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The IDEA Muon detector

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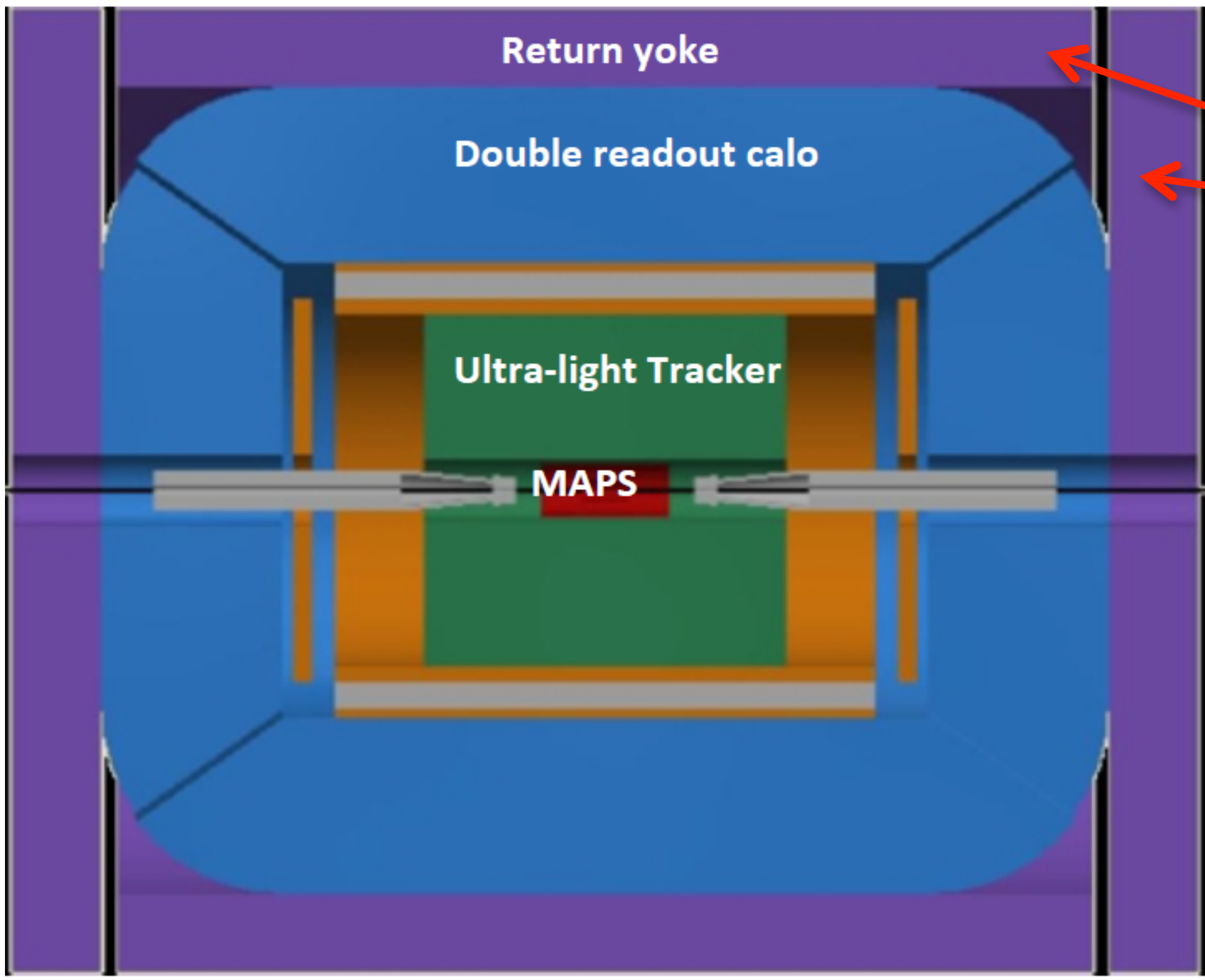
on behalf of the IDEA group

IDEA Muon detector for CepC

In the IDEA detector, the muon detection system is made of 3 (or 4) MPGD stations interleaved in the iron return yoke.

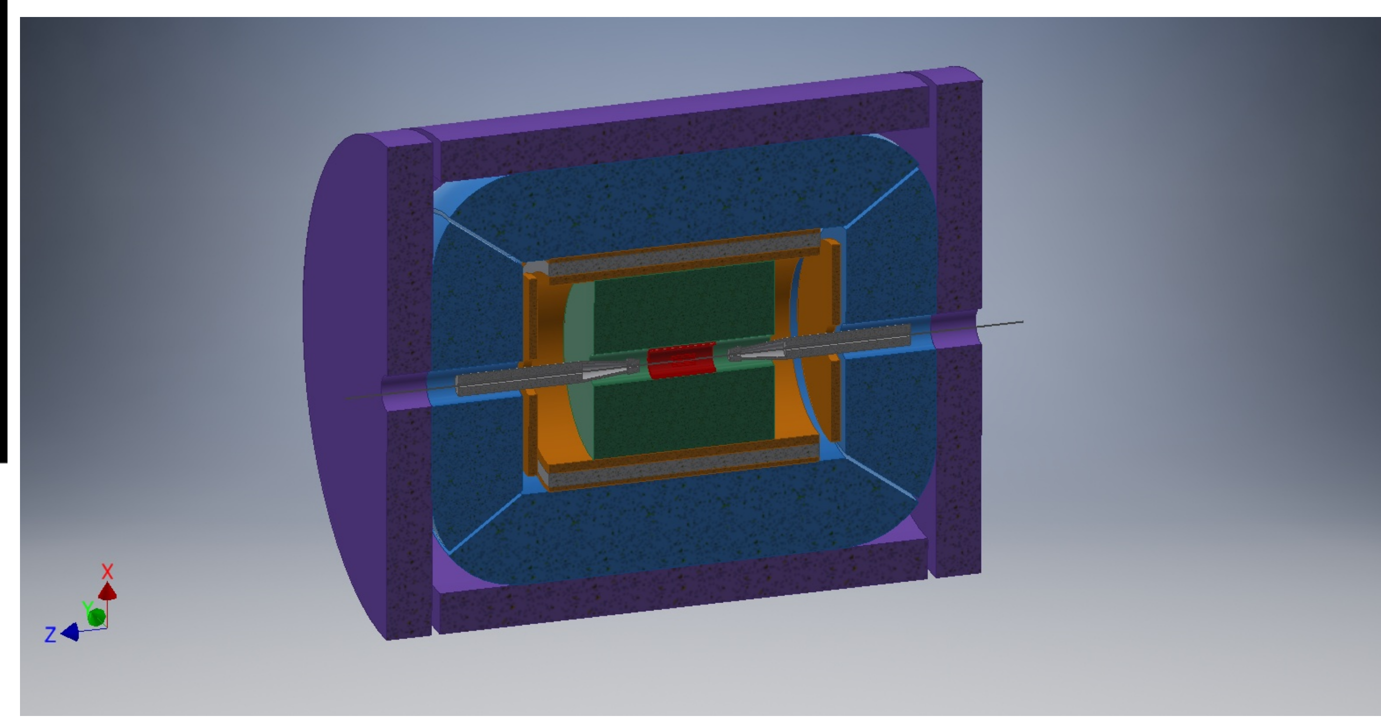
Typical geometry with a central barrel hermetically closed by 2 endcaps.

IDEA



Muon stations

B = 2 Tesla



μ-RWELL detectors have demonstrated very high detection efficiency → no need of many layers.

Muon detector dimensions

- Muon detector with 3 stations in both barrel and endcaps
  - Barrel surface ~850 x 2 (layers) = 1700 m^2
  - Endcap surface ~900 x 2 (layers) = 1800 m^2
  - Total muon detector surface 3500 m^2
- μRWELL detector dimensions 50 x 50 cm^2
- Strip pitch ~ 1000 μm (1 mm)
- Total number of channels ~7 million
- Position resolution ~270-300 μm per layer in both spatial directions
- Time resolution ~ 5-7 ns

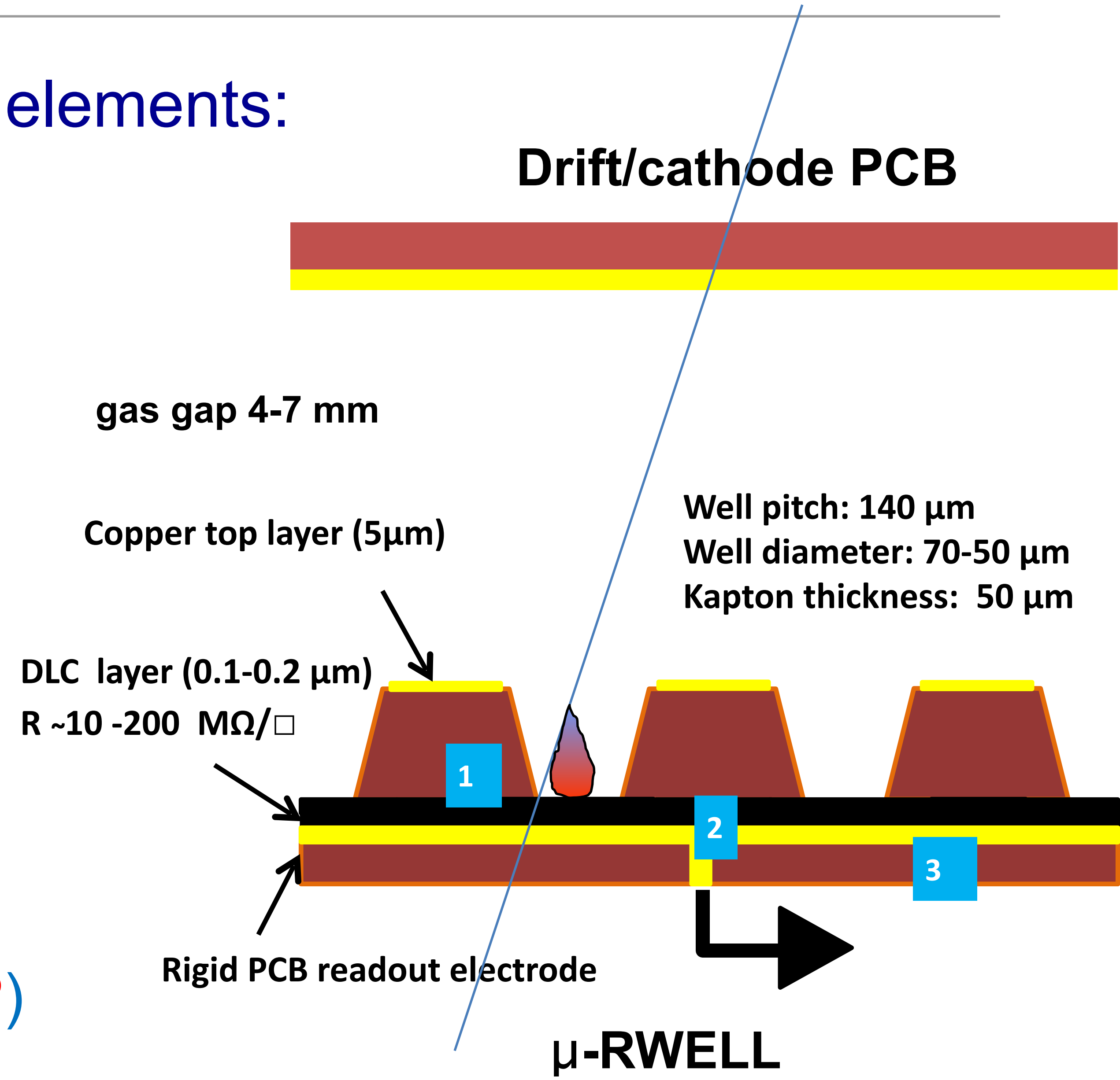
- Detectors mass producible by industry
- Quality control can be performed by collaborating institutes

The μ-RWELL technology

The μ-RWELL detector is composed of two elements:
the **cathode** and the μ**-RWELL_PCB .**

The μ**-RWELL_PCB** is realized by **coupling:**

1. a "**suitable WELL patterned kapton foil** as "amplification stage"
2. a **"resistive stage"** for the discharge suppression & current evacuation
   - **"Low particle rate" (LR)** ~ 100 kHz/cm^2**:** single resistive layer → surface resistivity ~100 MΩ/□ (CMS-phase2 upgrade - SHIP)
3. a **standard readout PCB**



G. Bencivenni et al., 2015_JINST_10_P02008

Collaboration of INFN, CERN, Eltos

Chinese institute USTC-Hefei involved on DLC+Cu resistive layer

Techtra company involved on chemical etching

μ-RWELL features

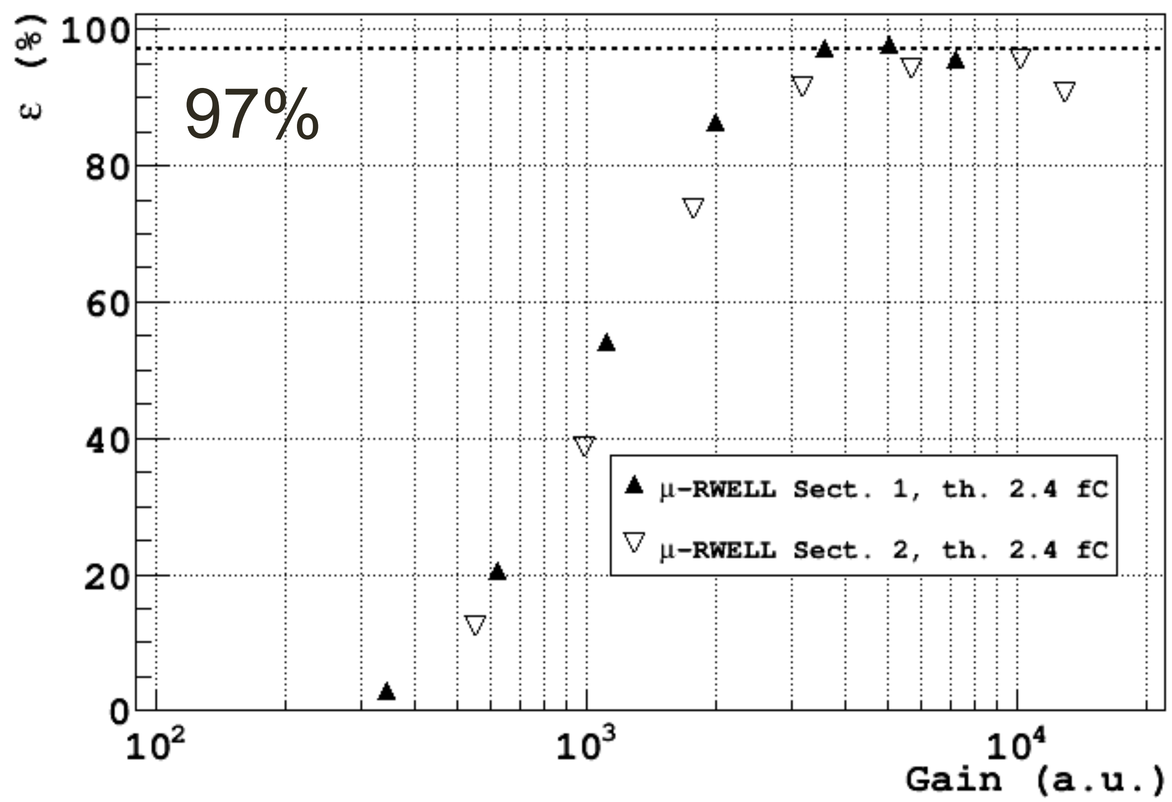
- μ-RWELL guiding principles
  - Retain the same excellent performances of GEM and MicroMegas
  - Improve the resistance to sparks
  - Simplify the components construction and final assembly
- Simpler construction
  - Only 1 kapton foil instead of 3 (GEM)
  - Single amplification layer
  - Simpler etching of the kapton foil
- More robust
  - Resistive DLC layer makes the detector very spark safe
- Simpler final assembly
  - Kapton foil glued to PCB: no stretching needed

- Less components, simpler construction → **significant cost reduction**

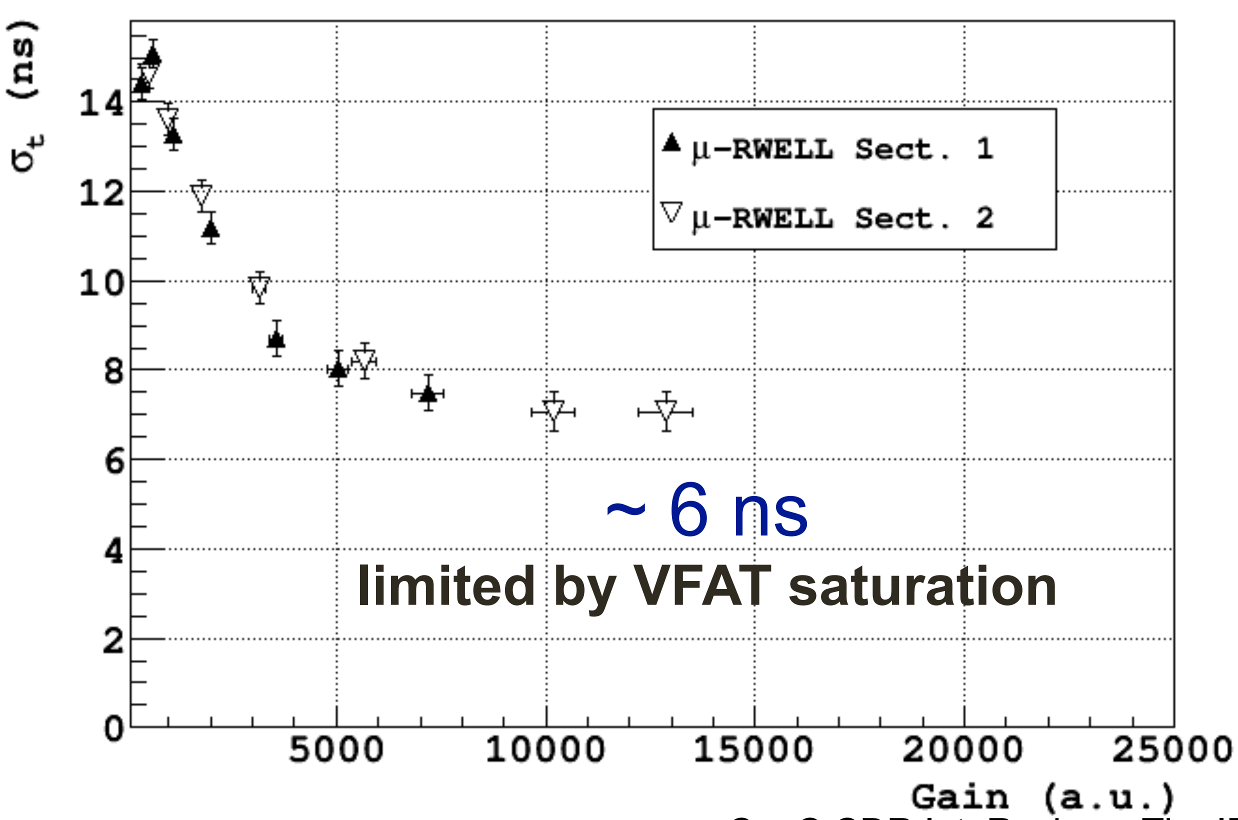
- Technology transfer to industry (Eltos, Techtra) started 2 years ago

CMS GE1/1 μ-RWELL prototype at H8 test beam

Efficiency



Time resolution



$Ar/CO_2/CF_4$ 45/15/40

VFAT FEE

INFN Istituto Nazionale di Fisica Nucleare

CMS GE2/1 sector μ-RWELL prototype

H4 test beam with 150 GeV muons:

- **Voltage scan (amplification scan)**
- **Uniformity scan across the surface of the detector at 530 V (~12000 gain, still to be conditioned)**

The excellent results obtained demonstrate the great collaboration between INFN-Eltos and Rui de Oliveira's lab

GE2/1 20^0 sector with 2 M4 μRWells (2 m height, 1.2 m base)

M4 μ-RWELL

M4 μ-RWELL prototype is a trapezoid of ~55-60x50 cm^2

Largest μ-RWELL ever built and operated!

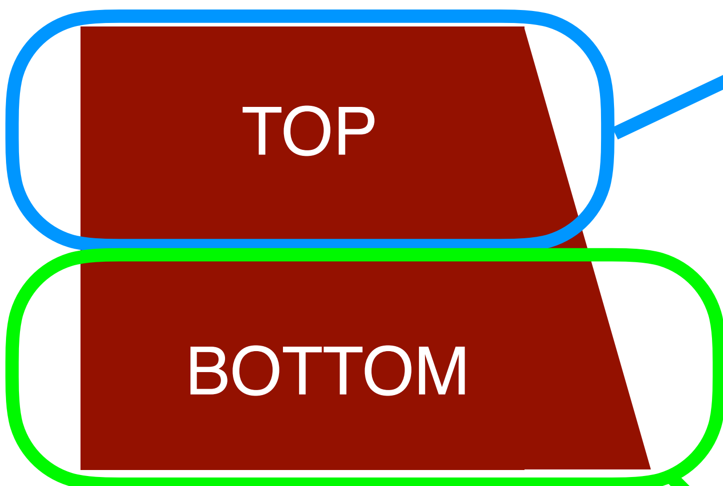
CMS M4 μ-RWELL: homogeneity

$$\text{Efficiency} = \frac{\text{\# hits (Tracker 1 \& Tracker 2 \& M4 right)}}{\text{\# hits (Tracker 1 \& Tracker 2)}}$$

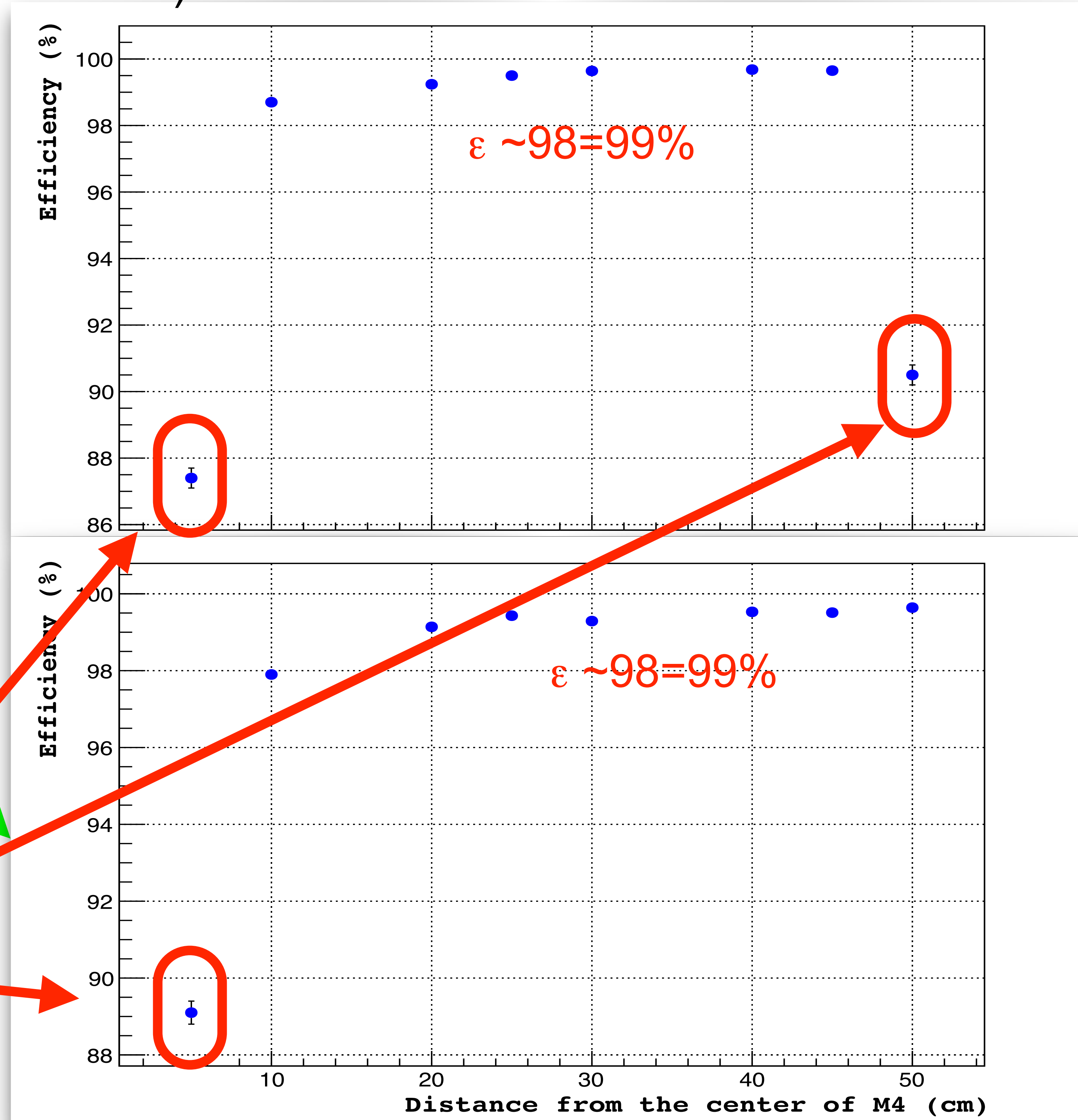
Muon beam

M4 right side:

- Drift Field = 3.0 kV/cm
- $V_{\mu\text{-RWELL}}$ = 530 V



M4 right scheme



Beam on the edge of the detector
NOT inefficiency!!

Summary of results with μ-RWELLs

- CMS GE1/1 prototype at H8 test beam in 2016
  - Very good time resolution, σ_t <6 ns (about 4.5 ns obtained)
  - Fully efficient for a gain of >3000
  - Tested with a rate up to ~35 kHz/cm^2 (only limited by beam rate)
- Position resolution
  - μ-RWELL prototypes have obtained position resolution of ~60 μm
- GIF++ ageing (radiation tolerance) test
  - Tested with global irradiation up to 100 kHz/cm^2 for CMS prototype
  - Gain stability up to 20000
  - No dark current, no discharges
  - Q_{int} > Q_{int} ~ 32 mC/cm^2

- Technology Transfer with the Eltos and Techtra companies
- Large 50-60x50 cm^2 μ-RWELL modules built
  - Exposed at the CERN H4 test beam in July 2017
  - Excellent uniformity! Efficiency between 98-99% over the whole surface.

Conclusions

- IDEA Muon detector based on a 3 station configuration in both barrel and endcap regions
- Each station made of two layers of μRWELL detectors (in the future could use one layer of detectors with bidimensional readout)
- Total surface of the muon detector: ~850 m^2 (barrel) and ~900 m^2 endcap
  - ~3500 m^2 of monodimensional μRWELL detectors
  - ~1750 m^2 of bidimensional μRWELL detectors
- Dimensions of μRWELL detectors 50x50 cm^2
  - 500 channels per detector (monodimensional)
- Position resolution ~270-300 μm
- Time resolution ~5-7 ns
- Efficiency >97% per station
- Total of ~7 million channels
- Mass production of detectors by industry

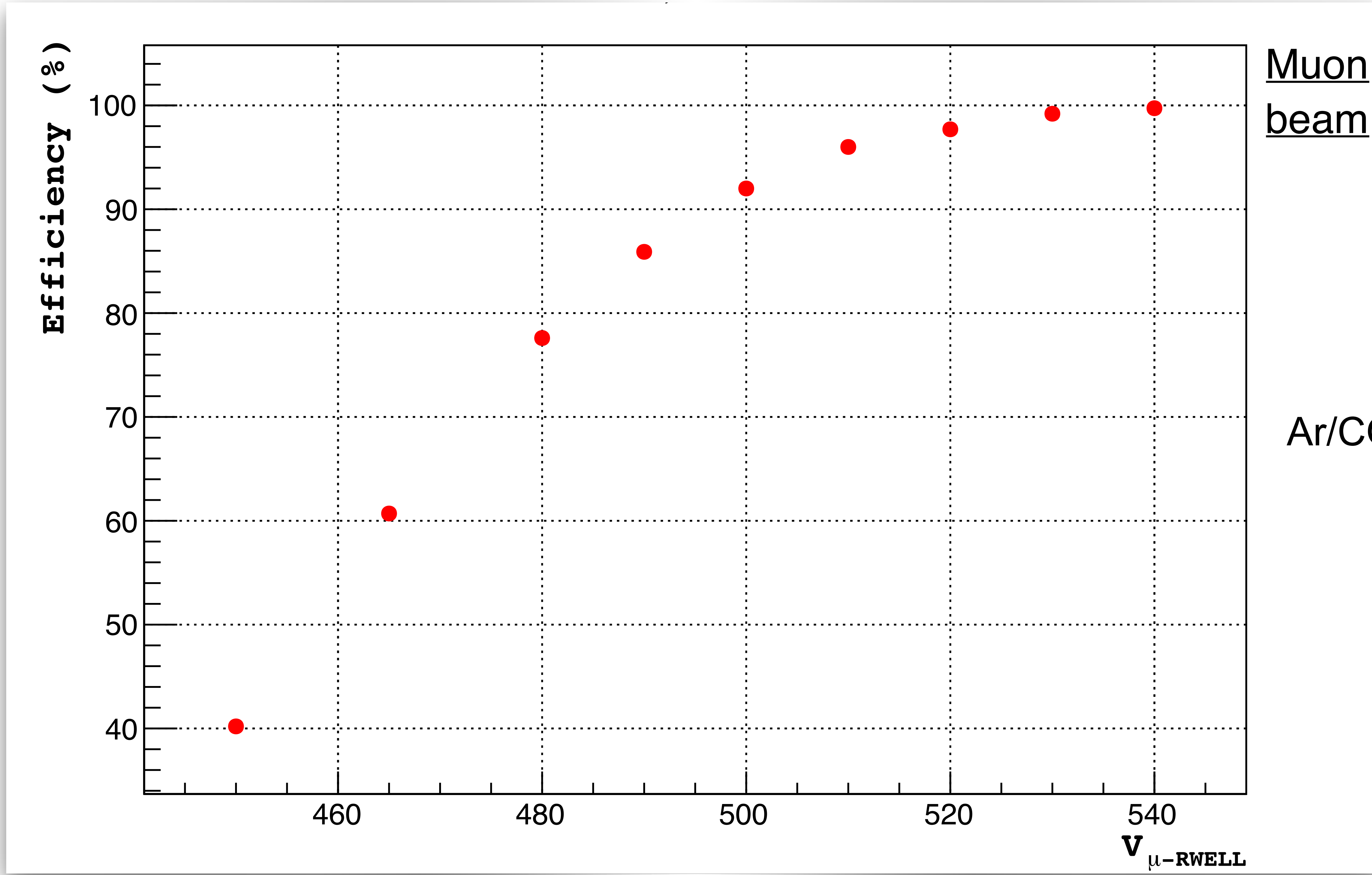
Backup

CMS GE2/1 sector μ-RWELL: HV scan

M4 right side:

- Drift Field = 3.0 kV/cm
- $V_{\mu\text{-RWELL}}$ = scan

Efficiency = # hits (Tracker 1 & Tracker 2 & M4 right) / # hits (Tracker 1 & Tracker 2)



Muon beam

Ar/CO_2 70/30

Muon detector dimensions, channels, cost

- Muon detector with 3 layers in both barrel and endcaps
  - Barrel surface ~850 x 2 (layers) = 1700 m^2
  - Endcap surface ~900 x 2 (layers) = 1800 m^2
- μRWELL Detector dimensions 50 x 50 cm^2
- Strip pitch ~ 1000 μm (1 mm)
- Total number of channels ~7 million
- Position resolution ~300 μm per layer in both spatial directions
- Time resolution ~ 5 ns

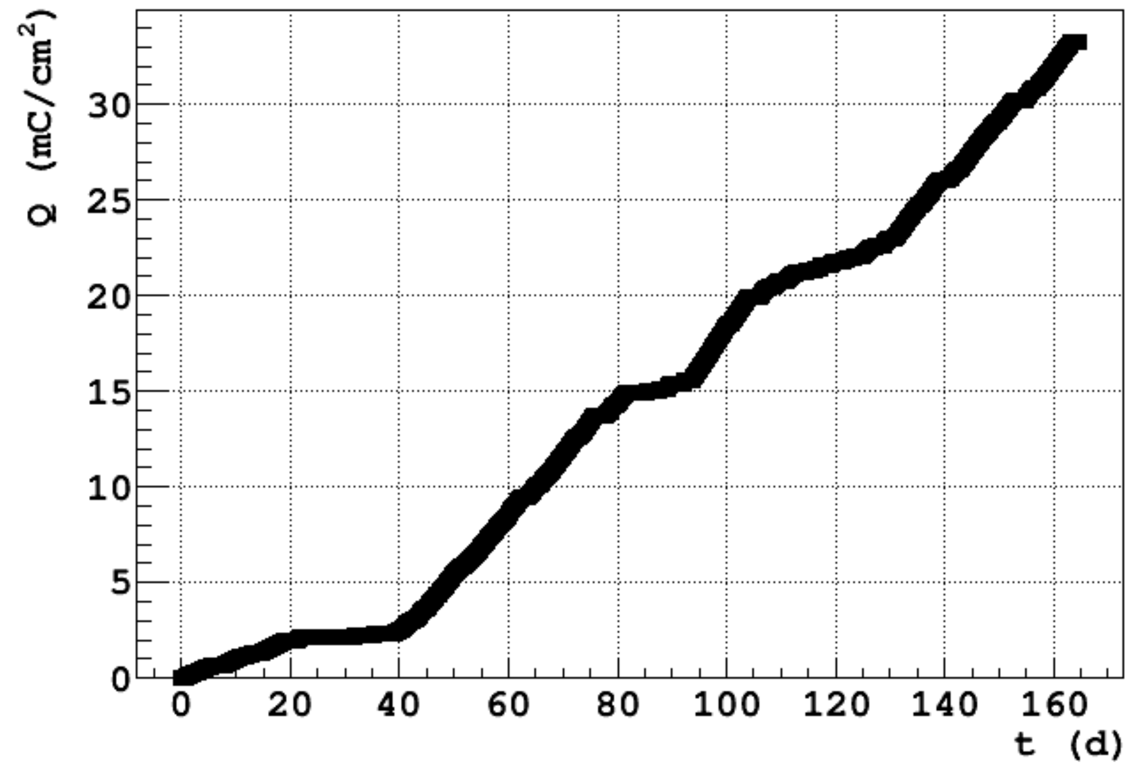
- Today's μRWELL cost ~5 keuro/m^2
  - Mass production by industry should decrease this cost by at least a factor of 2 $\rightarrow$ 2.5 keuro/m^2
  - Cost for the whole muon detector ~8.5 Meuro
  - Cost of electronics ~15-17 Meuro
  - Total cost ~25 Meuro

CMS GE1/1 μ-RWELL: GIF++ ageing test

1) GE1/1 μ-RWELL ($ArCO_2$)

2) "high rate" μ-RWELL ($ArCO_2CF_4$) 10cmx10cm

3) reference μ-RWELL ($ArCO_2$) 10cmx10cm



GE1/1 has accumulated a dose of ~32 mC/cm² (more than 10 times the dose after 10 years of HL-LHC)

μRWELL prototypes exposed inside the GIF++