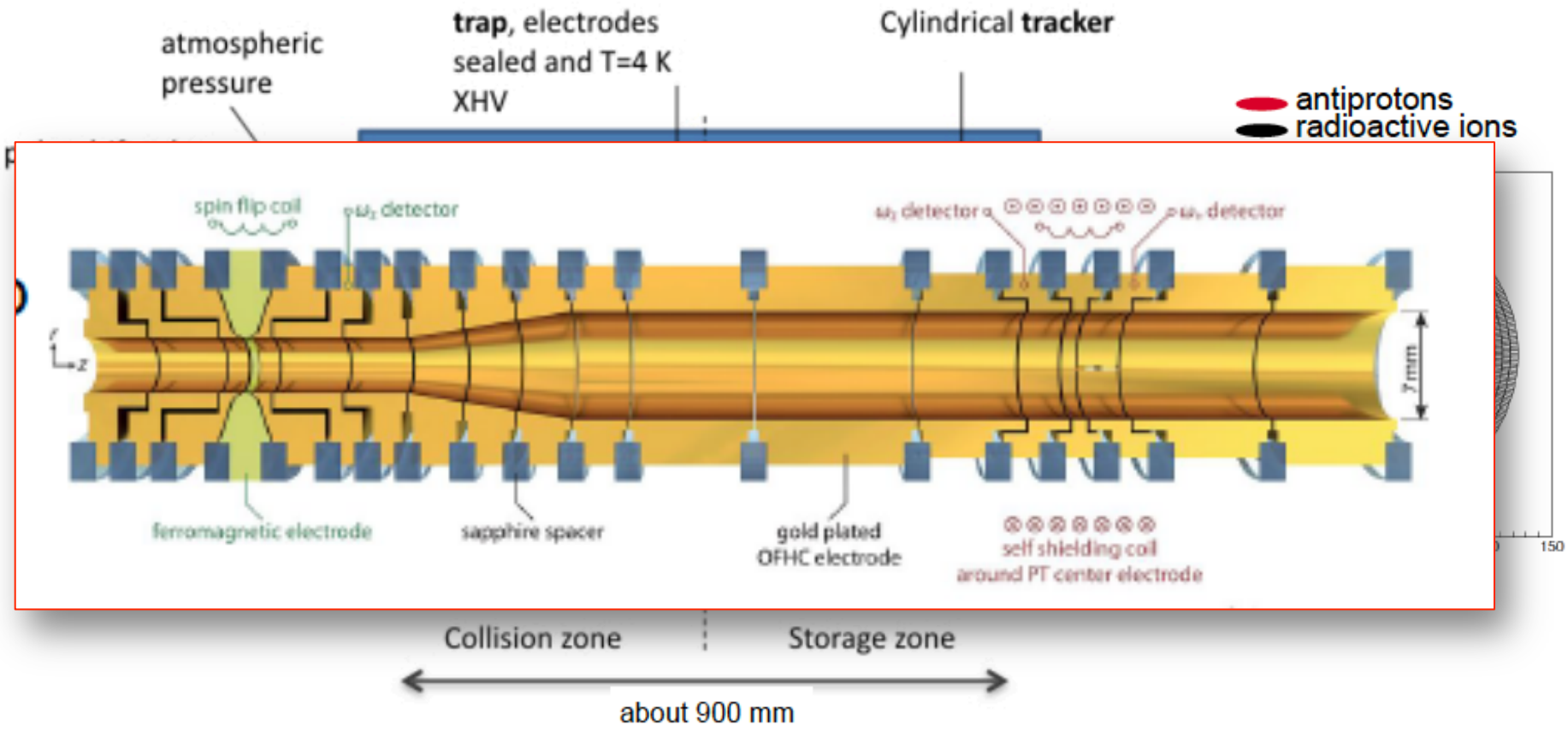




Technical challenges:

- ❑ Store a large number of antiproton (<10^8) for a long time
- ❑ Transport low-energy ions inside the ultra high vacuum

PUMA: a magnetic bottle for antiprotons



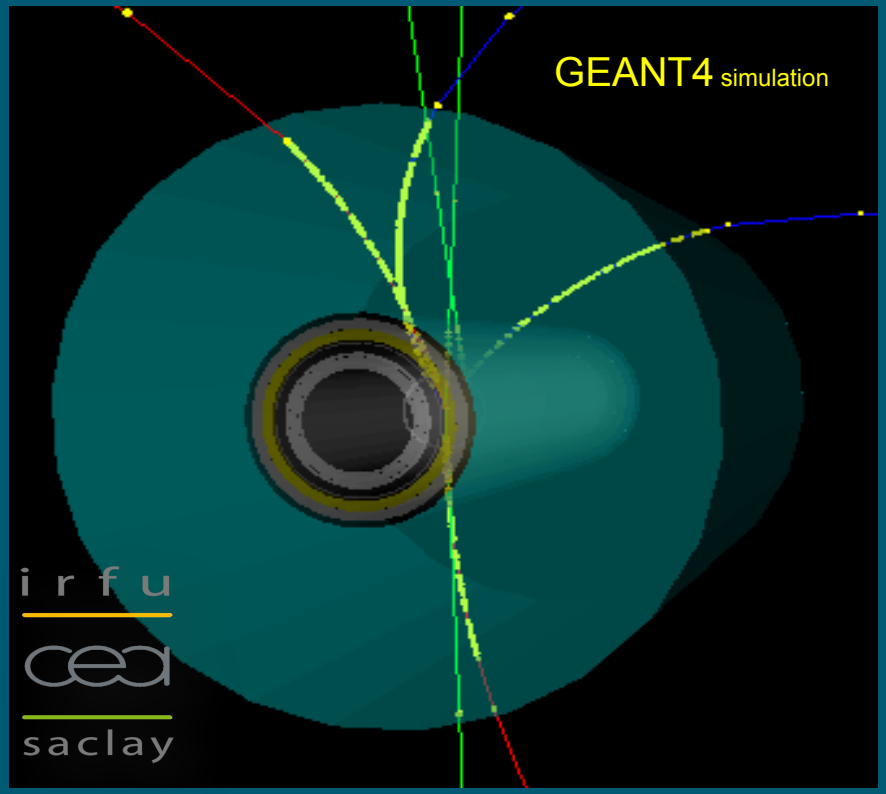
Technical challenges:

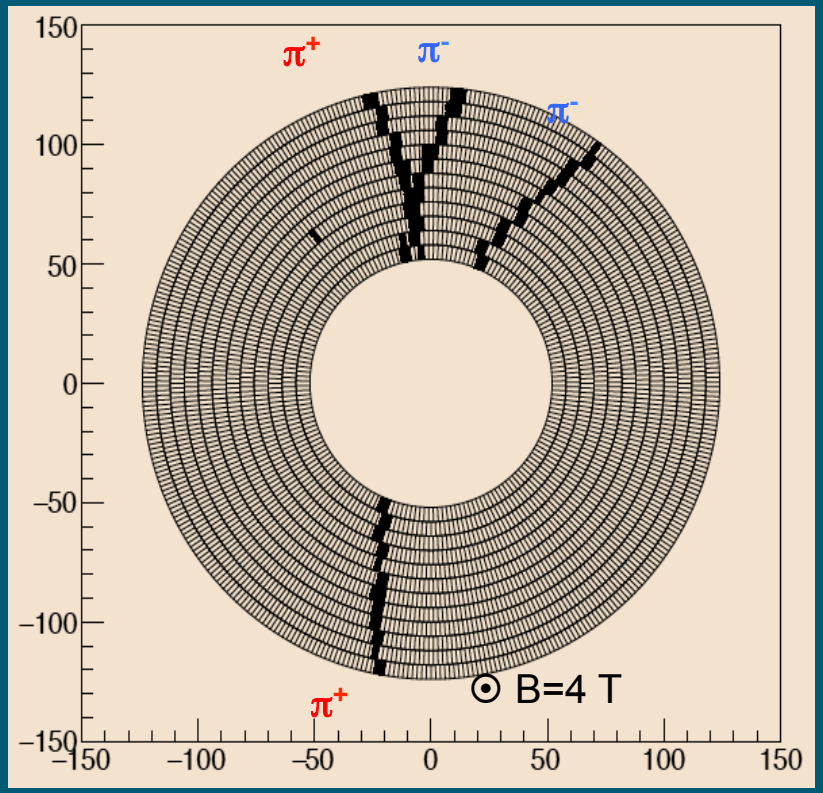
- ❑ Store a large number of antiproton (<10^8) for a long time
- ❑ Transport low-energy ions inside the ultra high vacuum

PUMA detection system

TPC (π+/π- identification, vertex tracking)

Anna Corsi IRFU/DPhN

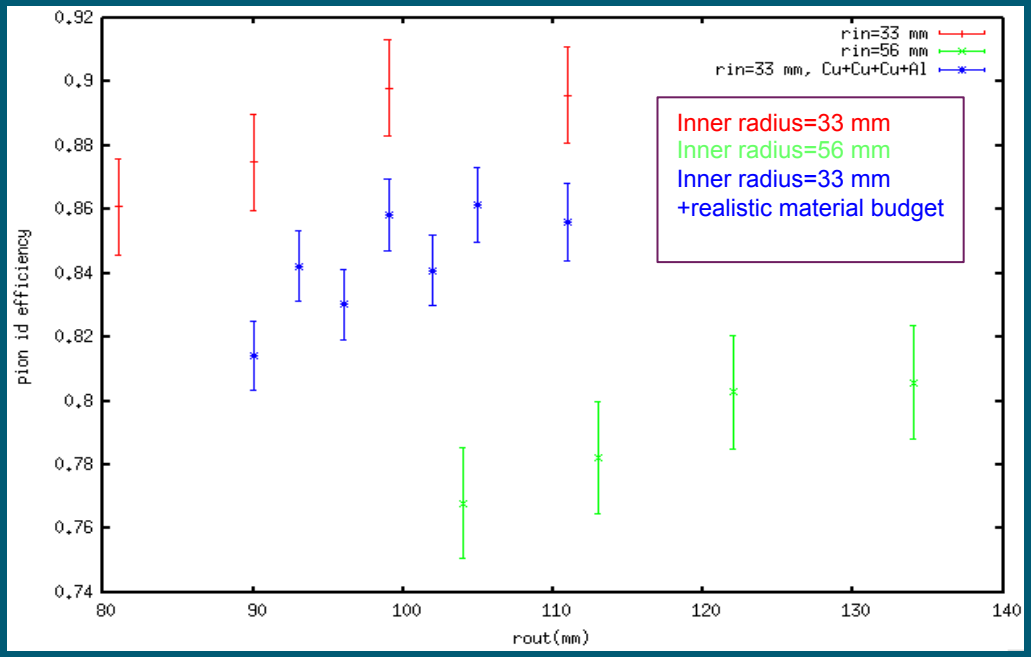




MINOS like TPC & Circle extraction

Anna Corsi

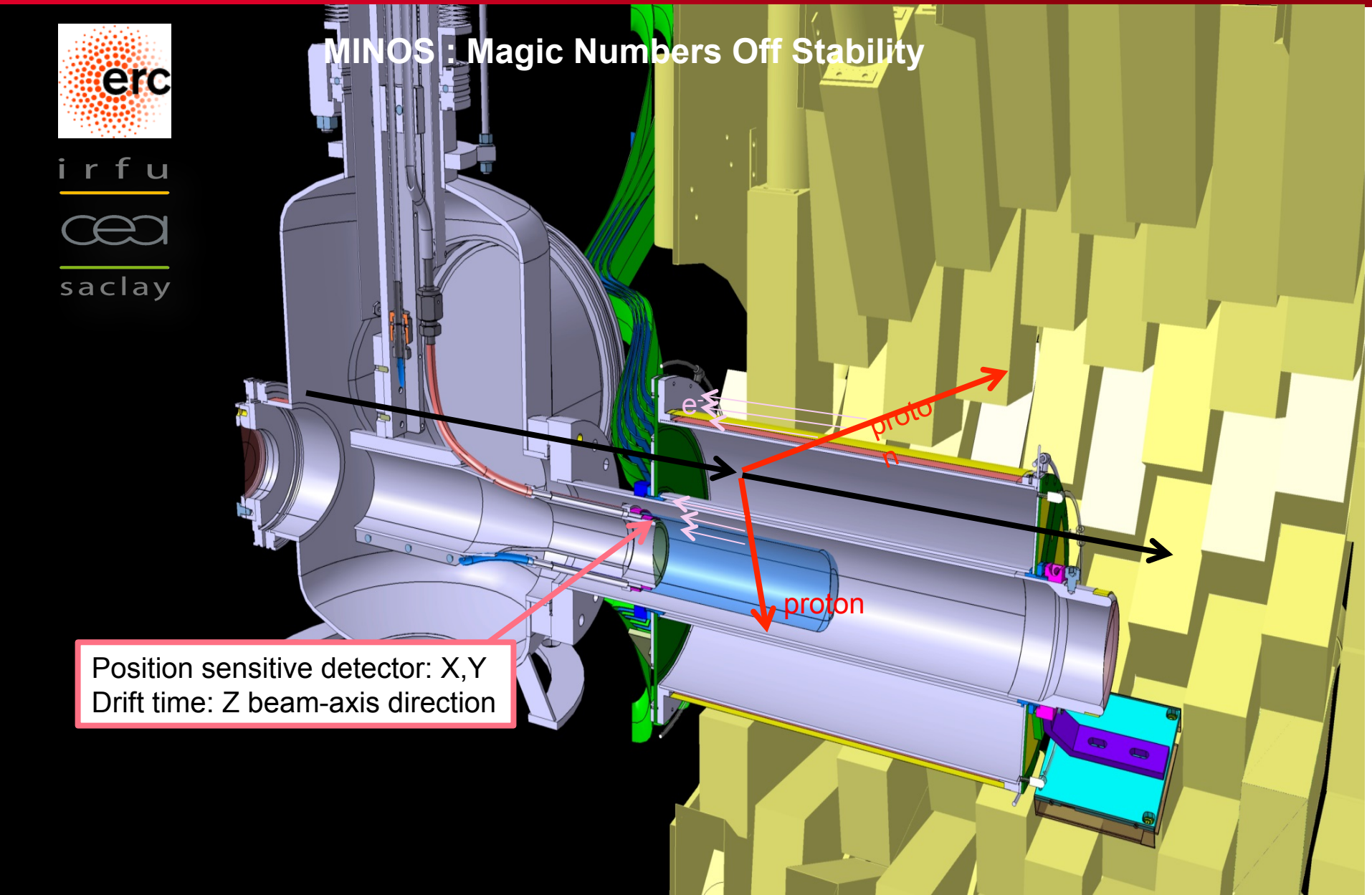
PID effi (%)



External TPC radius (mm)

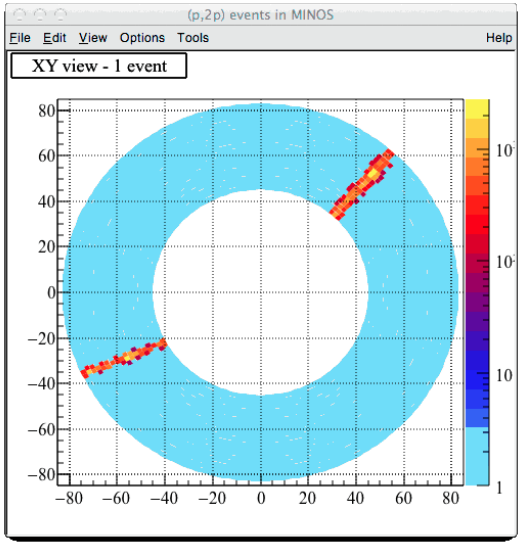
Simulation parameters:

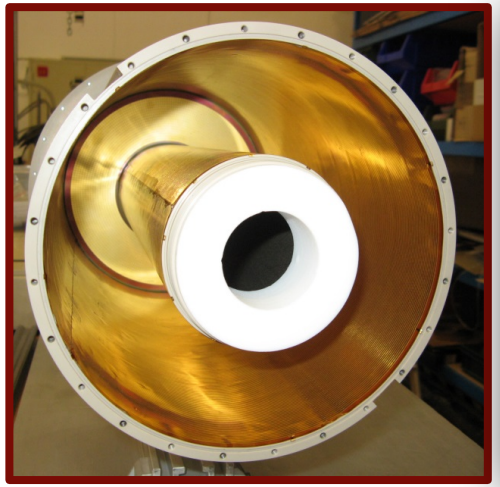
- Readout: ~5000 2x3 mm^2 pads
- Ar-based gas mixture with transverse diffusivity of 0.04 mm/ sqrt(cm)
- Electronics: gain of 1500, noise of 3000 electrons rms (MINOS-like)
- 4T uniform solenoidal magnetic field

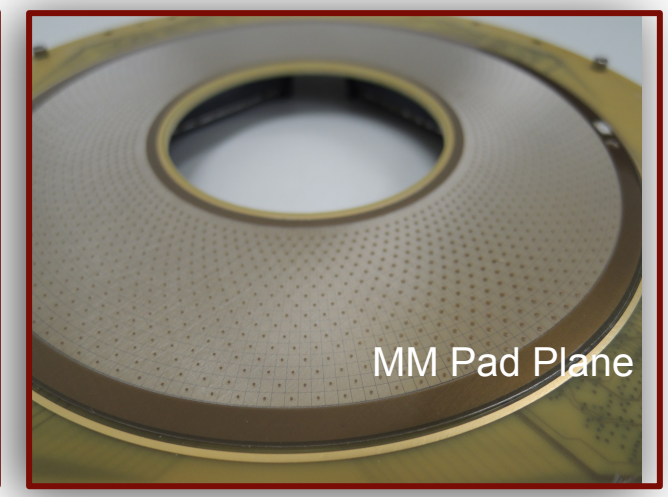

MINOS : Magic Numbers Off Stability
e-
proton
proton
Position sensitive detector: X,Y
Drift time: Z beam-axis direction

SIMILAR TO MINOS

MINOS: TPC dedicated to Nucl. Phys. *5000 **AGET** channels TPC+DSSSD*







irfu cea saclay

PUMA reliability emphasis

➔ Double-Wall for Field Cage
➔ Spark-Less design
➔ Field Uniformity
➔ Low gas contamination
➔ µ-electronics (5000 Channels)

PUMA – TPC
VERTEX & CHARGE CATCHER

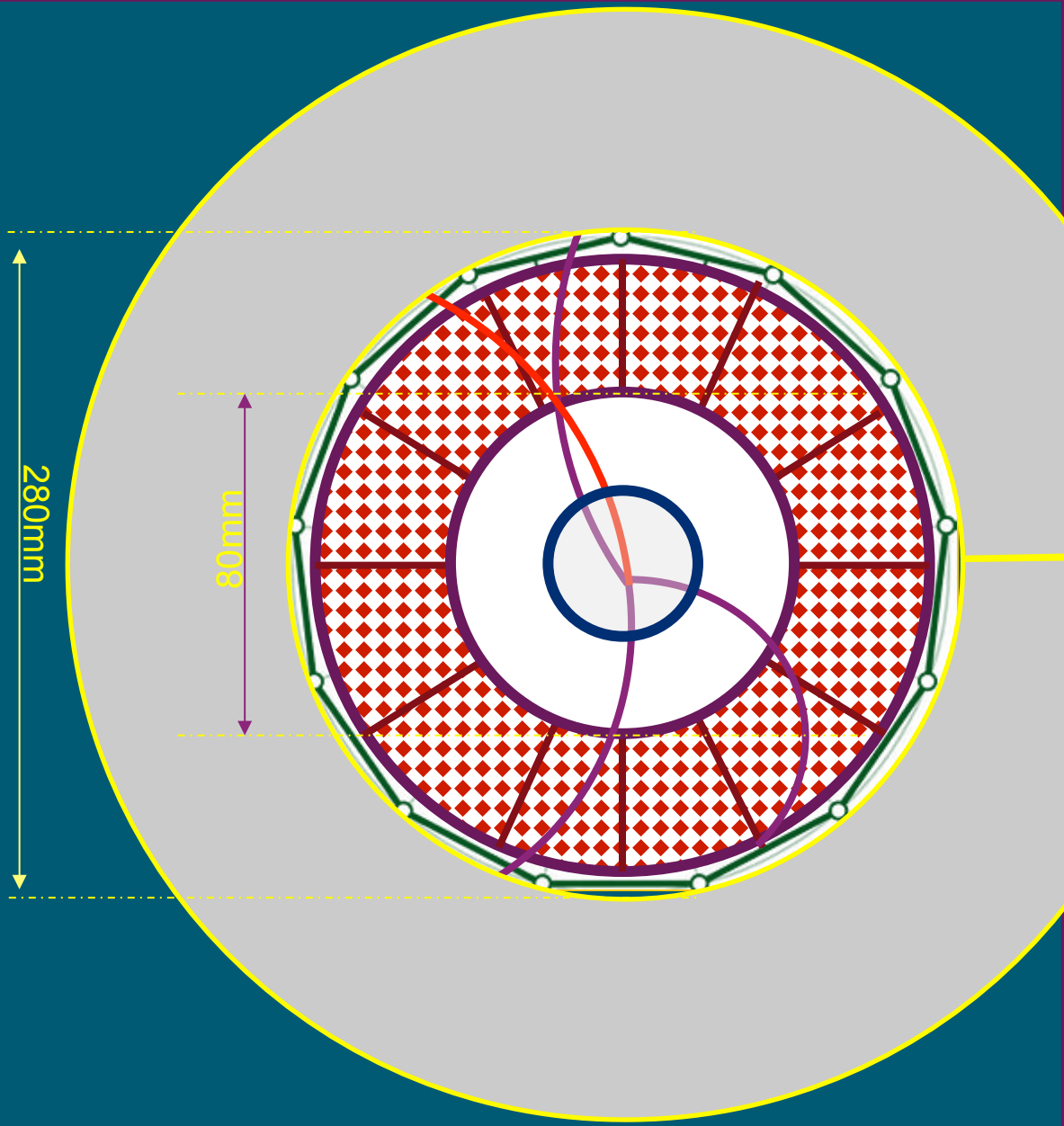
Active Volume – high 89% L = 300mm

Field Cage
- Extra “Simple” PCB
- Low **E**-field distortion

Pad Plane – PCB
- Pads – 2x2mm^2 – 5Kch
- Micromegas MPGD
- Resistive (DLC) & **B**-Field
- Charge 15%
- Low sparking probabilities

Electronics – GET derivative

High Reliability Design
- No internal maintaining <2years.
- Mechanically Stable (Transport)
- Low sparking prob.

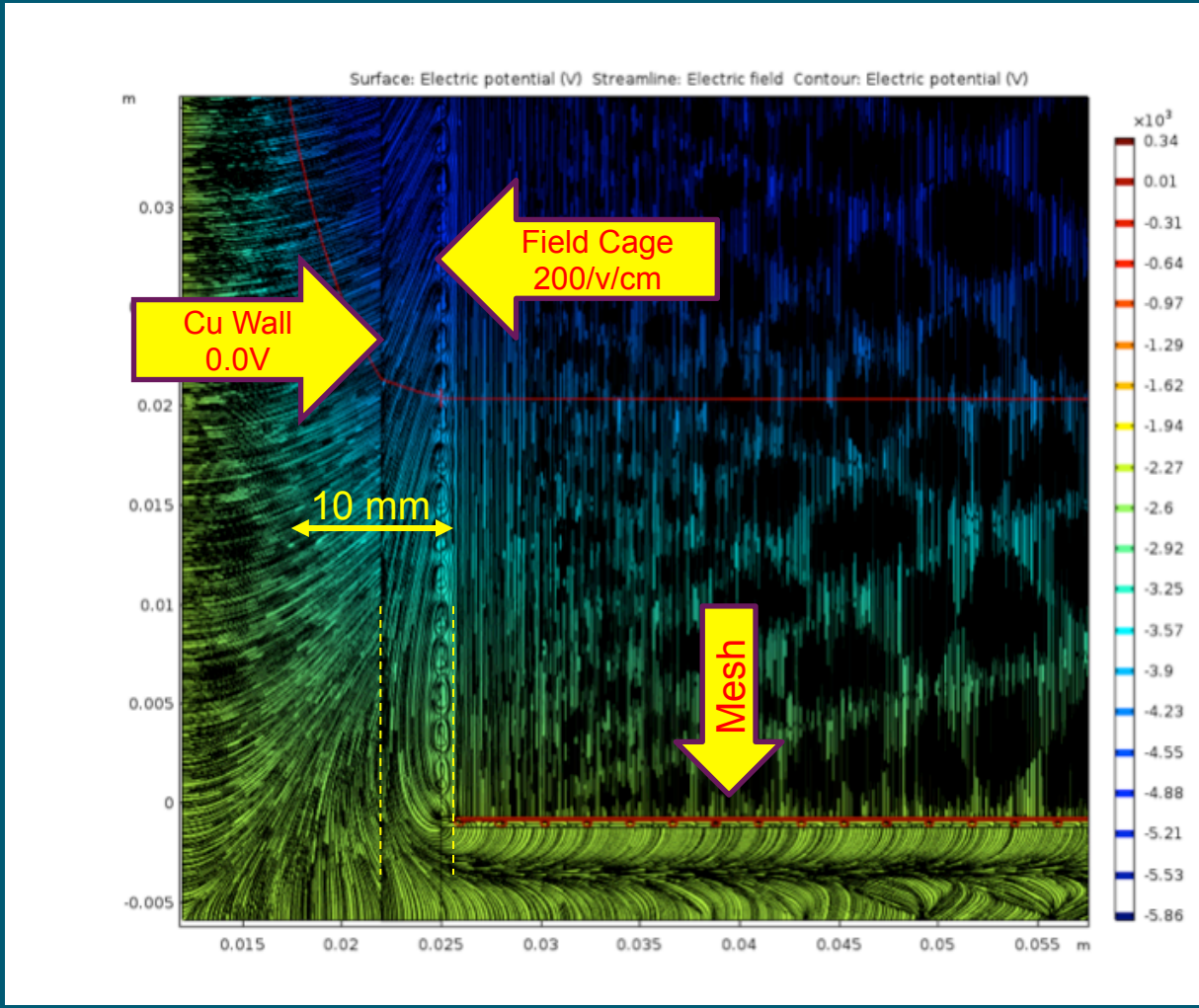


irfu cea saclay

COMSOL Simulation Of the E-Field

➔implies that we will use 90% of the Gas volume.

Cathod OK



Nancy PAUL

DETECTION PUMA

Micromegas MPGD pad plane

Mesh

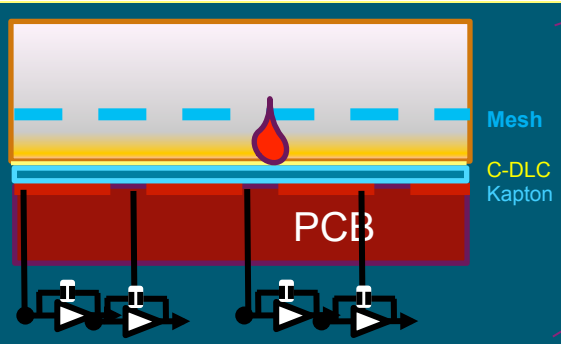
Resistive DLC – spreading of signal

- Robust & charge distribution
- Higher resoln

50µm Kapton

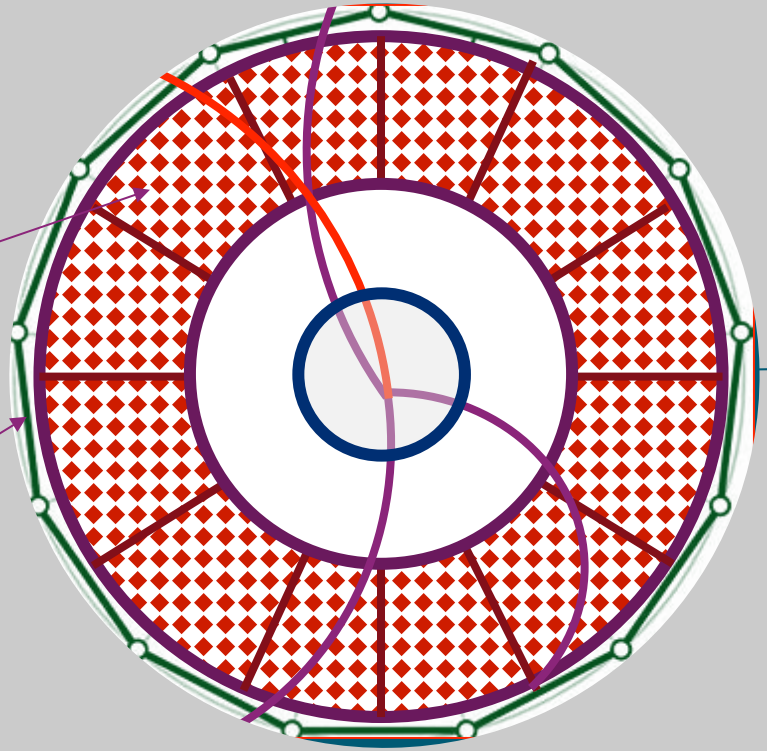
2x2mm^2 - 5k pads

GET/MINOS electronics



Trigger
Plastic
SiPM

Solenoid
4T



PUMA – BARRELS
TRIGGER

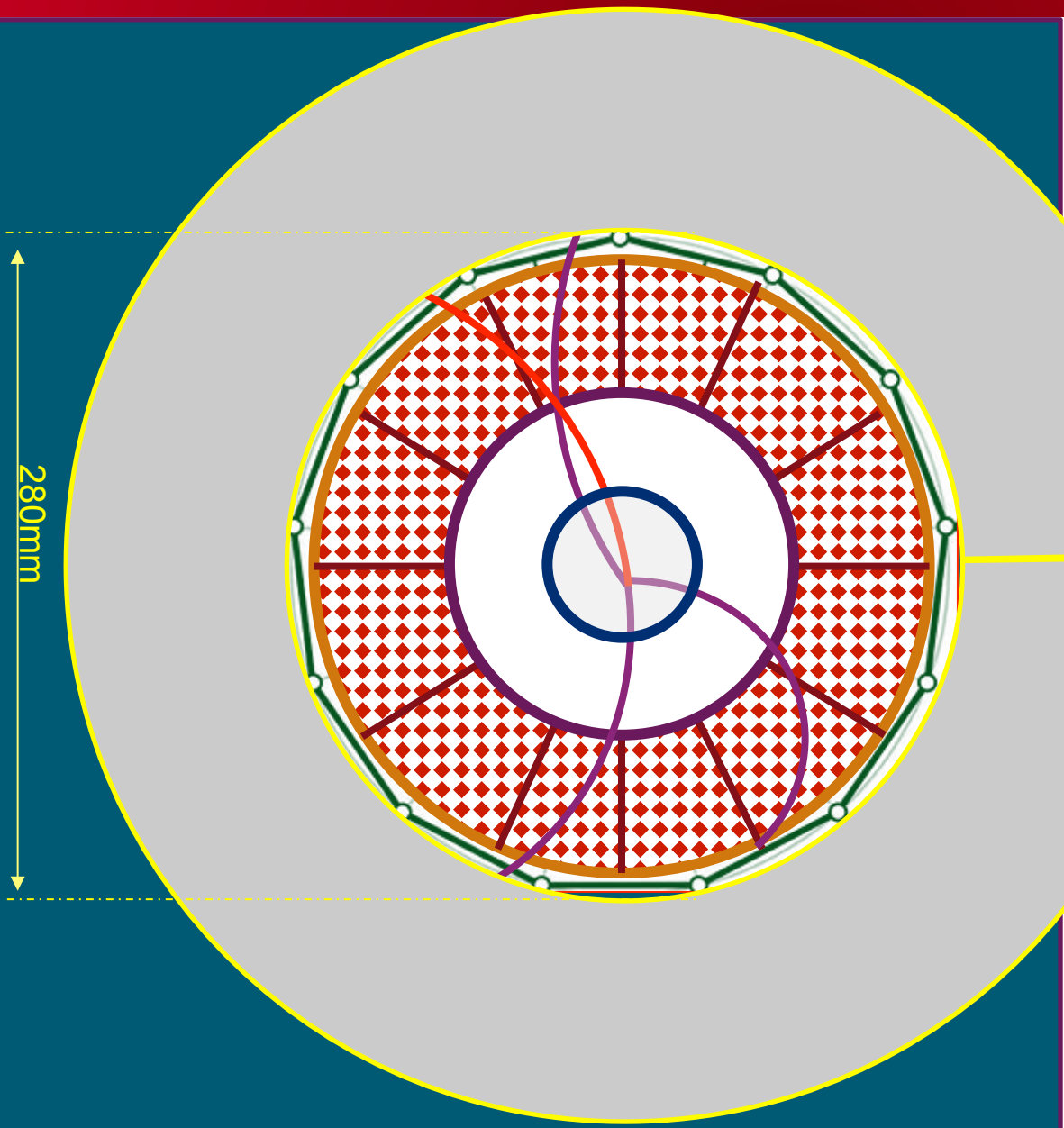
PUMA-Collision Barrel (TPC)
- 24 Strips 35x5x350mm
- 4 SiPM per strip
  - 2 SiPM on either end

PUMA-Store Barrel
- Inner Barrel – 12/24 strips
- Outer Barrel – 24/48 strips

Electronics
- GET Derivative – 240/480 channels

Trigger
- Given the low rates the STORE & COLLISION will be a common trigger.
- The COLLISION trigger will be the TPC trigger

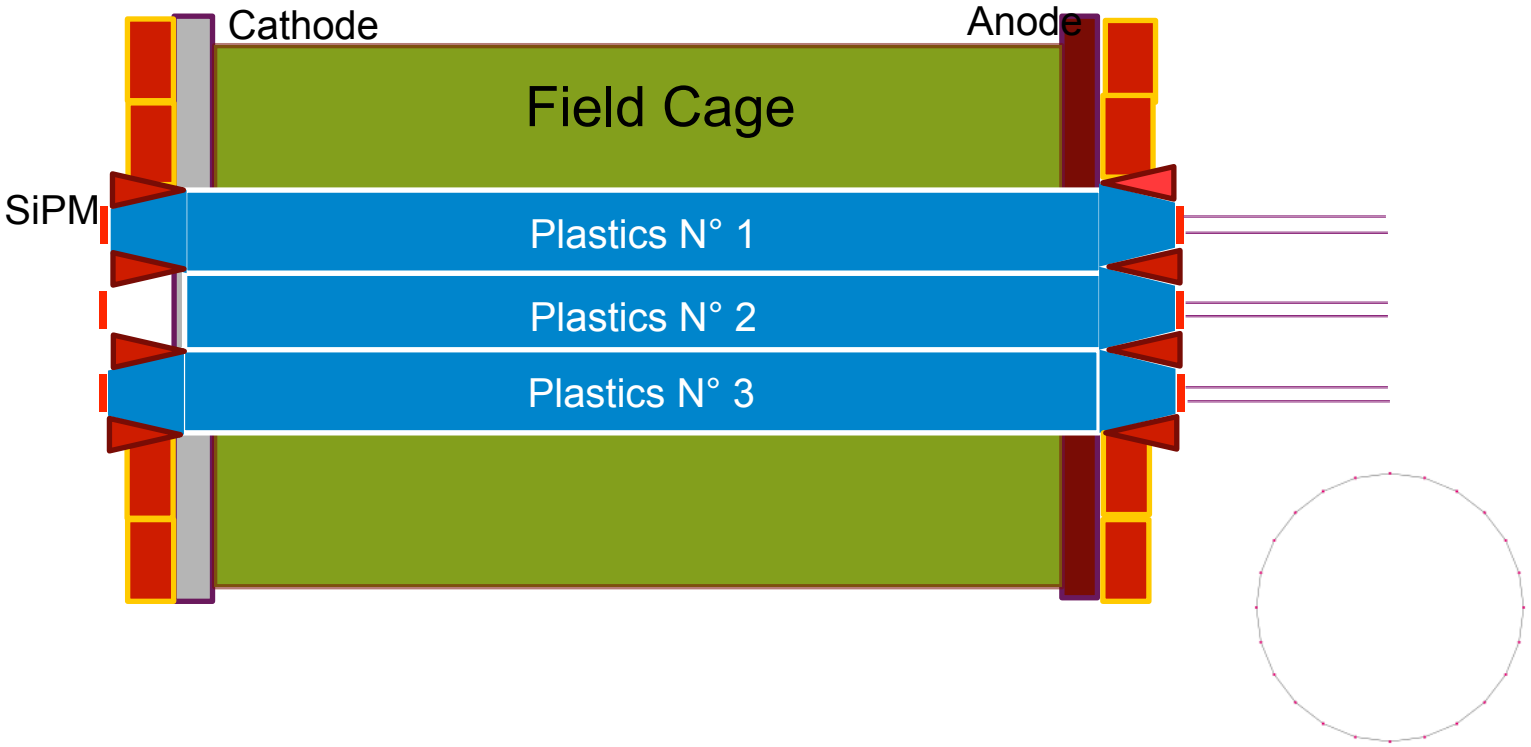
High Reliability & Efficiency

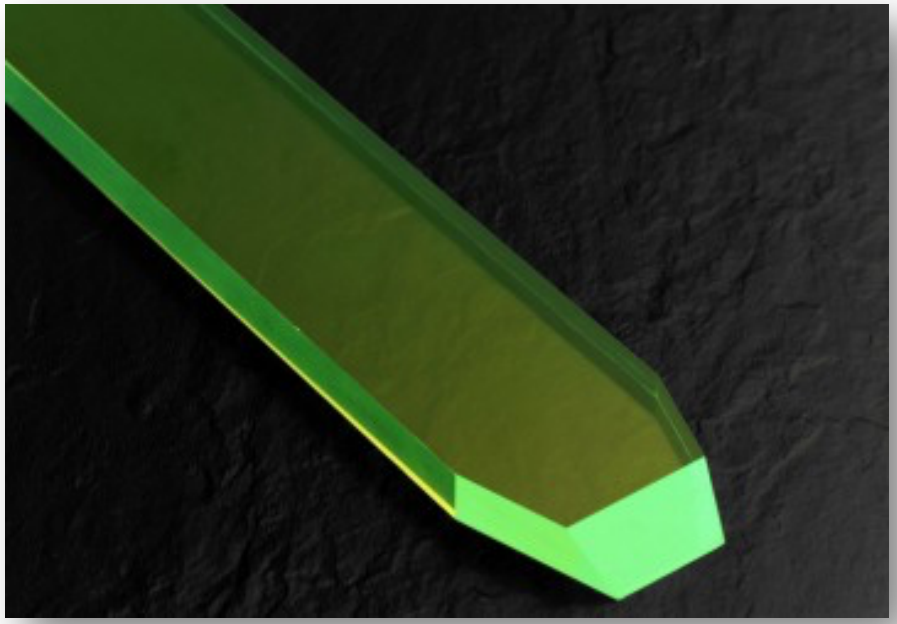


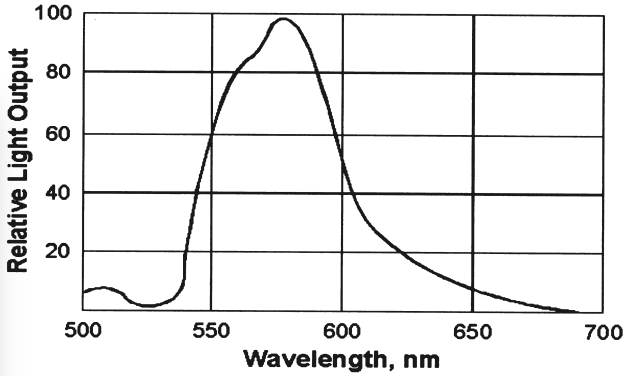
$\Pi^{+/-}$ IN PLASTIC

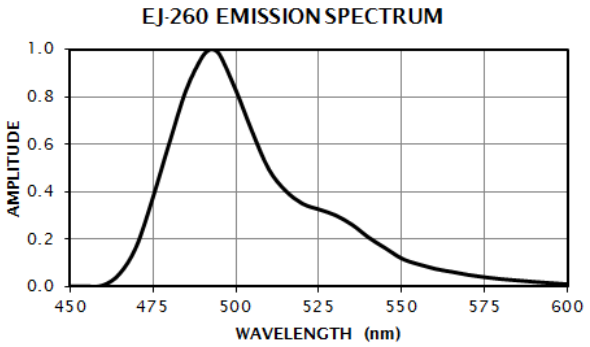
MIP – 10^3 photons/mm of scintillating Plastic

Plastic Scintillator - Light Output, % Anthracene 35% - 45%

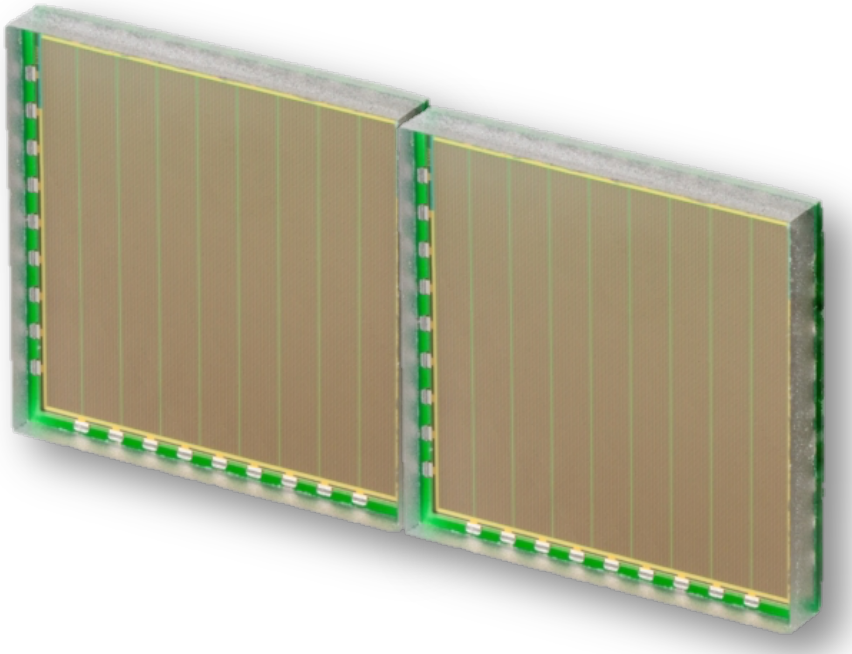


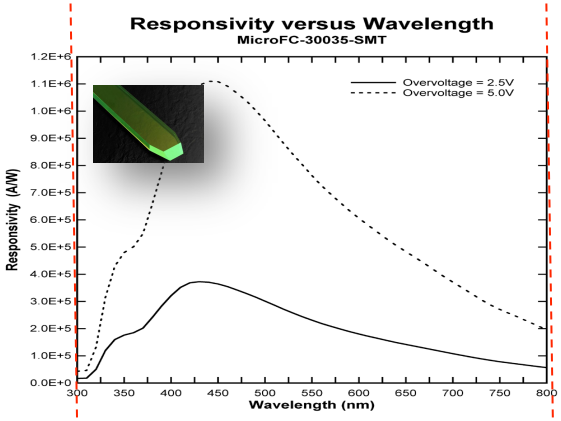


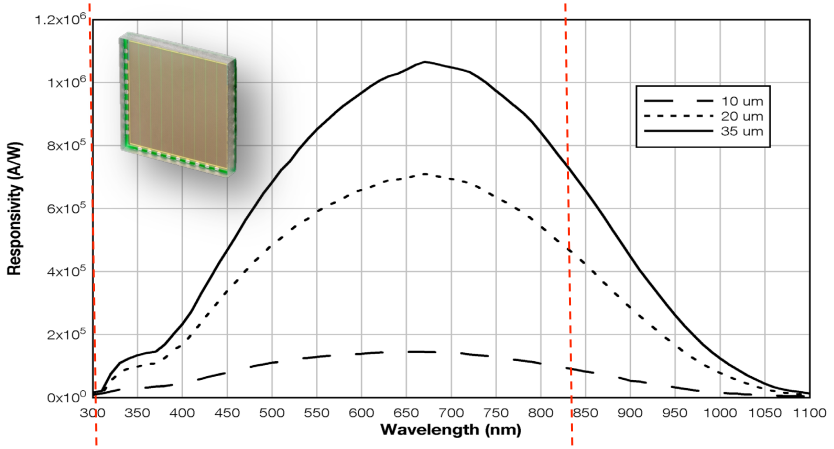

Relative Light Output
100
80
60
40
20
500
550
600
650
700
Wavelength, nm


EJ-260 EMISSION SPECTRUM
AMPLITUDE
1.0
0.8
0.6
0.4
0.2
0.0
450
475
500
525
550
575
600
WAVELENGTH (nm)

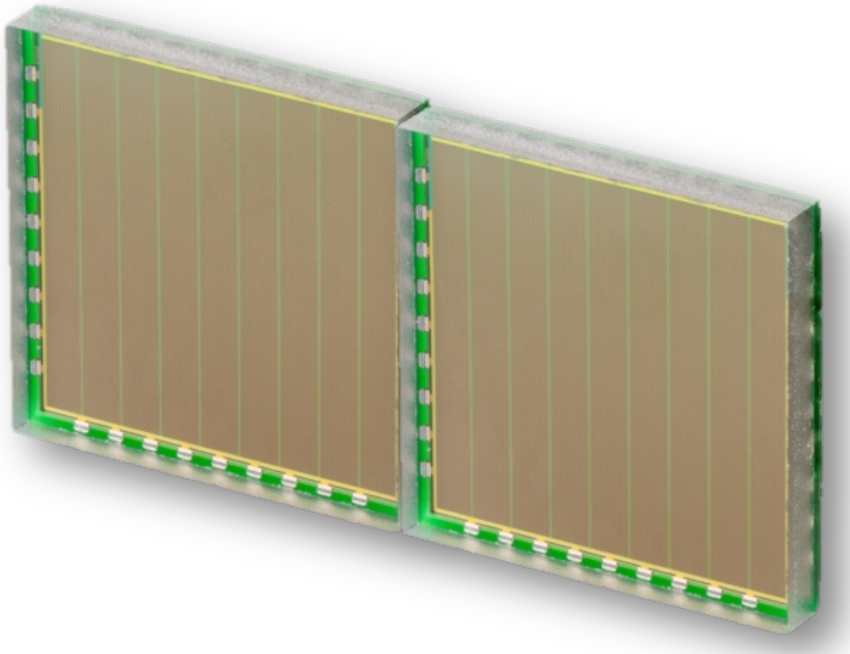
SIPM 4X4MM²

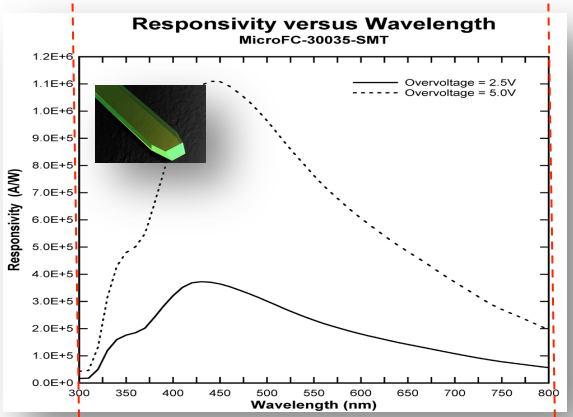


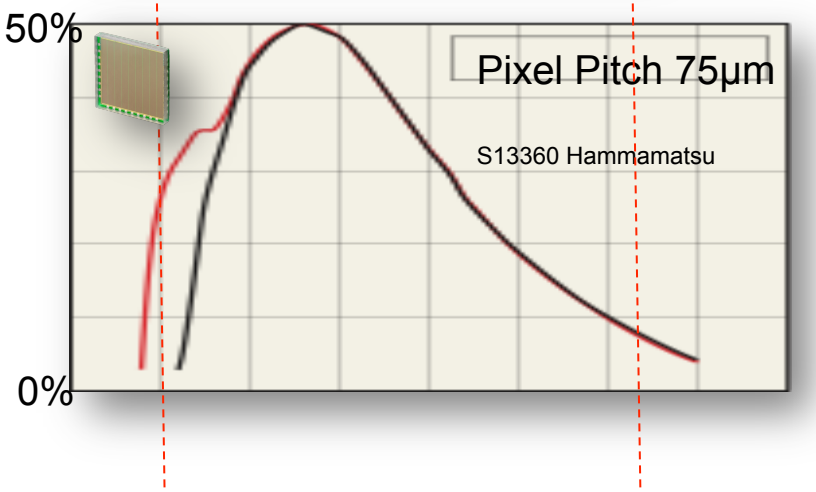

Responsivity versus Wavelength
MicroFC-30035-SMT
Overvoltage = 2.5V
Overvoltage = 5.0V
Responsivity (A/W)
Wavelength (nm)


10 um
20 um
35 um
Responsivity (A/W)
Wavelength (nm)

SIPM 4X4MM²




Responsivity versus Wavelength
MicroFC-30035-SMT
Overvoltage = 2.5V
Overvoltage = 5.0V
Responsivity (A/W)
Wavelength (nm)
1.2E+6
1.1E+6
1.0E+6
9.0E+5
8.0E+5
7.0E+5
6.0E+5
5.0E+5
4.0E+5
3.0E+5
2.0E+5
1.0E+5
0.0E+0
300
350
400
450
500
550
600
650
700
750
800


50%
0%
Pixel Pitch 75µm
S13360 Hammamatsu

Options are relatively small

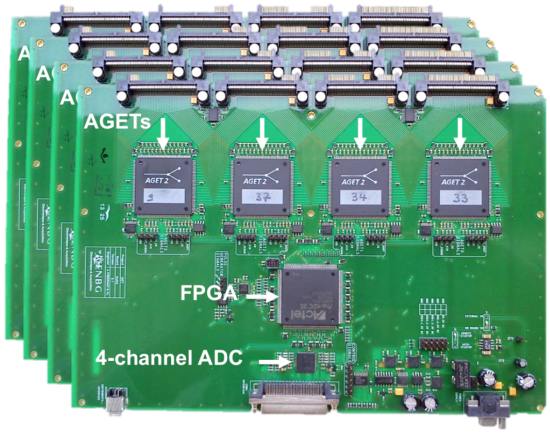
Decision is yet to be done.

An example given are:-

- GET is a Nuclear Physics development
- MINOS uses the GET ASIC

HARDWARE – PUMA EST.

23 AsAd
=5888 ch
20+3 AsAd



Chip Card 64X4

10G
bit/s

1
MUTANT

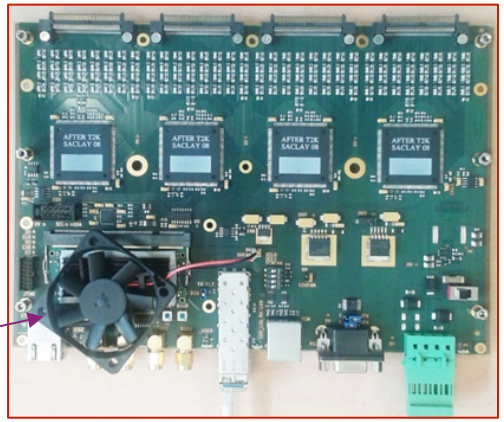
Numeric 3-
Level Trigger
Σ = 30,720
max channels

Concentration
Board
Σ = 1024 channels

6 CoBo

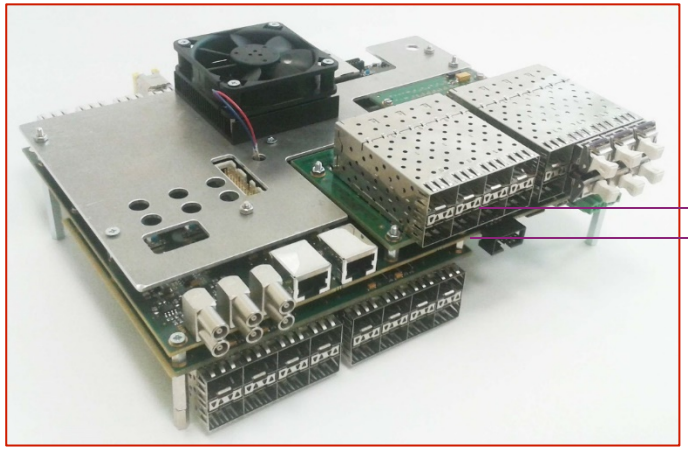
ARC – TDCM SYSEM

ARC
23 ARC
=5888 ch
20+3 AsAd



FPGA

ARC Chip Card 64X4



OPTIC LINKS

PC FARM

Denis Calvet IRFU/Saclay

No More