Parallel Ionization Multiplier (PIM): a new concept of gaseous detector for radiation detection improvement

PIM : a new concept of gaseous detector for radiation detection improvement

- Improvement of $\beta$ detection :
  - Principle
  - Realization
  - Results

- First PIM results for application to other ionizing particles :
  - Gain measurement
  - Discharges rate for $\alpha$ particles
β particle detection: difficulties and goals

- β detection for biology with gaseous detectors
  - A4 total sensitive area with no dead zone (21 μscope slides)
  - 2D reconstruction with a resolution FWHM < 100 μm
  - Uncollimated source

- Middle to high range in gas at CNTP
  - \( L(^3\text{H}) \sim 600 \, \mu\text{m} \) in argon
  - \( L(^{14}\text{C}) \sim 2.4 \, \text{cm} \)

Amplify primary electrons directly in the contact of the emitter

**Parallel Ionizing Multiplier Idea**
PIM principle for uncollimated $\beta$ particles detection

Multiplication stage

Diffusion stage

$E \sim 25\ kV/cm$

$E \sim 5\ kV/cm$

Segmented anode with pixels for 2D position measurement

Micromegas micromesh

$\beta$ particles source

$300\ \mu m$

$4\ mm$

**Multiplication in a microgap directly in contact with the source**

**Diffusion stage for 2 dimensional read-out with Gassiplex front-end electronics**

**Difficulty: mechanical definition of the microgap on A4 area?**
PIM spacers

- New spacer to define multiplication stages
  - polyimide (kapton) mesh, laser-machined
    - thickness from 25 µm to 300 µm
    - minimum line width: 30 µm

Mechanical definition of multiplication stages everywhere inside a parallel plates detector

A patented technology
PIM prototype for $\beta$ detection: mechanics

- **Active area**: 180 x 288 mm$^2$

*Top view*  
*Bottom view*

Approx 100 000 pixels at a 750 µm pitch
PIM prototype for $\beta$ detection: pixel read-out

- Each pixel is connected to one read-out strip by micro-vias

- The PCB has two internals layers (X and Y layers)
- Each read-out strip connects 50 to 100 pixels to the same channel

Minimizes the # of electronics channels to read all the pixels
PIM prototype for $\beta$ detection: results with $^{14}\text{C}$

- Gas mixture: Ne+10% iC4H10
  - $E_1 = 21.7$ kV/cm
  - $E_2 = 4$ kV/cm
PIM prototype for $\beta$ detection: results with $^{14}\text{C}$

- Reconstruction efficiency $\sim 50\%$
- Resolution $\sim 60$ $\mu$m (FWHM)
PIM prototype for β detection: results with $^3$H

- Gas mixture: Ne+10% iC4H10
- $E_1 = 21.7$ kV/cm
- $E_2 = 4$ kV/cm

Reconstruction efficiency ~ 75%

Resolution ~ 50 $\mu$m (FWHM)
PIM prototype for $\beta$ detection: conclusion

- **New $\beta$ imaging approach**
  - Resolution $^3\text{H} \sim 50 \mu\text{m}$, efficiency $\sim 75\%$
  - Resolution $^{14}\text{C} \sim 60 \mu\text{m}$, efficiency $\sim 50\%$

- **First evidence of PIM potentiality**
  - Patent since Mars 2002

- **A starting point for other applications**
  - MiP’s detection
  - Photon detection
Detection’s principle with a PIM detector

- Gaseous detector similar to MICROMEGAS or GEM

- Detection in 3 steps:
  - energy-electron conversion
  - Electron multiplication
    - novel concept
      - metallic and insulating meshes sandwich
      - directly in contact
      - micro gaps
  - electron diffusion
    - adapted to the anode segmentation
PIM : Multiplication Gain measurement.

- $^{55}$Fe source :
  - conversion (5.9 keV = 170 primary electrons with Ne+10% iC$_4$H$_{10}$)
  - total charge measurement on the anode

Comparison of the measured gain for one amplification stage PIM versus two amplification stages PIM without diffusion stage.
PIM : Multiplication Gain with one stage.

Results comparable to Micromegas with a 500 LPI micro-mesh
PIM : Multiplication Gain with two stages.

$\text{Ne+10}\%i\text{C}_4\text{H}_{10}$

$\Delta V_1 = 190$ V

$G = G_{\text{max}} \sim 5 \times 10^5$

Energy resolution:

$\text{Ne+10}\%i\text{C}_4\text{H}_{10}$ $G = 300000$

FWHM = 18 %

High gain with two stages and good energy resolution
**Discharges probability with $\alpha$ from $^{241}$Am source**

- Geometry: 5 cm conversion gap to stop $\alpha$ emitted at the top of the detector
- Discharges per incident particles measurement as a function of the amplification gain for one or two multiplication stages

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\phi(\alpha) = 200 \text{ Hz}
\]

\[
P(\text{2 stages}) \sim \frac{P(\text{1 stage})}{1000}
\]

**Improvement of the amplification process stability**

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Parallel Ionization Multiplier: first conclusions and perspectives

- \( \beta \) Imaging:
  - Good solution for high resolution and efficiency on a large sensitive area
  - Intrinsic resolution not yet reached

  tests with smaller sensitive areas in progress at SUBATECH

- General ionizing particles detection:
  - First results with radioactive sources very promising
  - Beam tests needed to validate the decrease of the discharge probability for hadrons and to measure spatial resolution

  hadron beam tests scheduled at CERN and GSI