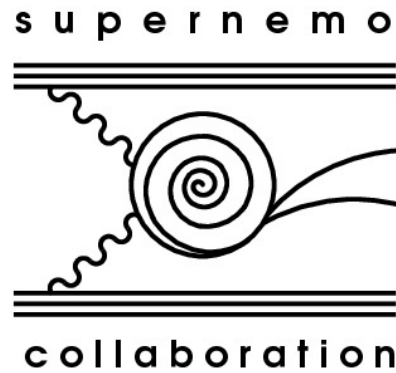




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ASTROCENT

# Detailed characterization of detection efficiency in SuperNEMO Demonstrator using $^{207}\text{Bi}$ calibration data

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## Why $\epsilon$ matters

Detection efficiency  $\epsilon$  enters directly in the half-life sensitivity formula

$$T_{1/2}^{\beta\beta} \geq \ln(2) \frac{N_A}{W} a \frac{m t \epsilon}{S(\bar{b})}$$

A higher, better-known  $\epsilon$  directly tightens the exclusion limit on the half-life and on the effective Majorana mass  $m_{\beta\beta}$

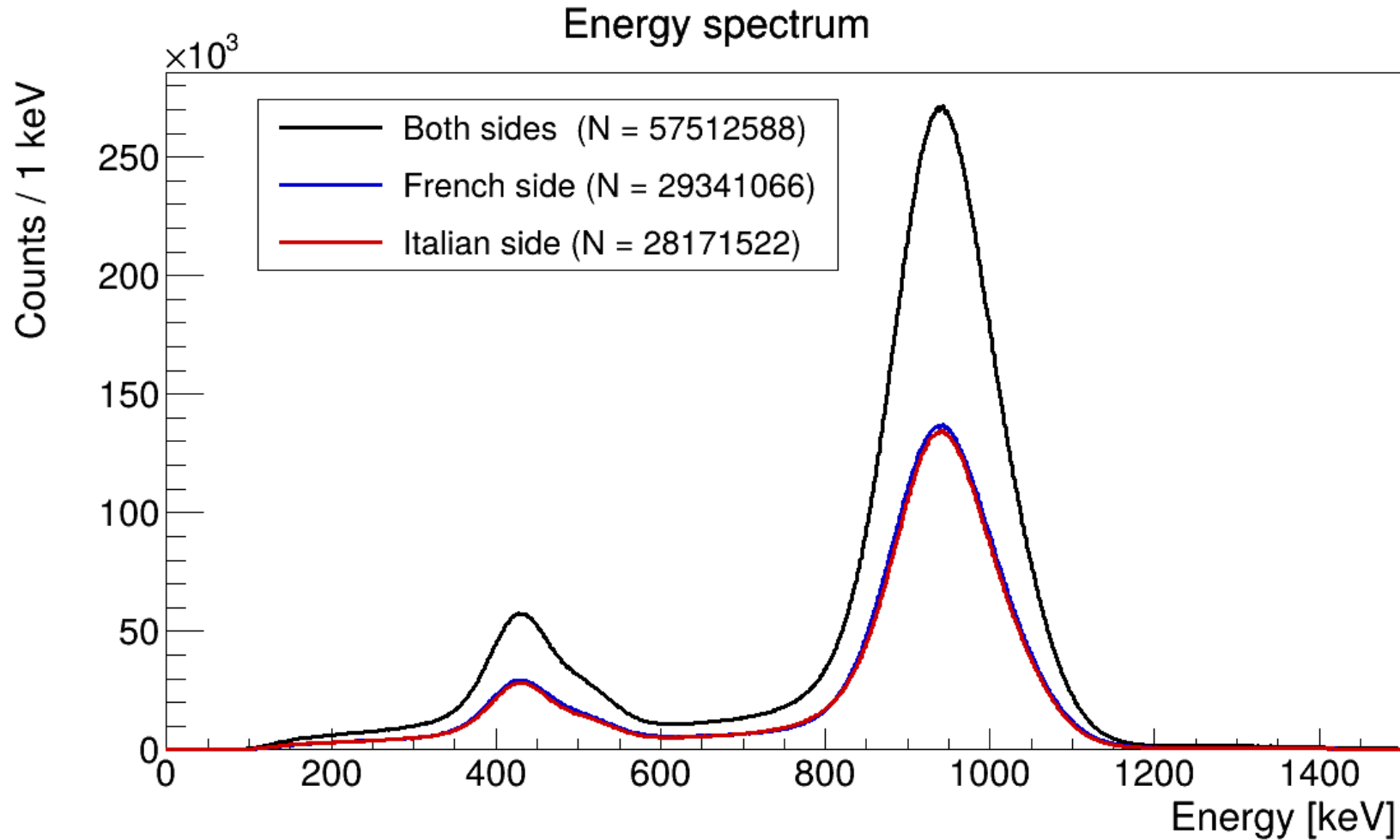
## One electron $\rightarrow 0\nu\beta\beta$

The single-electron  $\epsilon$  maps measured here can be benchmarked directly against the Falaise simulation, and combined pairwise across source-OM pairs, offer a first path toward an approximate two-electron efficiency for the full  $0\nu\beta\beta$  search

Main idea

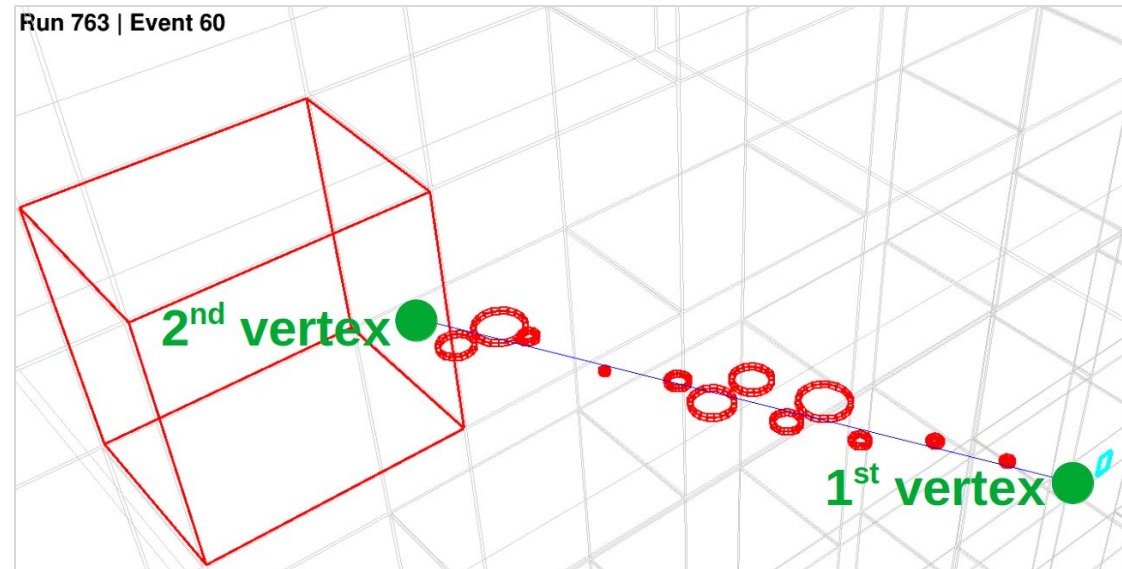


$$T_{1/2}^{\beta\beta} \sim \epsilon$$



The two  $^{207}\text{Bi}$  conversion-electron peaks (482 keV, 976 keV) are clearly resolved on both calorimeter walls (French = blue, Italian = red, combined = black), with consistent yields — confirming a clean, well-isolated event selection.

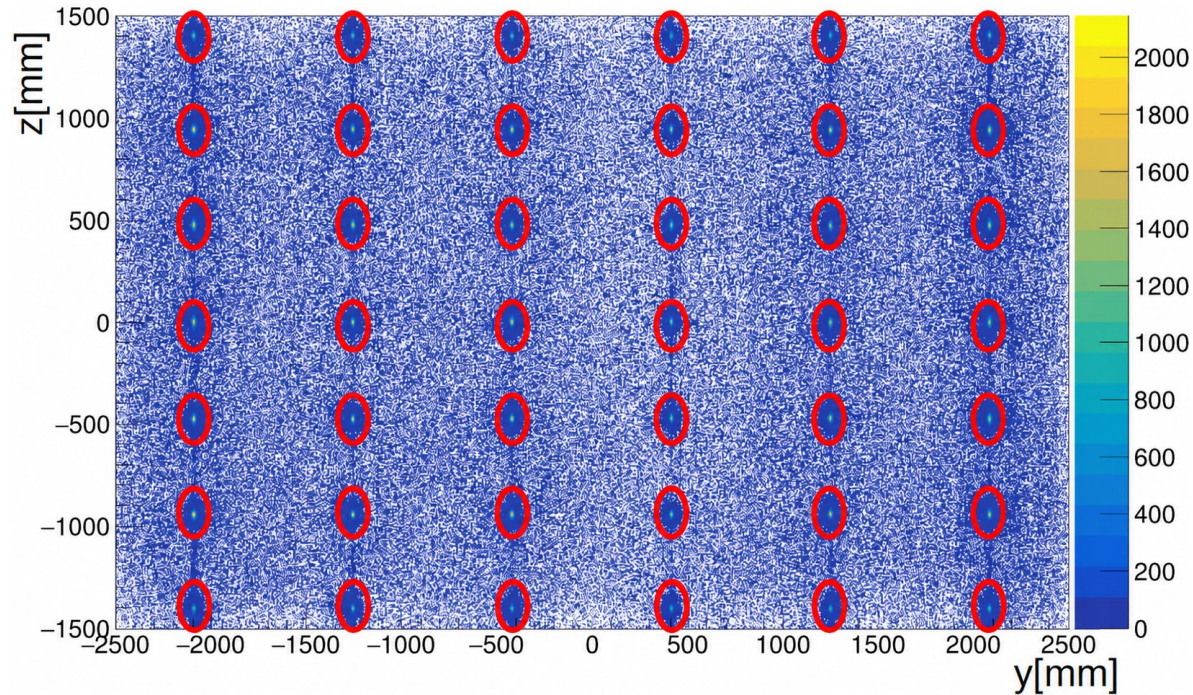
- Foil TPP within ellipse around source (15×40 mm)
- Exactly 1 reconstructed track, no kink segments
- 1 associated calorimeter hit
- Electron energy 0–3500 keV



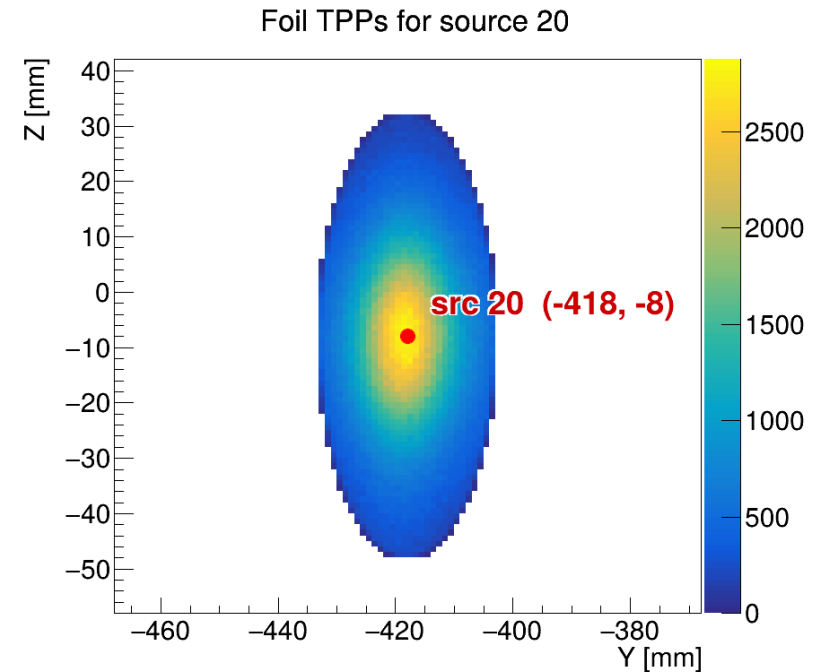
- **1st vertex (Foil TPP):** track crossing of the source-foil plane ( $x = 0$ ) — the electron's point of origin.
- **2nd vertex (OM TPP):** track crossing of the calorimeter front face — identifies the triggered optical module (OM).

*"Vertex" is the term used within the collaboration for what the thesis calls a Trajectory Projection Point (TPP).*

## Before: survey ellipse (all 42 sources)



## After: fitted center (source 20)



- **Before:** approximate  $\pm 15 \times 40$  mm ellipse from the as-built calibration-wire survey geometry, shown here on the cumulative Foil-TPP histogram of all 42 sources.
- **After:** each source cluster fit individually to its own 2D peak — e.g. source 20 at  $(Y, Z) = (-418, -8)$  mm — and the ellipse re-centered there for the final event selection (42 sources total).

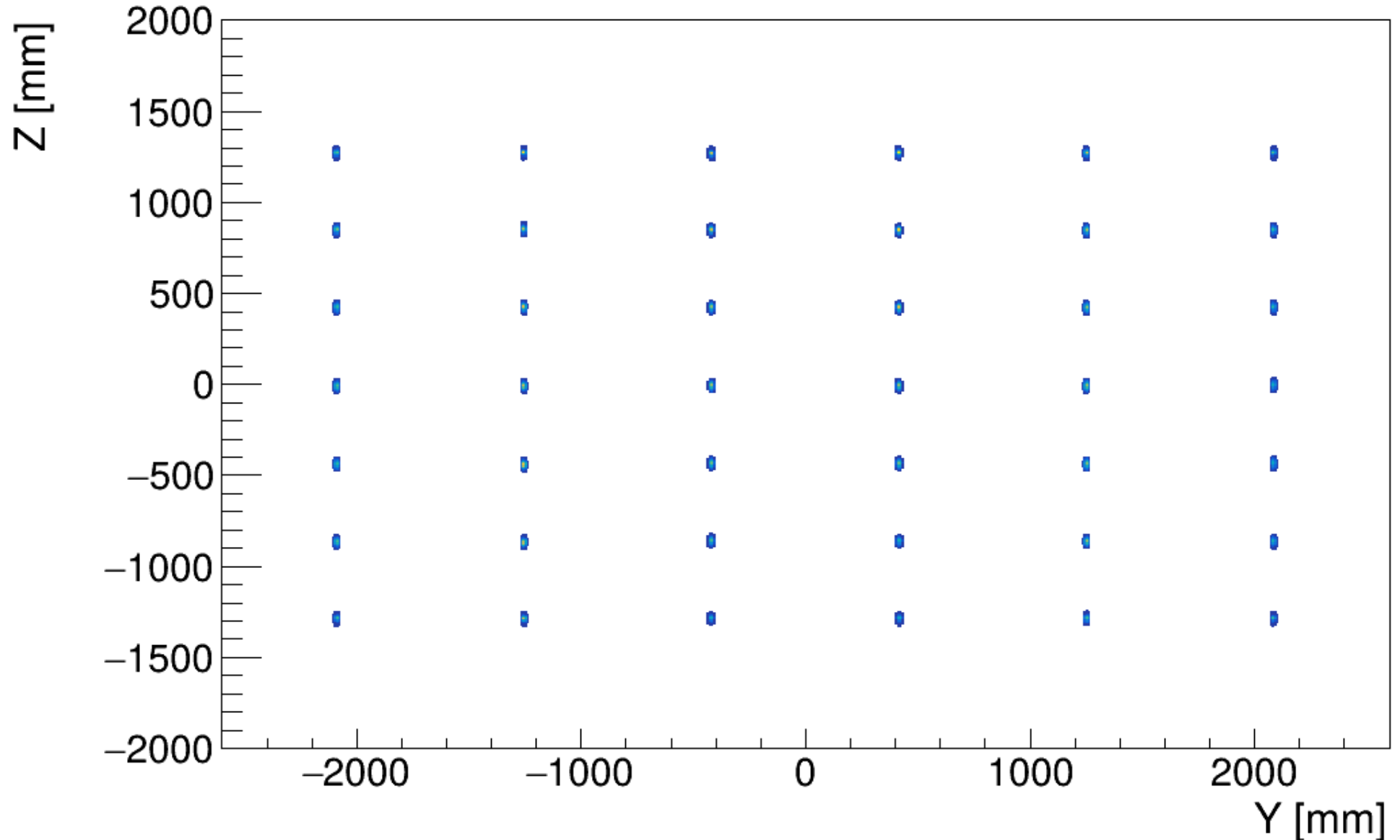
**367**  
runs · June 2025

**~181 h**  
live time

**57.5 M**  
events selected

**Standard  
cuts were  
applied**

Foil TPPs | Italian side

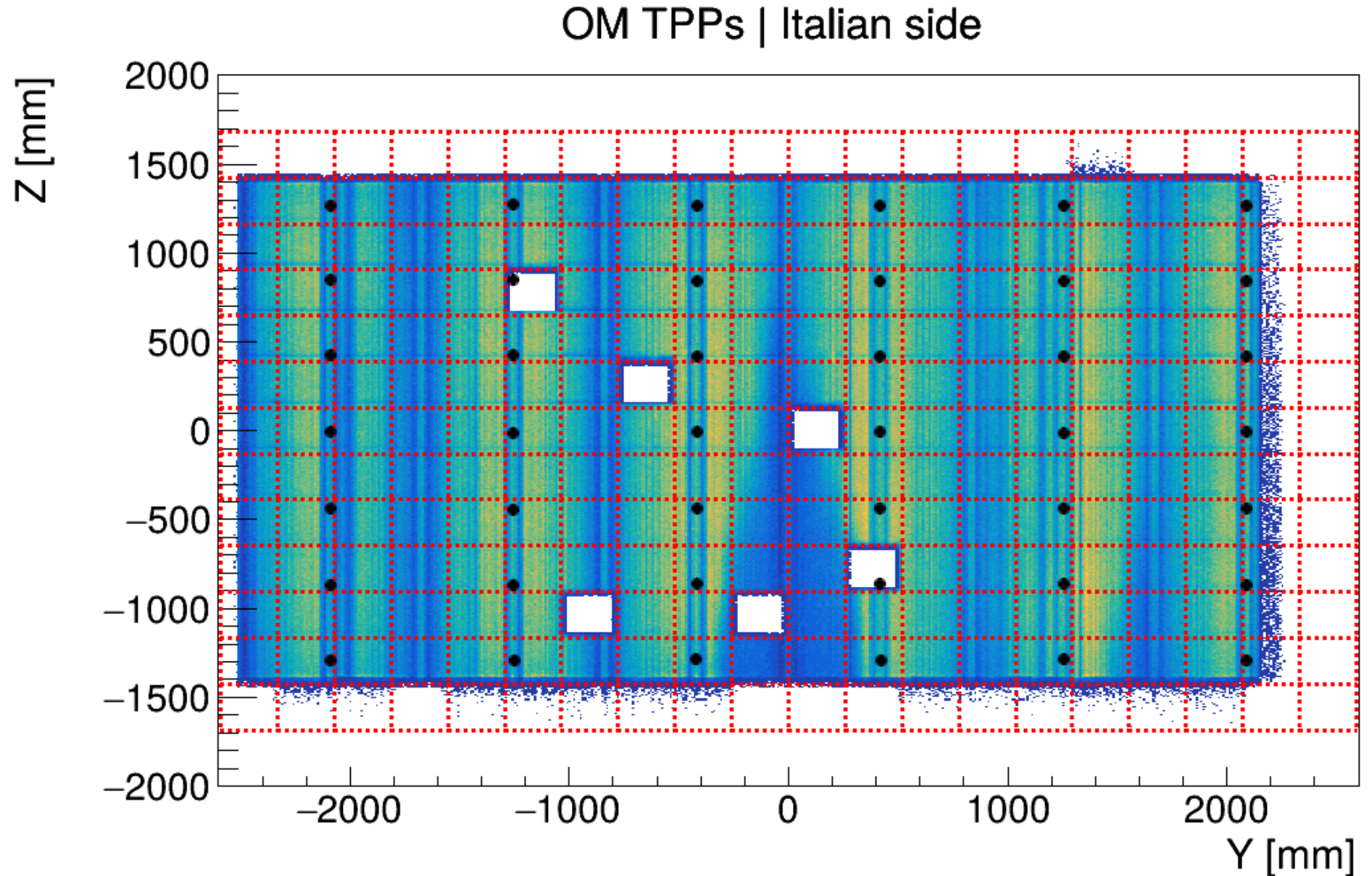


**367**  
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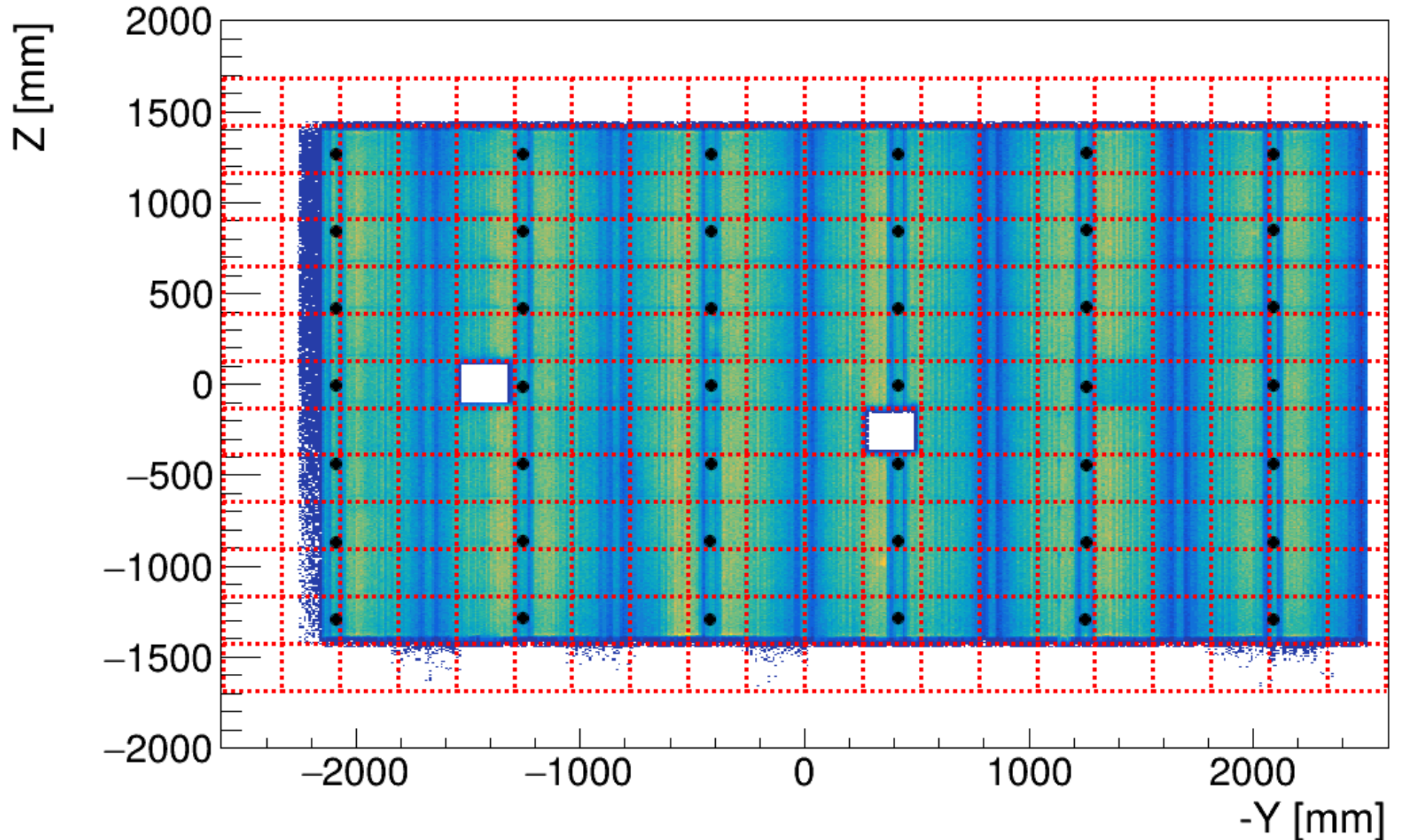
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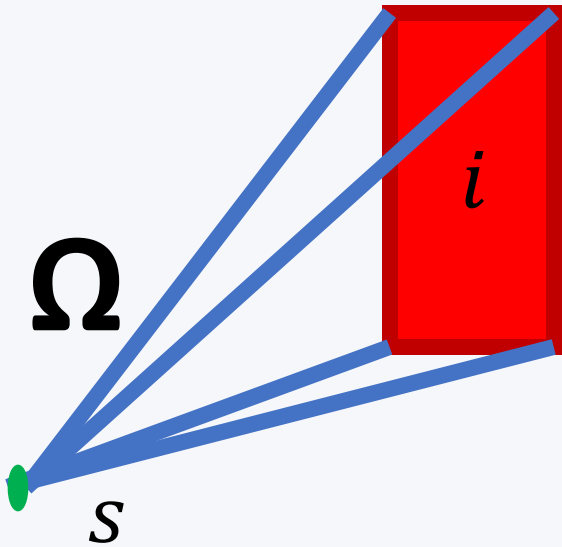
**Standard  
cuts were  
applied**

OM TPPs | French side



## Geometric efficiency

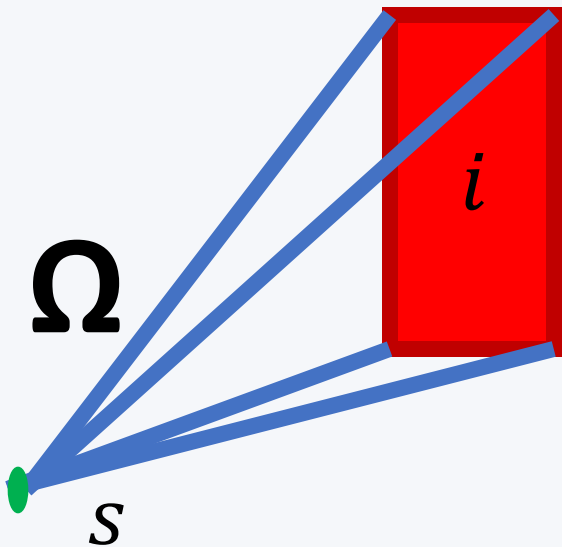
$$\varepsilon_{Geom}^{(s,i)} = \frac{\Omega^{(s,i)}}{4\pi}$$



Baseline (geometry only)

## Geometric efficiency

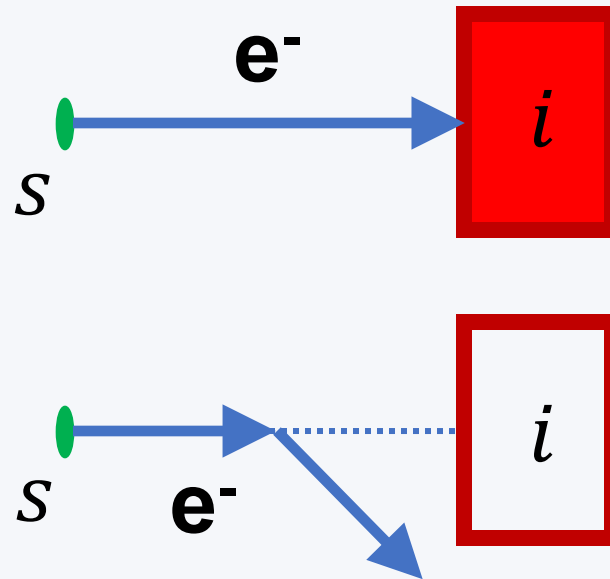
$$\varepsilon_{Geom}^{(s,i)} = \frac{\Omega(s,i)}{4\pi}$$



Baseline (geometry only)

## Experimental efficiency

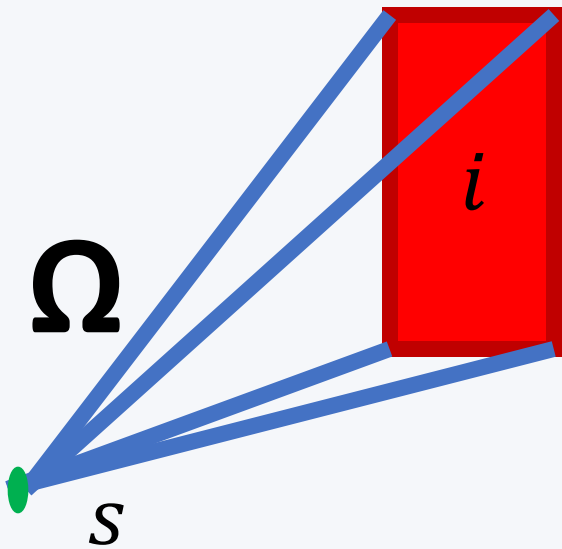
$$\varepsilon_{Exp}^{(s,i)} = \frac{N(s,i)}{N_{decay}^{(s)}}$$



Measured from data

## Geometric efficiency

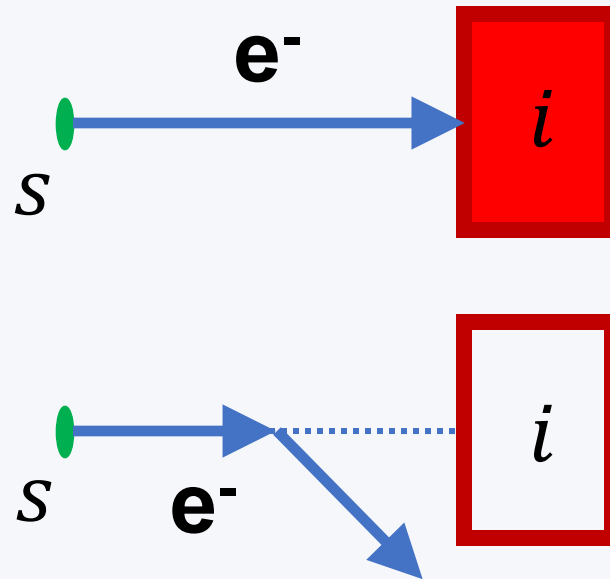
$$\epsilon_{Geom}^{(s,i)} = \frac{\Omega(s,i)}{4\pi}$$



Baseline (geometry only)

## Experimental efficiency

$$\epsilon_{Exp}^{(s,i)} = \frac{N(s,i)}{N_{decay}^{(s)}}$$



Measured from data

## Residual efficiency

$$\epsilon_{Res}^{(s,i)} = \frac{\epsilon_{Exp}^{(s,i)}}{\epsilon_{Geom}^{(s,i)}}$$

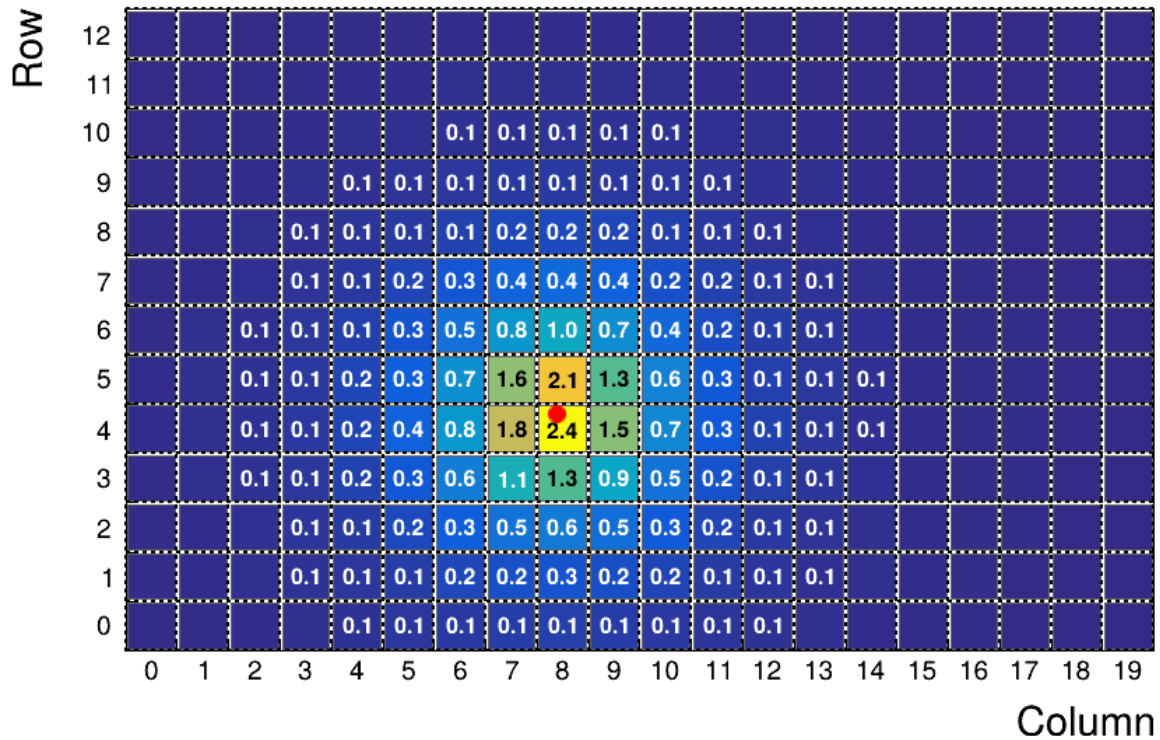


Effects except geometry

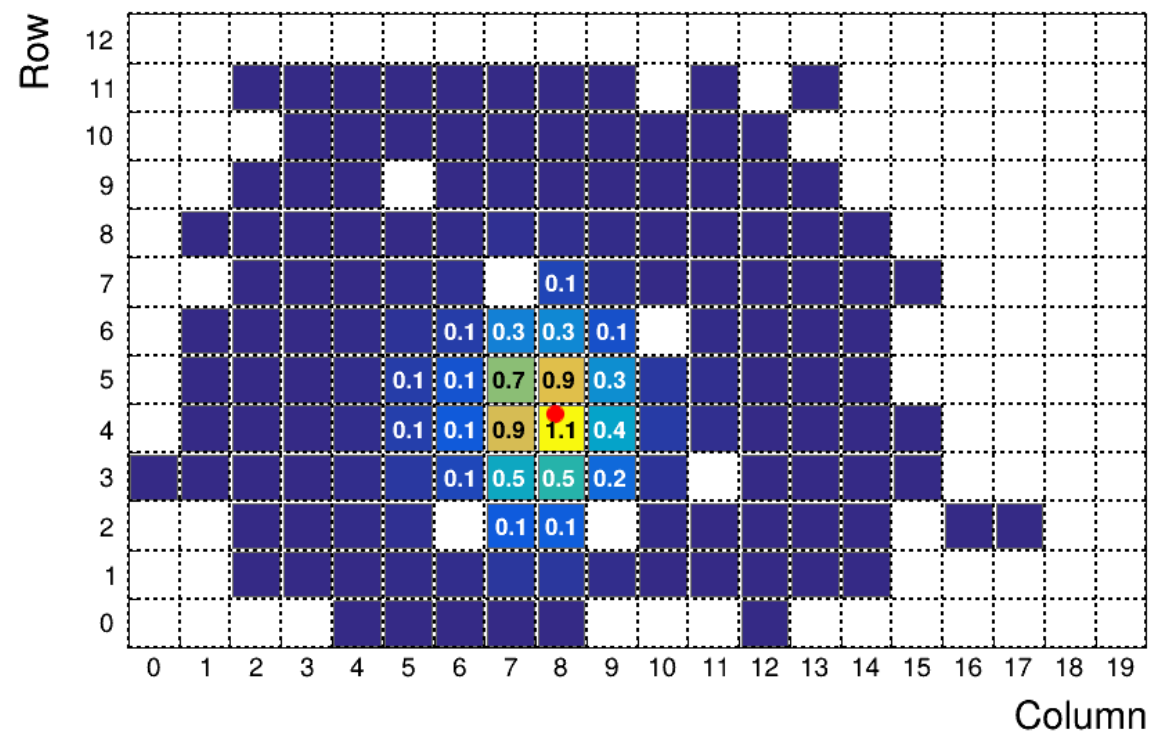
Primary result

## Geometric (%)

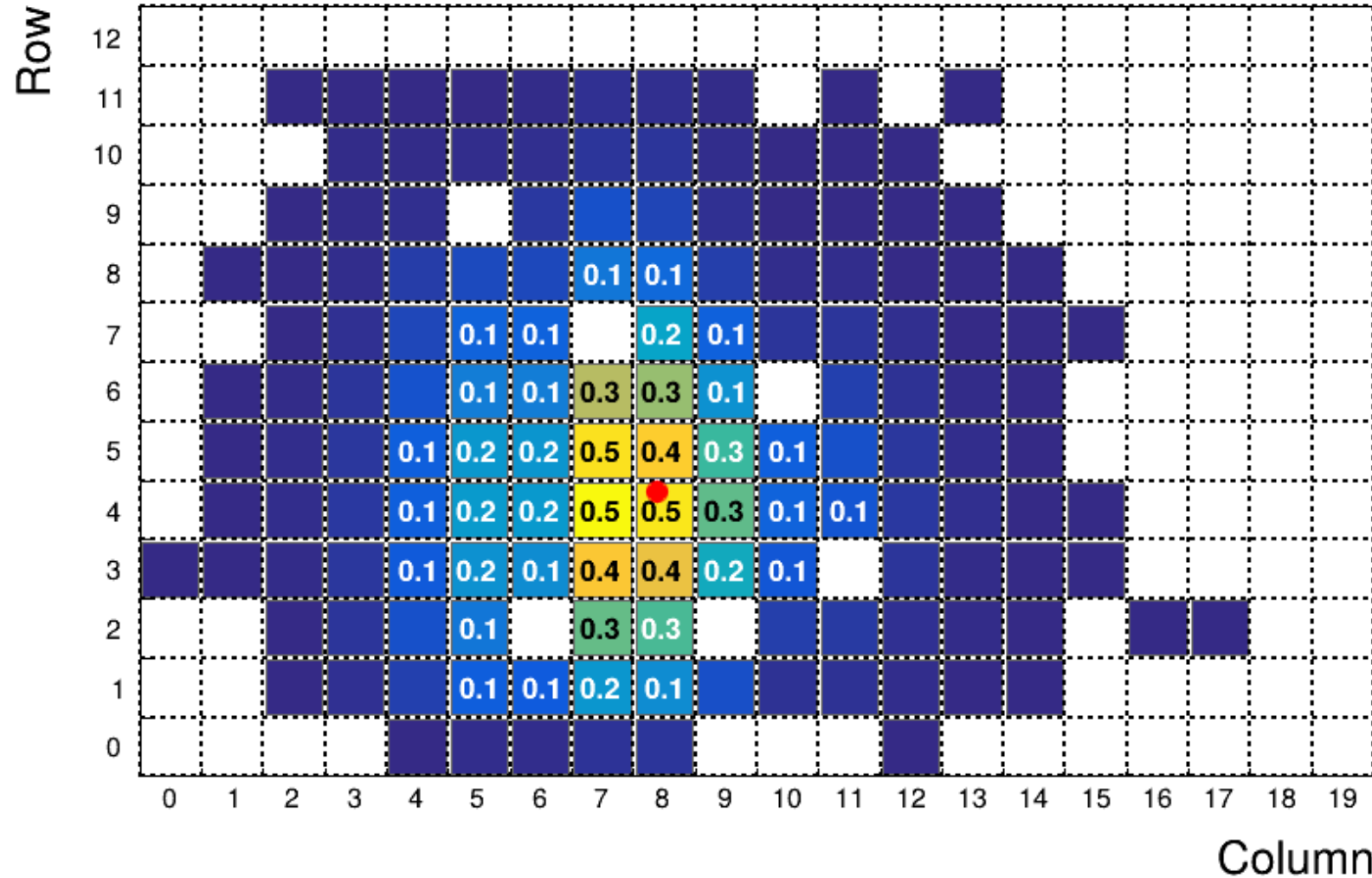
The algorithm for geometric efficiency provided by Elif Kozanoğlu (Princeton University)



## Experimental (%)



Geometric  $\epsilon$  (left, baseline solid-angle acceptance only) vs. experimental  $\epsilon$  (right, measured from  $^{207}\text{Bi}$  data) for source 26. Same localized illumination pattern around the source projection — their ratio gives the residual efficiency shown next.

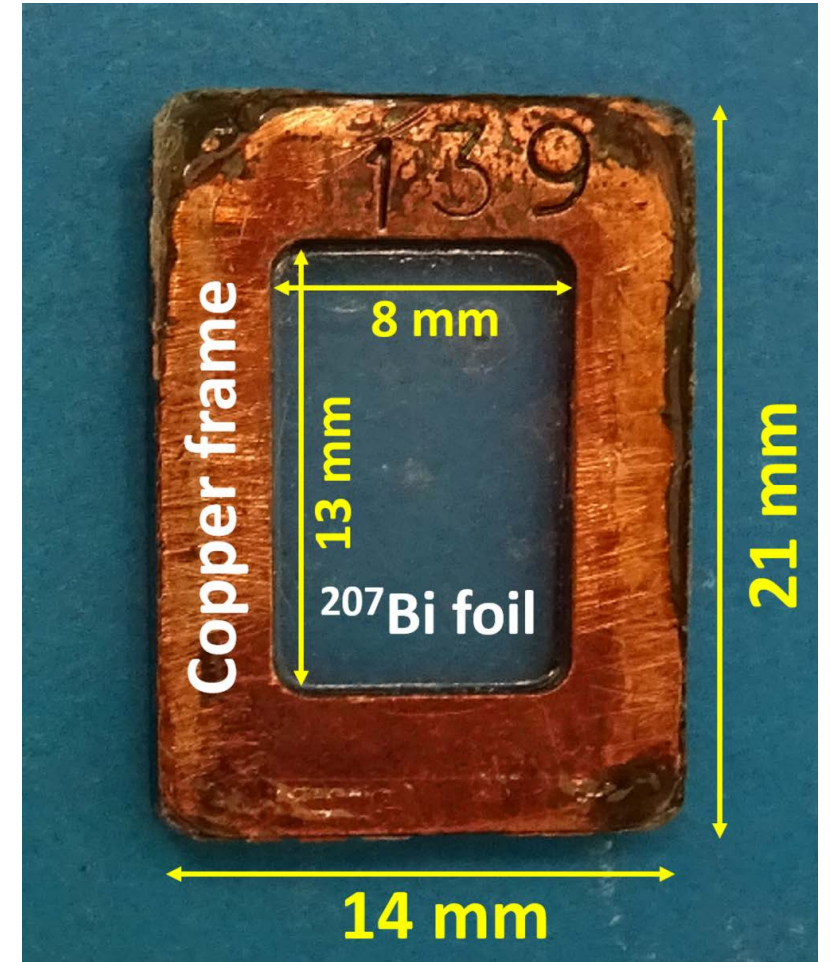


Dividing experimental by geometric  $\epsilon$  removes the steep solid-angle fall-off, isolating the residual efficiency  $\epsilon_{\text{res}} \approx 0.3\text{--}0.5$ . The rectangular (not circular) envelope points to the source-housing aperture and/or tracker-wire shadowing as the limiting factors.

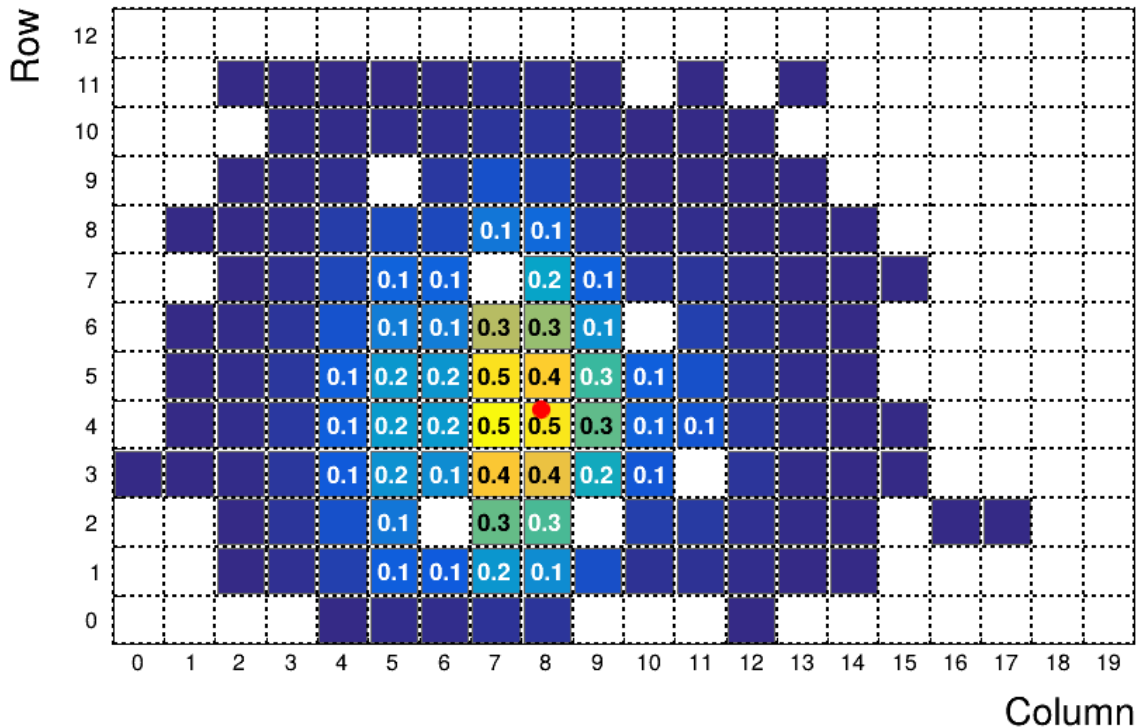


A droplet sealed between two 12  $\mu\text{m}$  Mylar foils inside a radiopure copper frame. Left: mounting bracket on the calibration wire. Right: 8 $\times$ 13 mm deposit window.

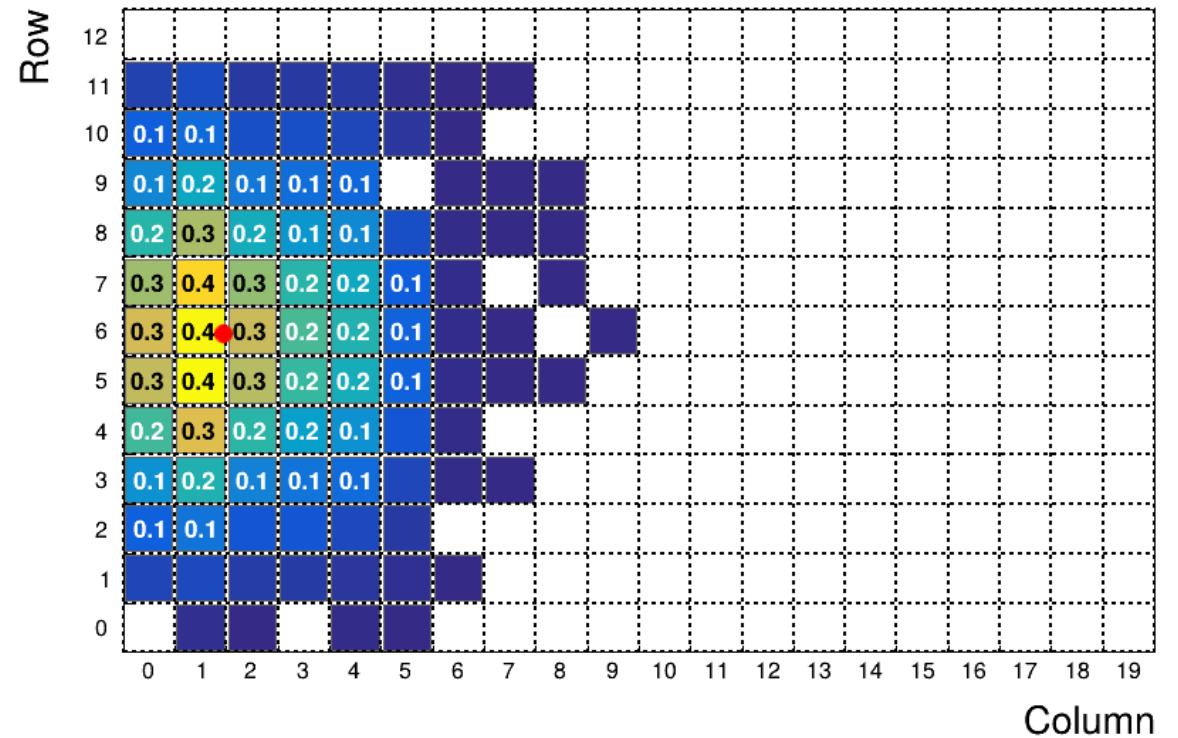
*42 such sources, individually surveyed, are installed.*



## Source 26 (Italian side)



## Source 18 (Italian side)



Source 26 (left) shows a deficit in the column facing the source — consistent with a tracker anode wire aligned with its projection. Source 18 (right) shows no such deficit, only the generic rectangular envelope — supporting the wire-shadow hypothesis.

## Established

First map of position-dependent single-electron detection efficiency across the SuperNEMO demonstrator calorimeter using  $^{207}\text{Bi}$  data.

## Key result

$\varepsilon^{\text{res}} \approx 0.3\text{--}0.5$  consistently across the illuminated region rectangular shape.

## Potential explanations

Aperture in source envelops or effect of tracker wire shadows.

*What can be done about this next? →  
from one electron to a two-electron  $0\nu\beta\beta$  efficiency*

## Cross-check

Single-electron efficiency maps  $\varepsilon_{s,i}$  can be cross-checked directly against the Falaise simulation used for the official  $0\nu\beta\beta$  efficiency estimate.

## Two-electron recipe

Pair OM  $i$  (source  $s_1$ ) with OM  $j$  (source  $s_2$ ) for back-to-back electrons, weighted by  $0\nu\beta\beta$  kinematics, to build an approximate two-electron efficiency  $\varepsilon_{i,j}$ .

## Next step

Validate  $\varepsilon_{i,j}$  against the full two-electron Monte Carlo, then feed it into equation to turn the position-resolved efficiency map into an improved, data-driven half-life sensitivity.

Thank you for your attention!