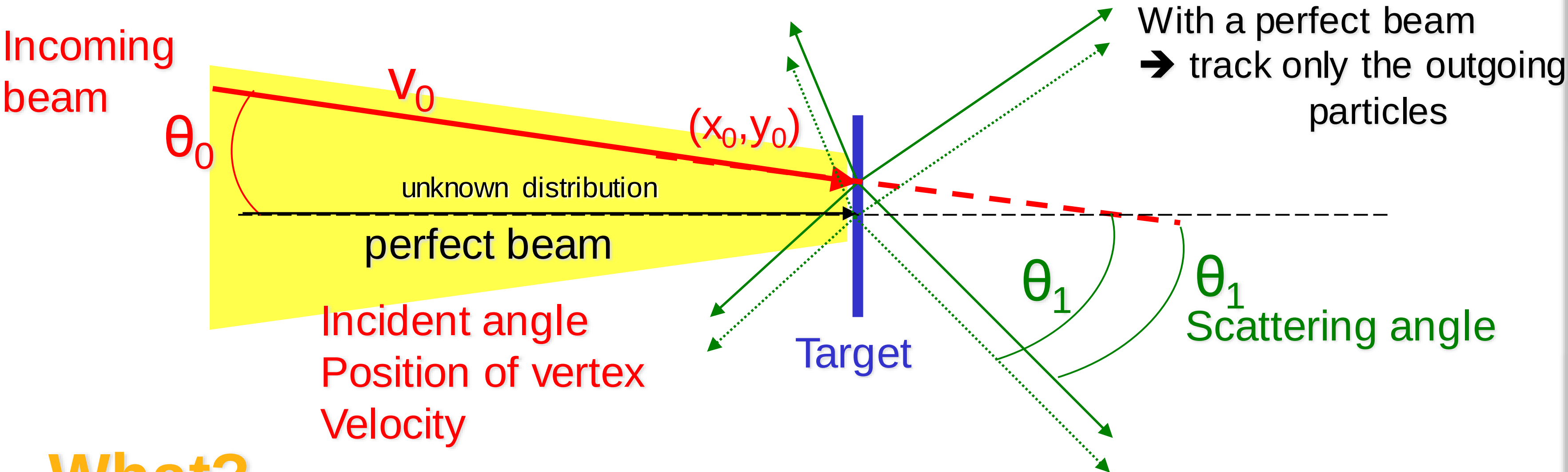
Beam Tracking Detectors

- ➔ For charged particles
- ➔ Transmission detectors
- ➔ Event by event (≠ monitoring)

Why measure the ion trajectory ?

Information about the reaction process
→ angular distributions, velocity
Identification of the particle
→ curvature radius in a magnetic field gives momentum



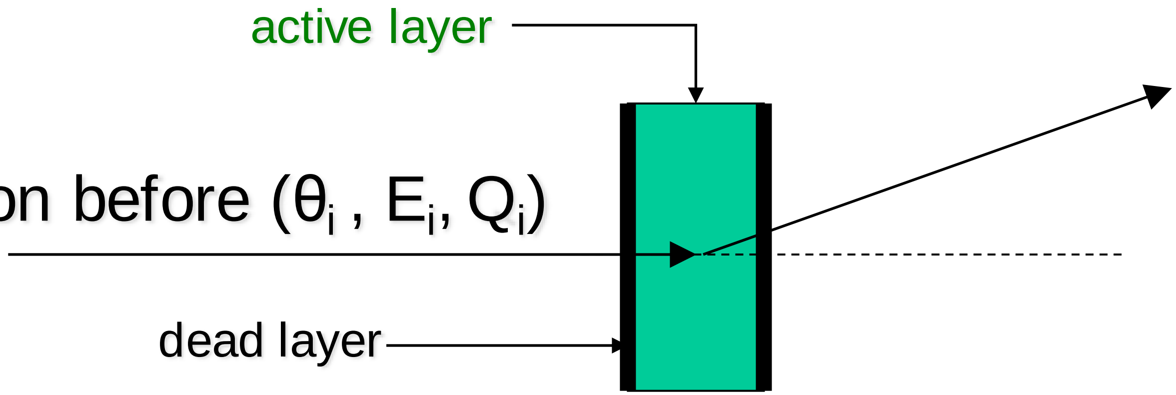
What?

Determine the trajectories of ions before the interaction point
→ positions + time of flight

Need a transmission detector, with position and time measurement on an event by event basis

Ion-matter interaction (Mainly electromagnetic)

enough to detect the ion
BUT
not too much, not to perturb its trajectory



ion after

$\theta_f = \theta_i + \delta\theta$

$E_i = E_i - \Delta E + \delta E$

$Q_f = Q_i + \delta Q$

Energy losses ΔE — can be calculated and corrected in the **active layer** ➔ gives the **detection signal**

Energy straggling δE
Angular straggling $\delta\theta$
— Stochastic processes ➔ **error on measurement**

Charge exchange δQ — Stochastic process ➔ **charge state distribution for E_i < 50MeV/u**

Losses, Straggling and Detection Set-up

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^{40}Ca

Material	500MeV/u	50MeV/u	5MeV/u
2mm BC400 **(scintillating plastic)**	ΔE = 227MeV δE = 0.08MeV/u δθ = 0.4mrad	1385 0.11 3.5	Stopped ! Rg=70μm
0.2mm Silicon **(solid state detector)**	42 0.04 0.27	185 0.03 2.4	Stopped ! Rg=46μm
1cm Ar at 1bar **(gas detector)**	13 0.023 0.17	57.8 [illegible]01 1.5	Stopped ! Rg=7mm
10cm C_4H_{10} at 10mbar **(low pressure detector)**	[illegible]29 0.003 0.014	1[illegible]28 0.002 0.11	6.02 0.002 1.14
[illegible]μm Mylar© foil **(window)**	0.14 0.0[illegible]2 0.01	0.64 [illegible].001 0.10	2.9 0.001 0.93
0.2μm carbon foil **(emissive foil)**	0.[illegible]2 0.0008 0.004	0.087 0.0006 0.035	0.39 0.0005 0.34

SLOWED DOWN BEAM AND TRACKING ACTIVITY AT GSI BY PLAMEN BOUTACHKOV

e.g. HISPEC/DESPEC @ GSI : 3 to 150 A.MeV

Relativistic regime : 500MeV/u

Sources:
R.Gernhäuser (TU-München)

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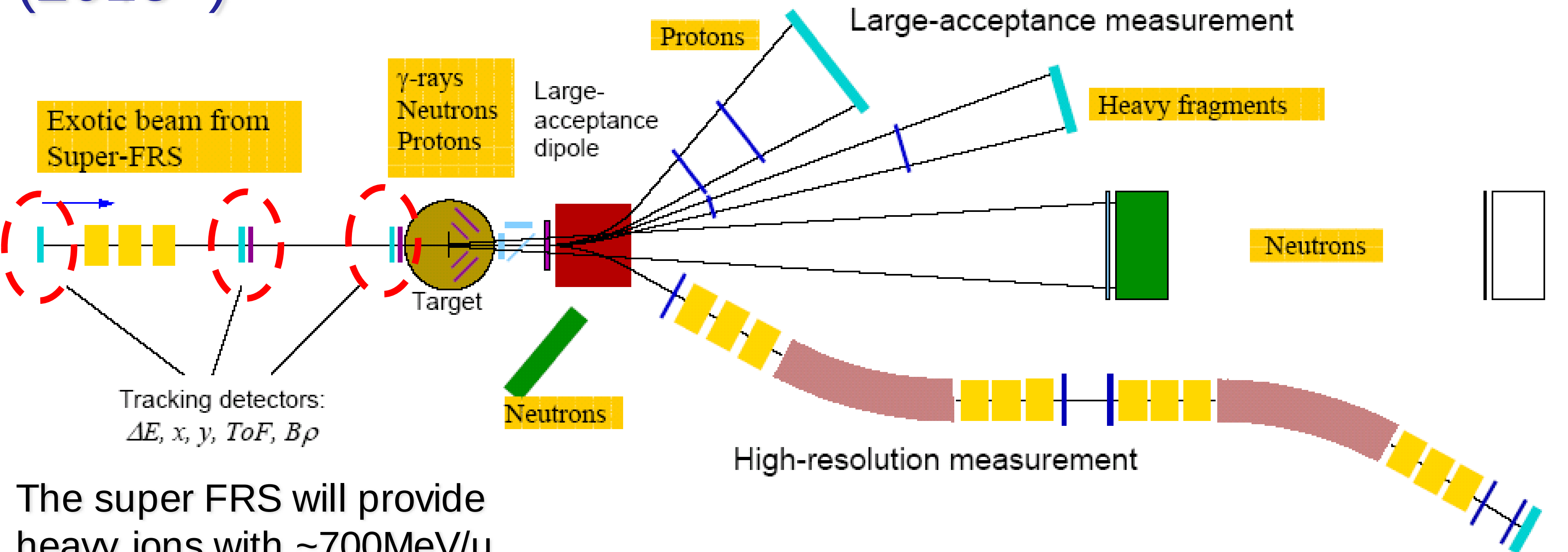
Diamond tracking for R^3B @ FAIR (2013+)



The super FRS will provide heavy ions with ~700MeV/u

Measurement of all kinematic variables in a HI reaction

Different tasks: High resolution tracking in the super FRS, radiation hard (SFRS) 10^6 cm^{-1} s^{-1}

2 x TOF (SFRS – target) (reaction products)

Short characteristics of CVD diamond detectors

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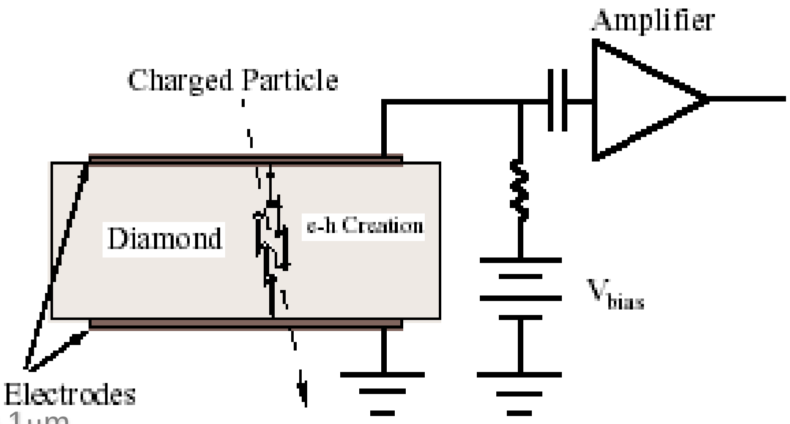
Diamond as a detector material

- low capacitance
- low noise
- good heat conductivity
  (5 x higher than Cu)
- large band gap of 5.5 eV
- small signal (< half of a Si of similar size)
- high charge carrier velocity saturation
- fast pulse response time



Cr-Au foil ~0.1μm

Fig. 1. A schematic view of a diamond detector.

- **Diamond Crystal production**

chemical vapour deposition (CVD)

- commercial production
- ***polycrystalline diamonds (PCD)***
  - thickness 50-500μm
  - max size ~ 5x5cm2
  - price ? (100 euro/det.)
- ***single crystal diamond (SCD)***
  - smaller (max 25x25 mm2)
  - better performance (energy resolution)
  - more expensive (5xPCD)

Diamond detectors performance

- very fast timing
  pulse risetime: 200 ps
  width: 2ns (PCD) 5ns (SCD)
- operating voltage 1 V/μm
- radiation hardness
  -Tests with $2x10^{15}$ p/cm^2 did not show any significant deterioration of a sig./noise
  -pumping effect (PCD) : improvement with increasing dose
- position resolution
  below 10μm can be achieved with strip detectors X and Y
- efficiency
  70%PCD-100% SCD
- Diamonds as TOF detectors
  tests with 1GeV/u U beam resulted in TOF of σ=20 ps

Source: M. Gorska (GSI)

Virtues & Flaws of diamond detectors

☺

- Radiation hard (>2.15p/cm^2)
- low occupation time ➔ high counting rate 10^7pps
- ultra fast signal ➔ time resolution σ = 30ps
- reasonable energy resolution σ = 17keV (single crystal)

☹

- small size, biggest in use 60x40mm^2 [PCD, Cave A @ GSI]
- thickness > 50µm ➔ restricted to high energy
- require high speed electronics

- single crystals have better performances but are smaller (few mm^2) ➔ Mosaic detector ?

➔ very promising technique, lot of developments

Relativistic regime : 500MeV/u

KaBes on the NA48 exp @ CERN (in use)
The micromegas TPC

B. Peynaud, NIM A 535 (2004) 427

Study of CP violation by the simultaneous detection of K^+ and K^-

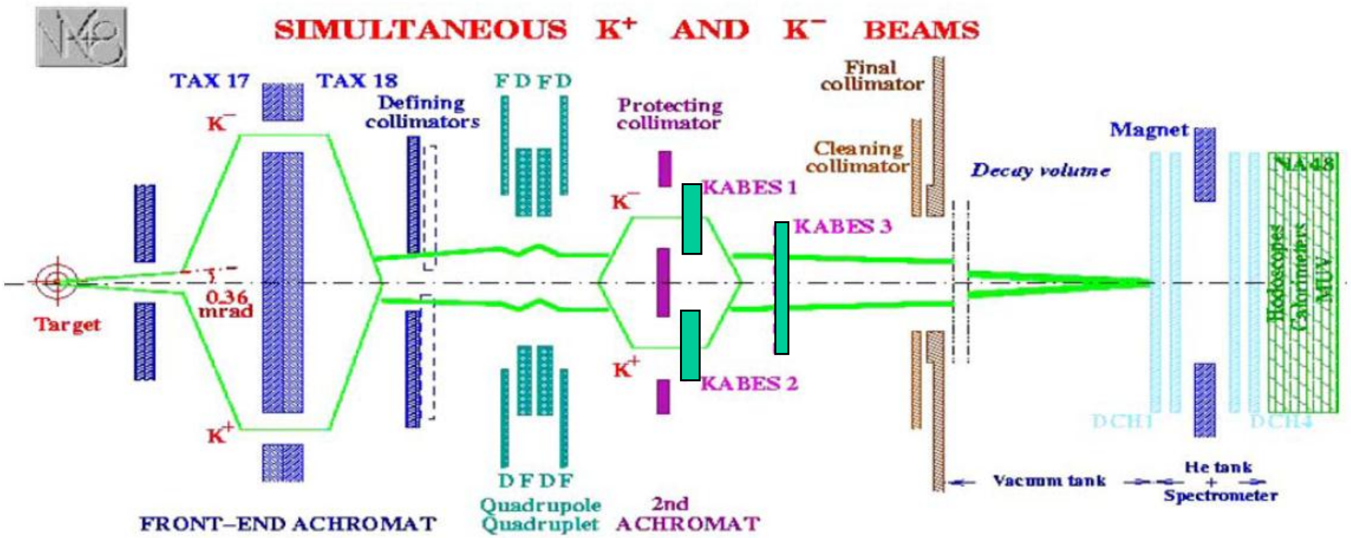


Fig. 1. The K12 charged kaon beam line with KABES and K^+/K^- focusing at the DCH spectrometer.

Need to measure trajectories to obtain the momentum of individual Kaons (~60GeV/c)

Time projection Chamber with Micromegas

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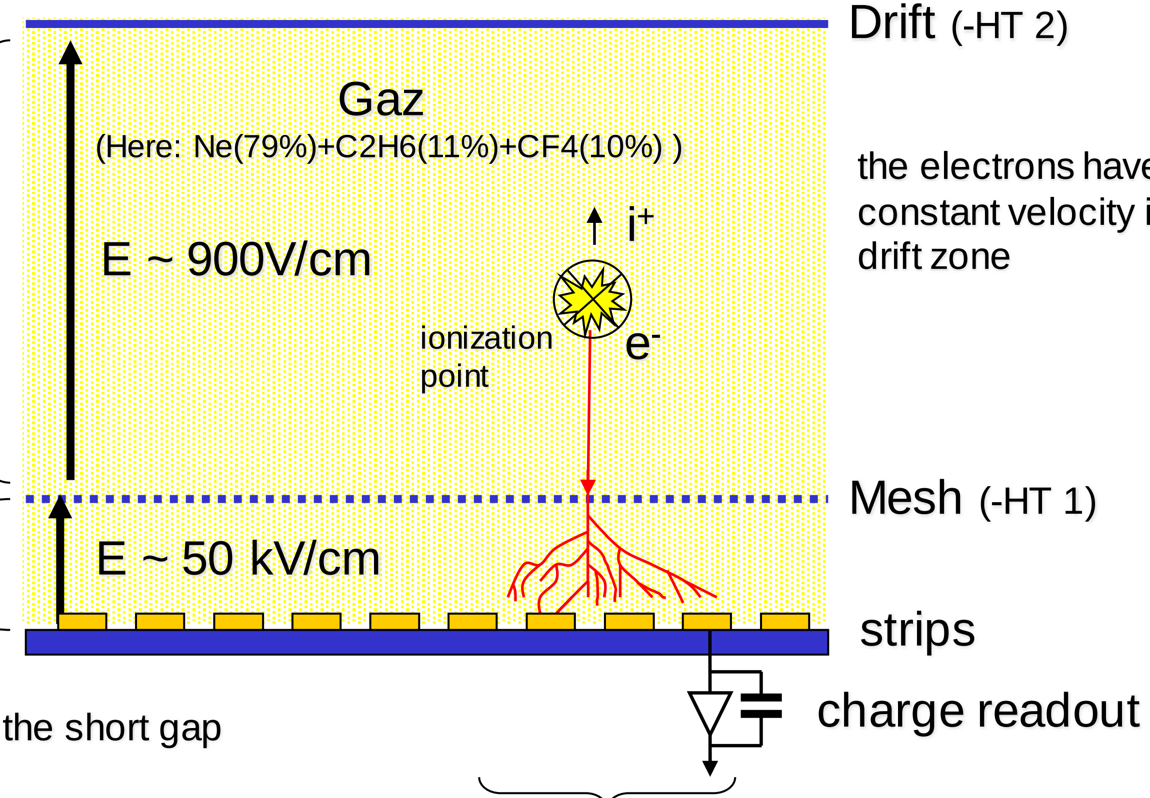
Drift Region
h=6cm
v_{e-} = 8cm/µs

Drift time
=
Y position

Amplification gap
< 100 µm



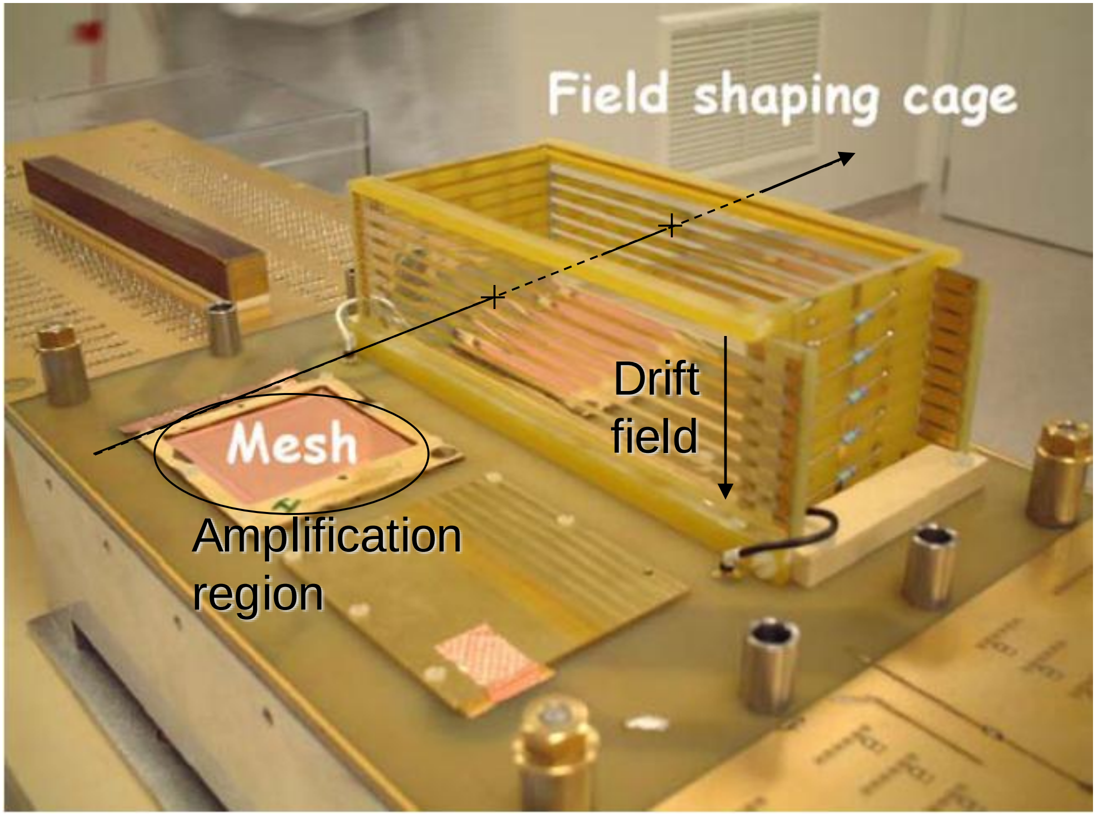
the electrons have a constant velocity in the drift zone

A fast avalanche occurs in the short gap
➔ fast electron signal
➔ no signal from the drifting ions because of the shielding mesh

Each strip gives an independent time signal
➔ high counting rate

2 orthogonal detectors required to have X and Y

KaBes drift chambers for real



Performances

•Time resolution = 0.7 ns (σ)

• Spatial res. of 70 μm

• 40 MHz, expected up to 1GHz

• Efficiency close to 100 %

Virtues & Flaws of Micromegas TPC

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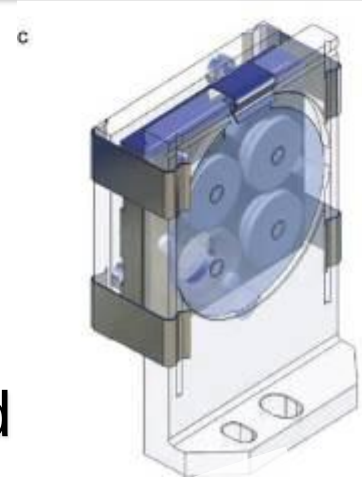


☺

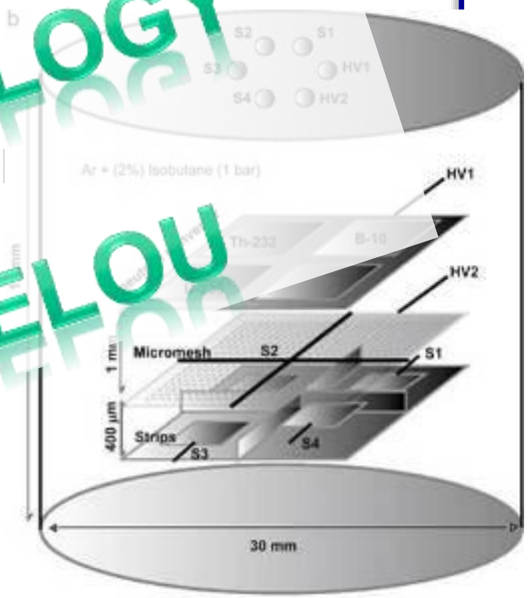
- Radiation hard
- Very high counting rate : up to 10^9pps !
- Very good position resolution < 100µm
- Bulk micromegas : robust and easy to build

☹

- 1 direction only
- Moderate energy resolution (~10%)
- Need an independent time signal for trigger

Micromegas gas detectors have a wide range of applications since the "drift zone" can include a converter that produces electrons from any kind of initial radiation

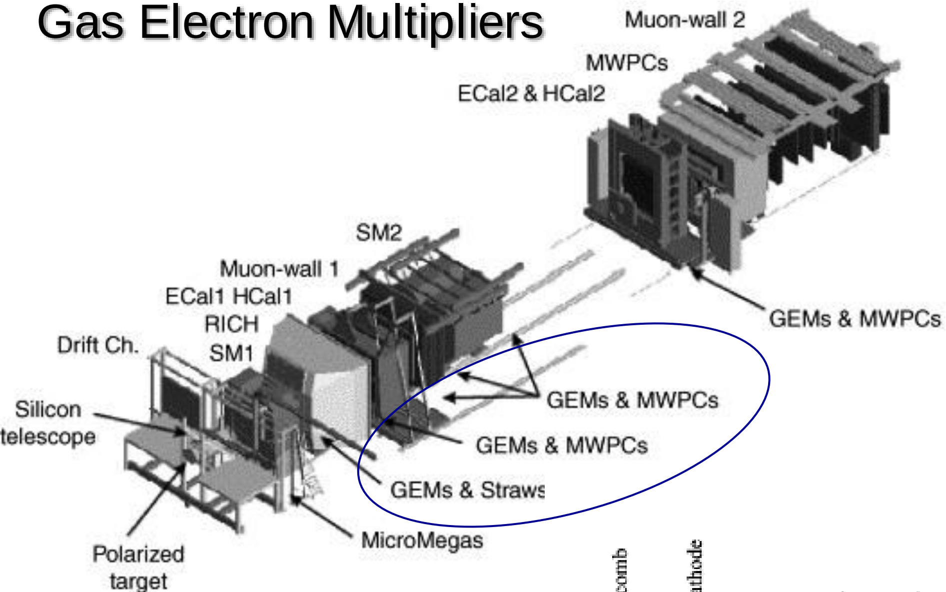
e.g. piccolo micromegas for neutron detection

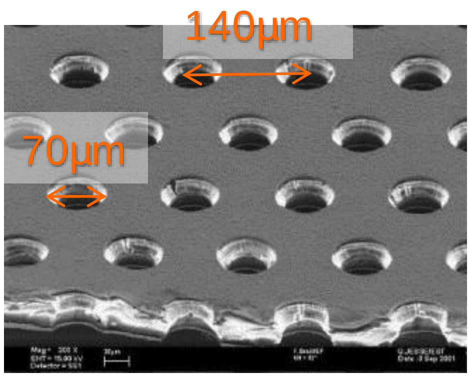


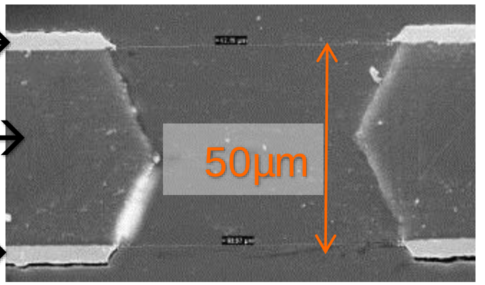
J. Pancin & al. NIMA 592 (2008) 104

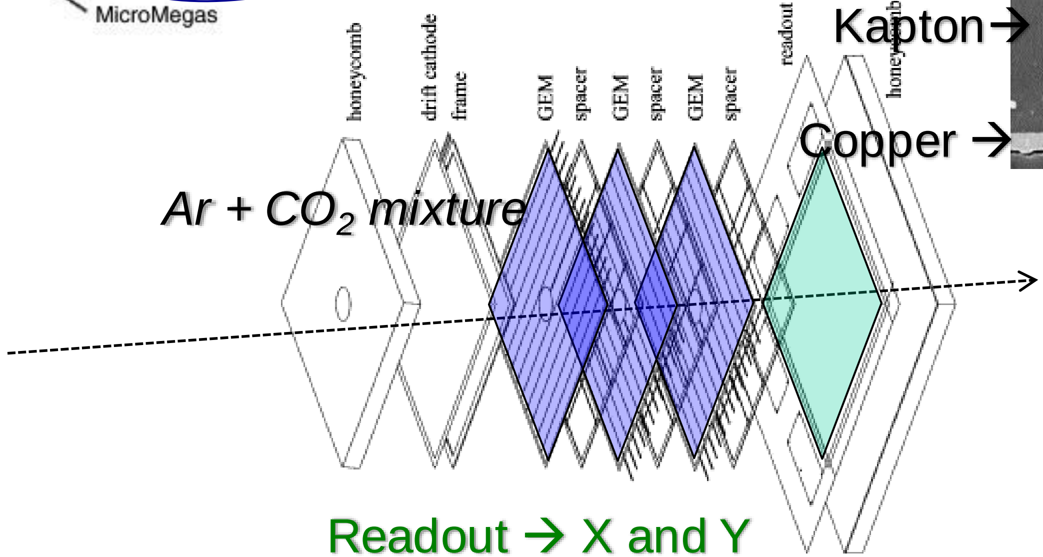
GEMs in the COMPASS experiment @ CERN

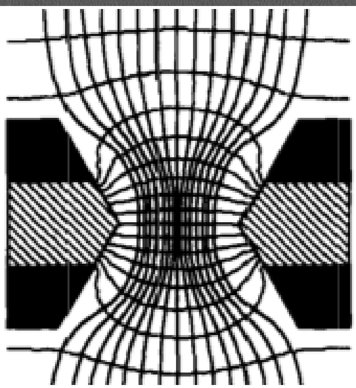
Gas Electron Multipliers











Readout → X and Y

Virtues & Flaws of GEM

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☺

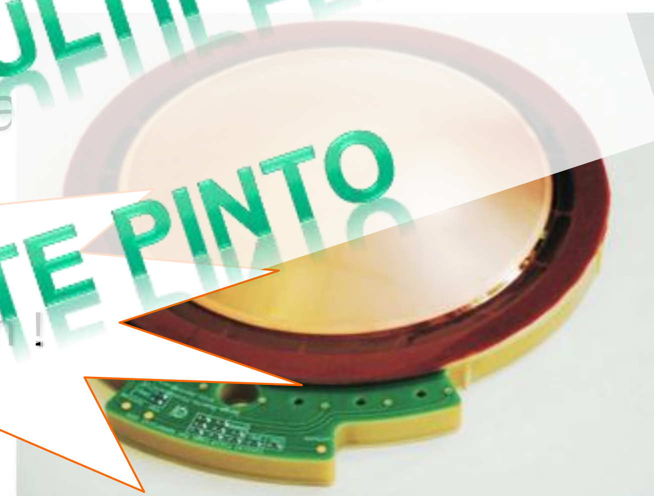
- Radiation hard
- Large size (>1m^2)
- Very high counting rate : 10^{5}Hz/mm^2
- Excellent position resolution σ ~ 40µm

☹

- Moderate gain (~30-50) but several stages can be added
- Dead zones due to spacers
- Poor energy resolution (~27%)
- High capacitance ➔ strong discha

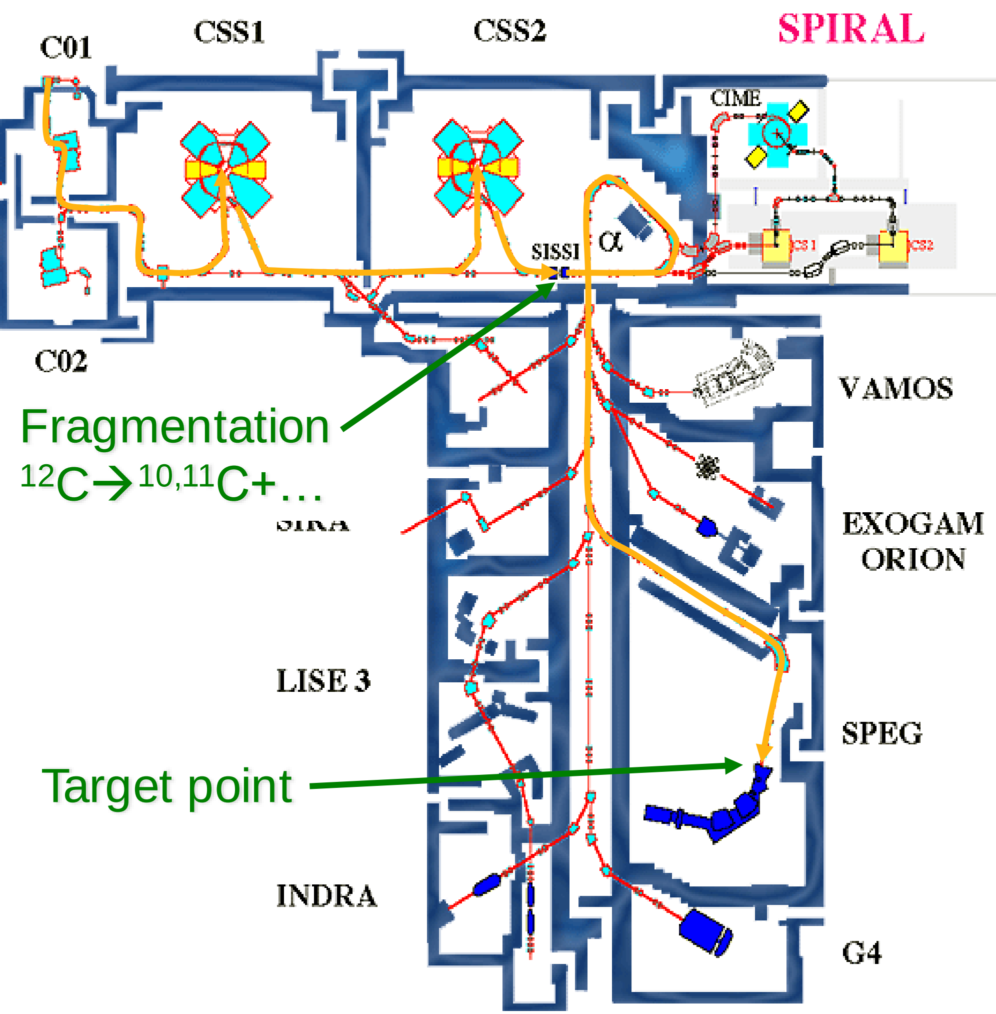
GAS ELECTRON MULTIPLIERS BY SERGE DUARTE PINTO

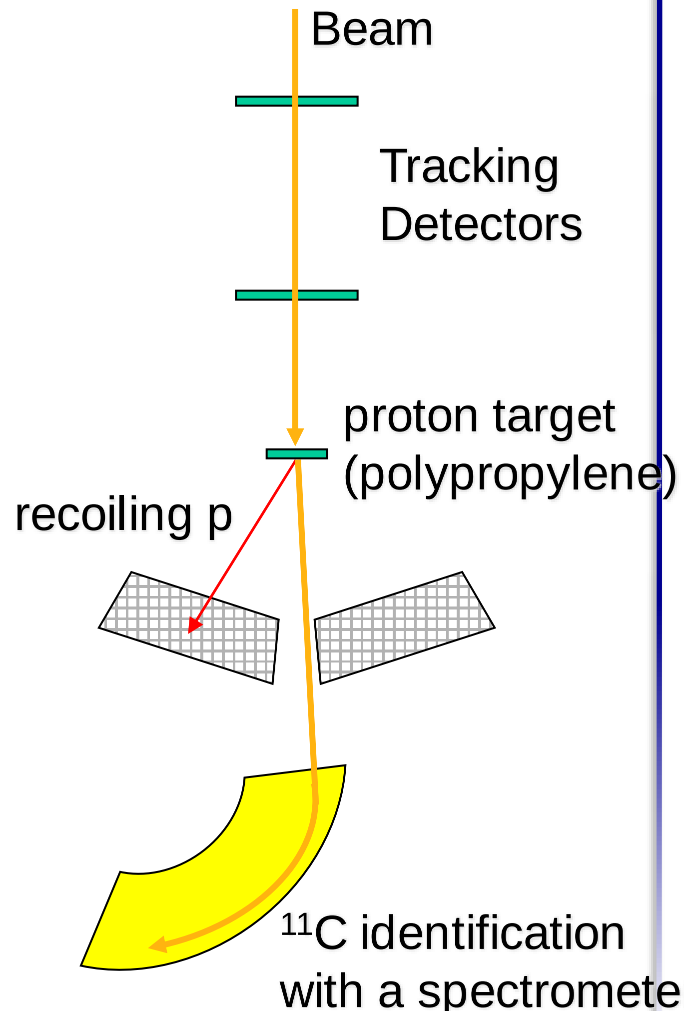
Spherical GEM
for parallax correction !

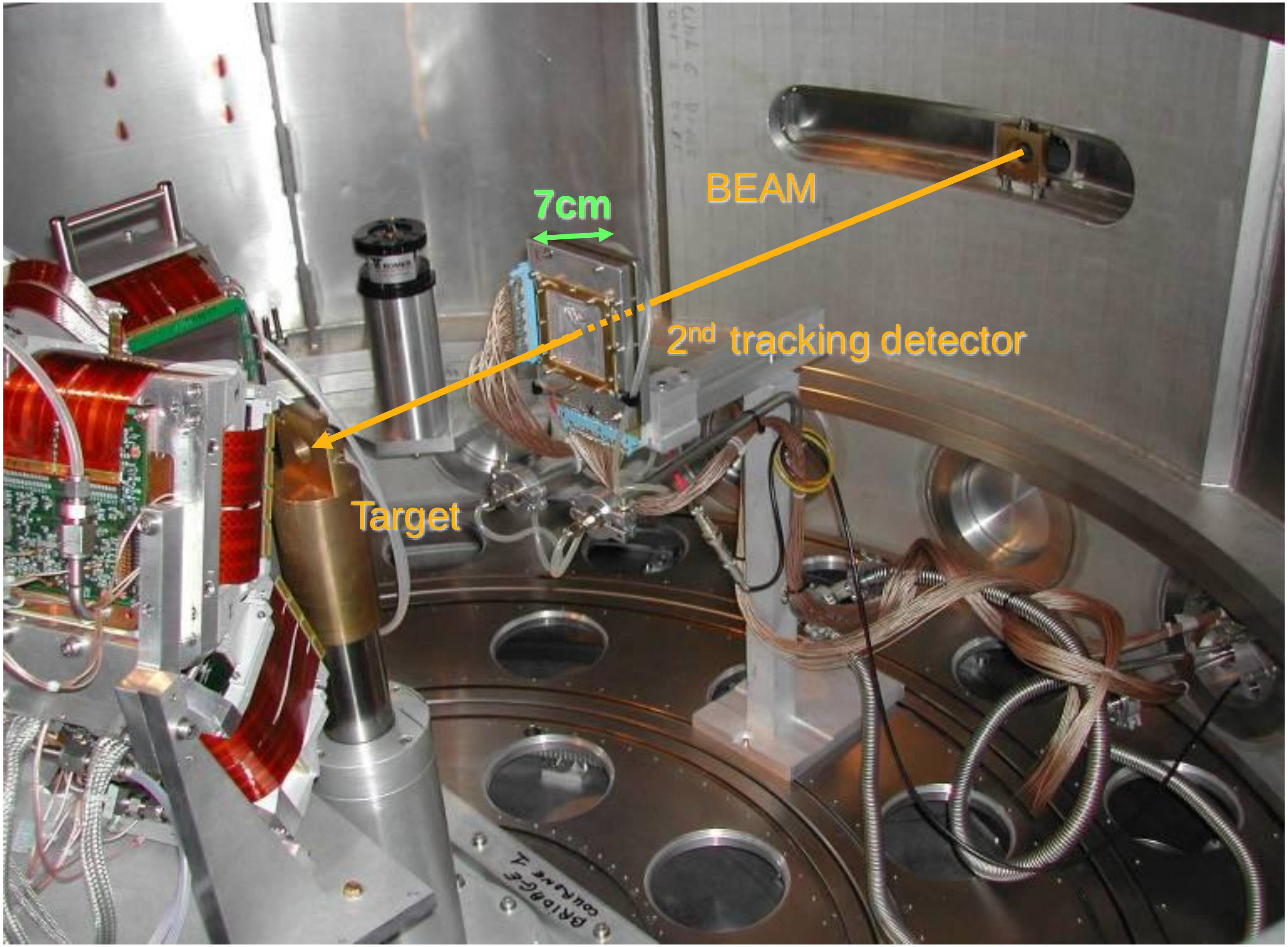


Intermediate energy : 50MeV/u

CATS detectors at GANIL, Caen (in use)
In Beam low pressure MWPC



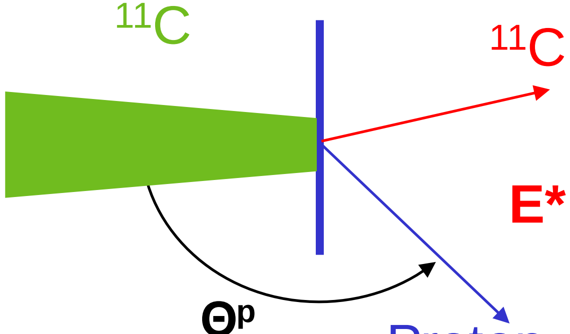


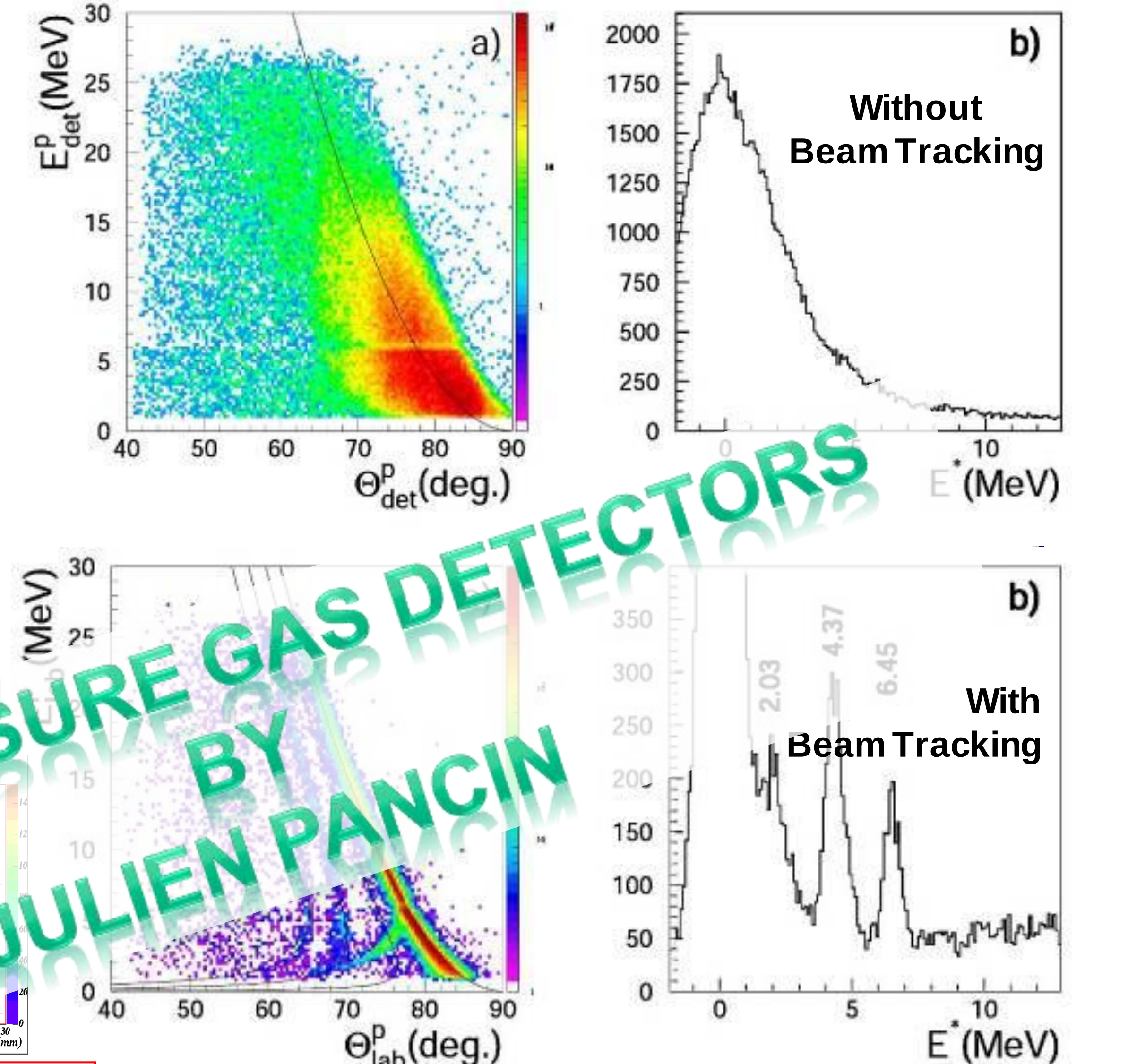

7cm
BEAM
2nd tracking detector
Target

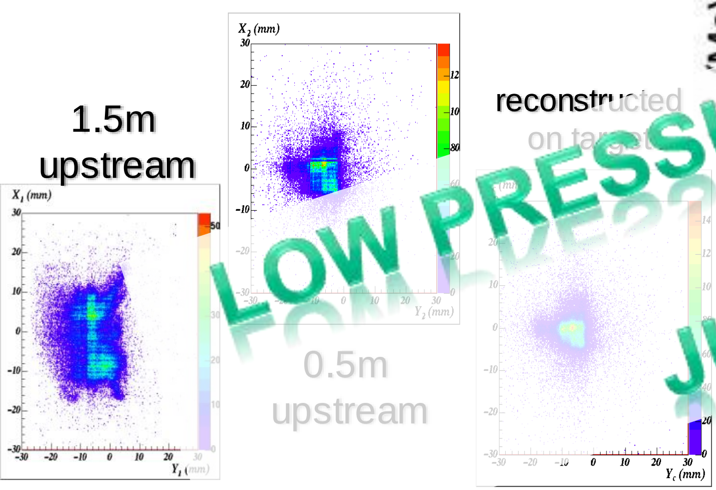
Effect of trajectory reconstruction

$^{11}C+p \rightarrow {}^{11}C+p'$ 40.6 MeV/u

C. JOUANNE (SPHN) PHD 2002







LOW PRESSURE GAS DETECTORS BY JULIEN PANCIN

Large Beam emittance ~10π mm.mrad (hor+vert)

Virtues & Flaws of in-beam low pressure MWPC

☺

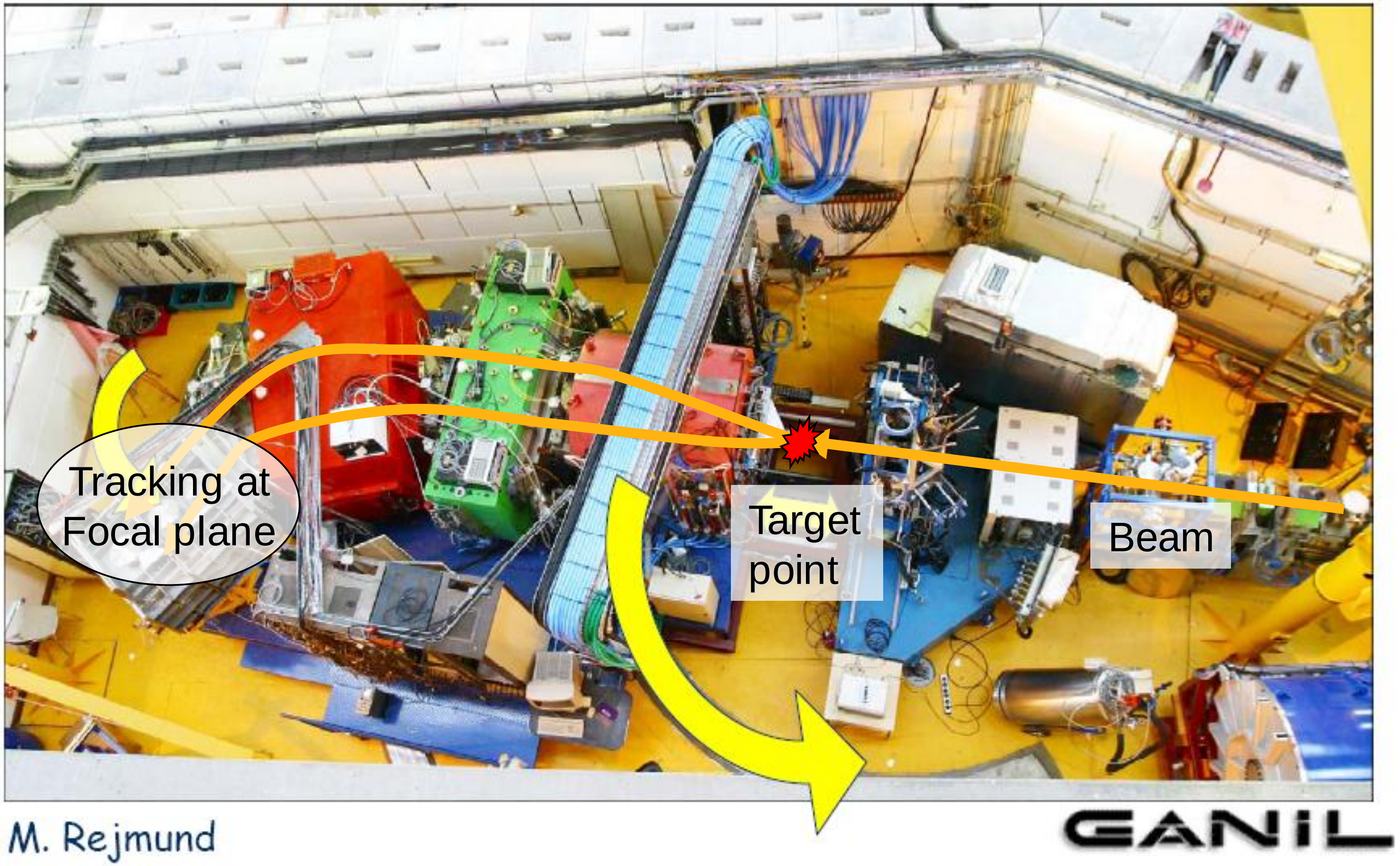
- fast signal ➔ good time resolution $\sigma = 100ps$
- good position resolution $\sigma = 100\mu m$
- high detection efficiency (~100%)
- large size available (>100cm^2)
- cheap and can be repaired
- Thin : ~5µm of Mylar (from windows and cathodes)

☹

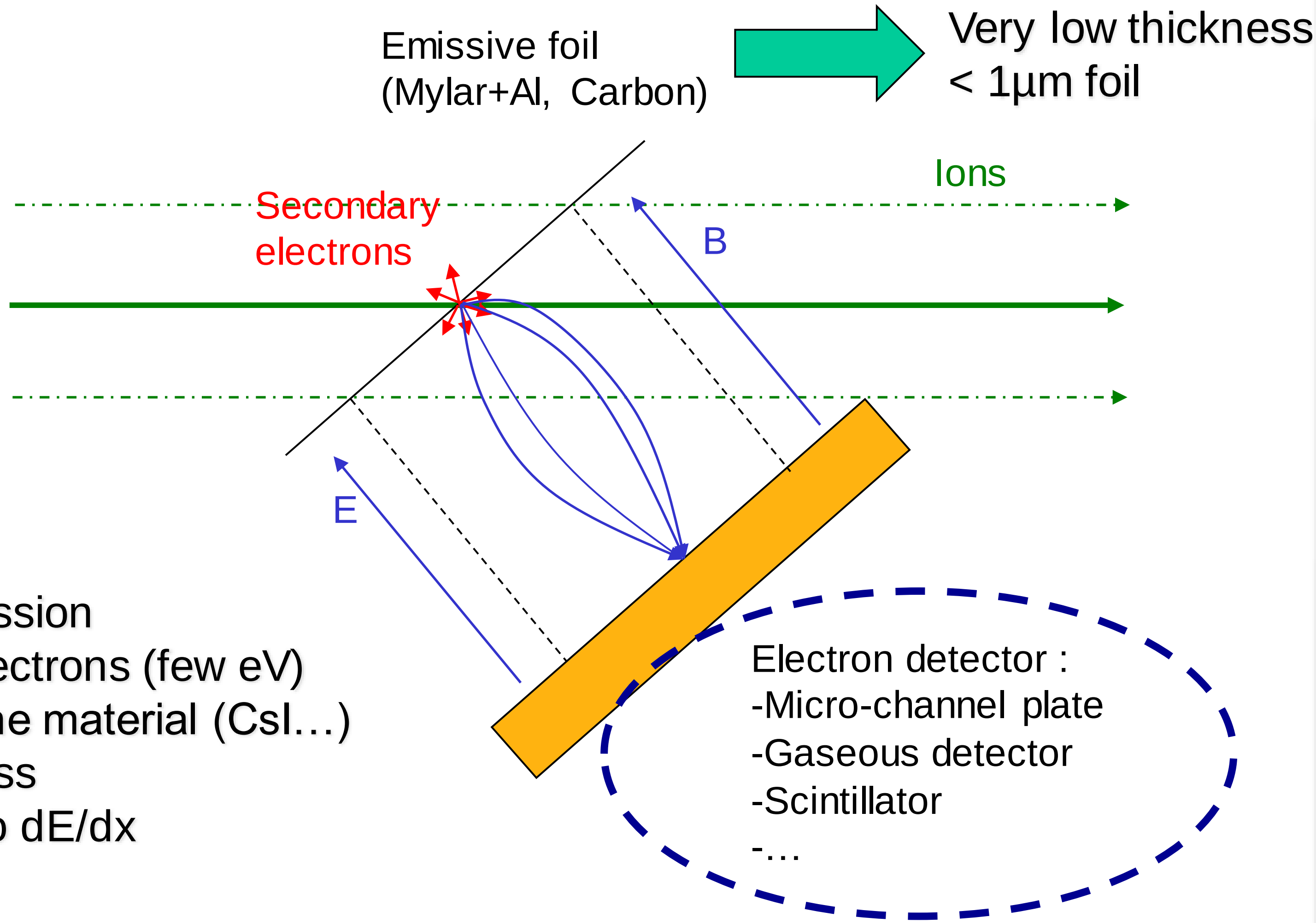
- vulnerable to discharge : rate ~ 10^5pps
- 1.5µm windows required ➔ E_{ion} > 10MeV/u
- fragile and delicate to use

Very low Energy regime : 5MeV/u

e.g.: SPIRAL/SPIRAL2 radioactive beams
(in use / 2014)



Emissive foil Detectors



Secondary emission
- low energy electrons (few eV)
- depends on the material (CsI…)
- surface process
- proportional to dE/dx

Micro Channel Plates

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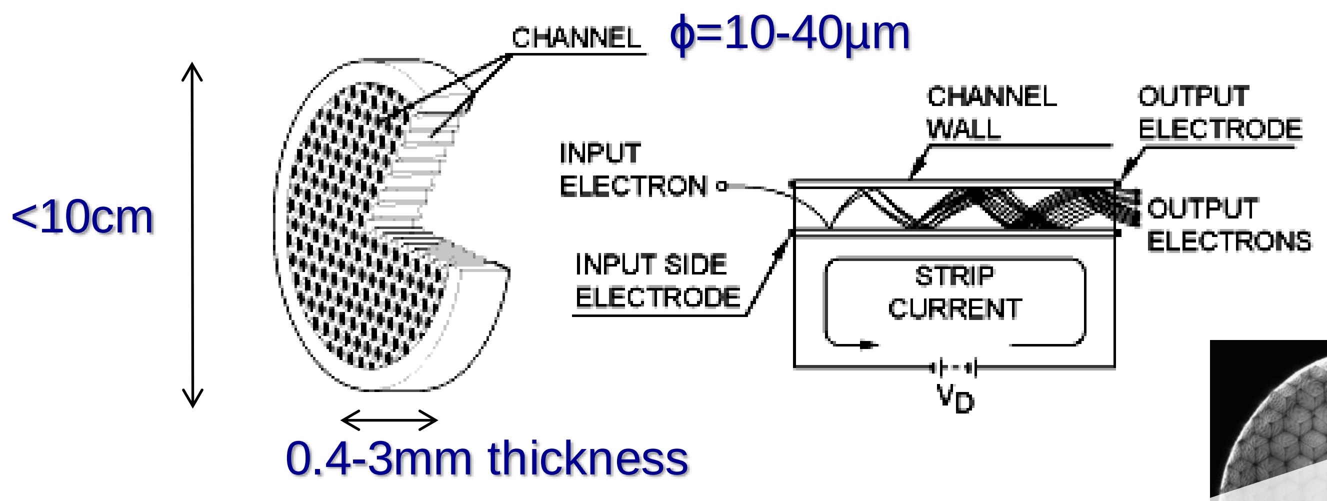
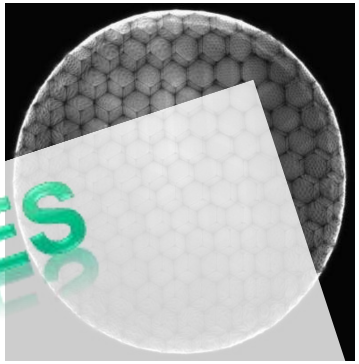
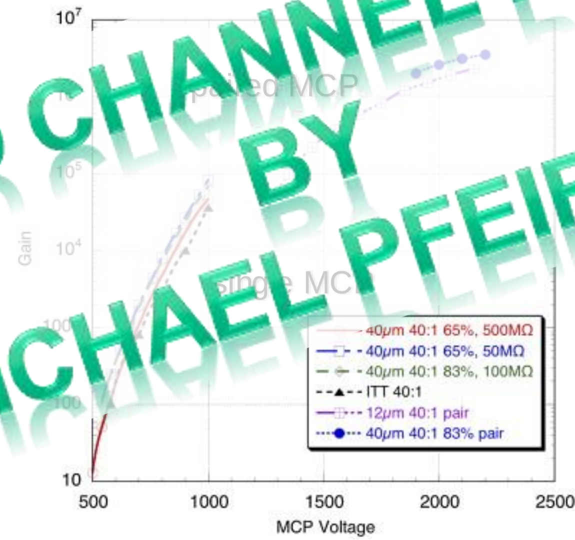
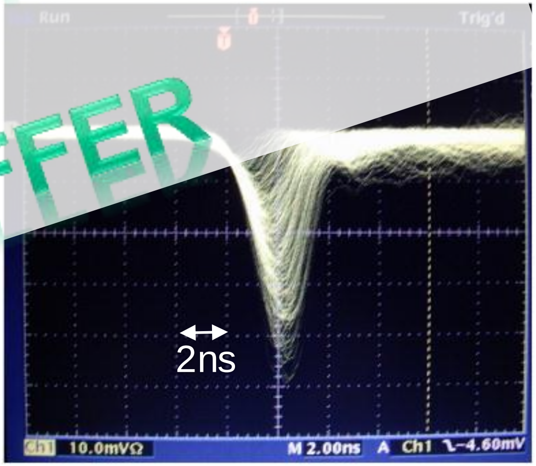




Borosilicate MCP developments 20x20cm^2 !

- Superposition of resistive and photo-emissive (Al_2O_3) atomic layers
- Similar gain as standard MCP
- Fast signals
- Poor uniformity (±10%)





O.H.W. Siegmund et al.
NIMA 639 (2011) 165

Low Pressure Gas Detector

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Focal plane size : 20 x 40 cm^2

A. Drouart & al, NIM A579, (2007) p1090

Virtues & Flaws of Emissive foil detectors

☺

- Detector as thin as it can be (down to 20µg/cm^2)
- Fast signal ➔ good time resolution σ < 100ps

☹

- Poor sensitivity to high energy, light ions
- Moderate position resolution σ~600µm
- Require high electric field and/or magnetic field

Characteristics depend on the secondary electron detector

- gas detector : large size
- micro channel plate : high counting rate
- scintillating plastic : easy to use

Conclusions

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Beam tracking requires

➔ low thickness not to perturb the incoming ion
➔ good position and time resolution
➔ cope with high flux of particles

Technique	Regime MeV/u	σ(time) ps	σ(pos.) µm	Max rate Hz
Diamonds	500	30	10 (strip)	10^7
Atm. pressure	500	700	<100	10^8
Low pressure	50	500	150	10^5
Emissive foils	5	100	500	10^{6-7}

Thank you for your Attention

➔Enjoy the next talks !