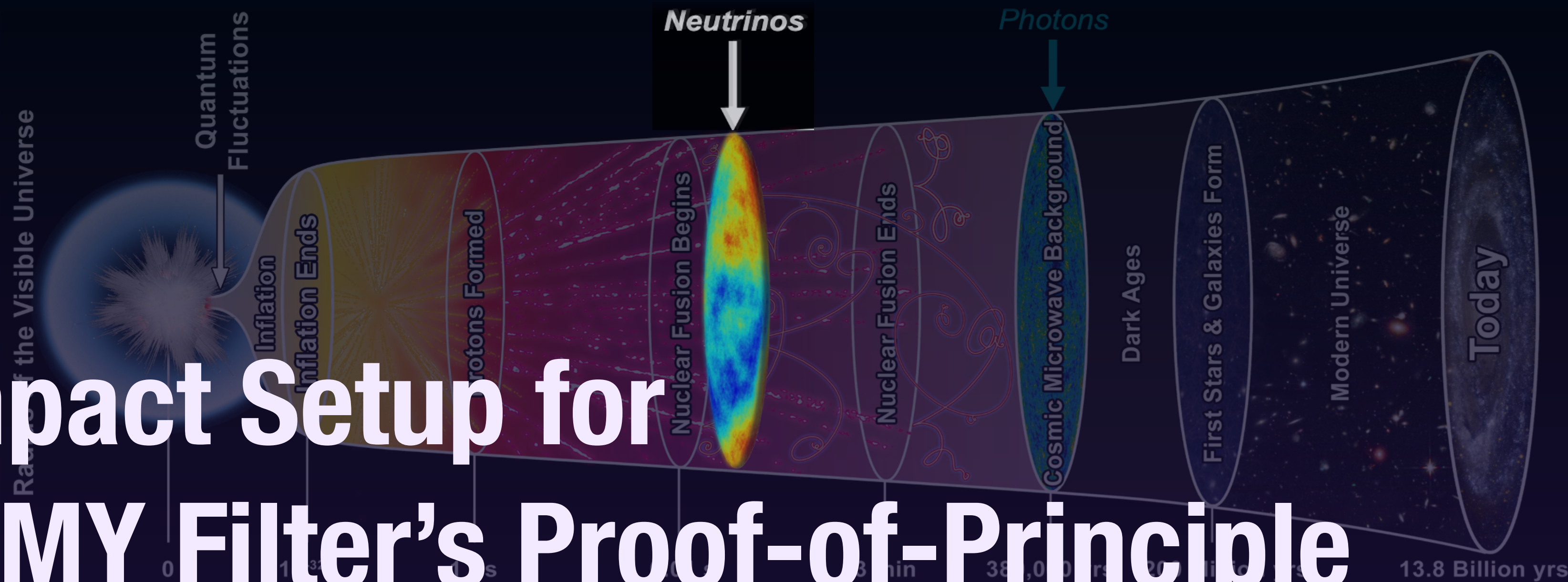


A Compact Setup for PTOLEMY Filter's Proof-of-Principle



GRAN SASSO
SCIENCE INSTITUTE

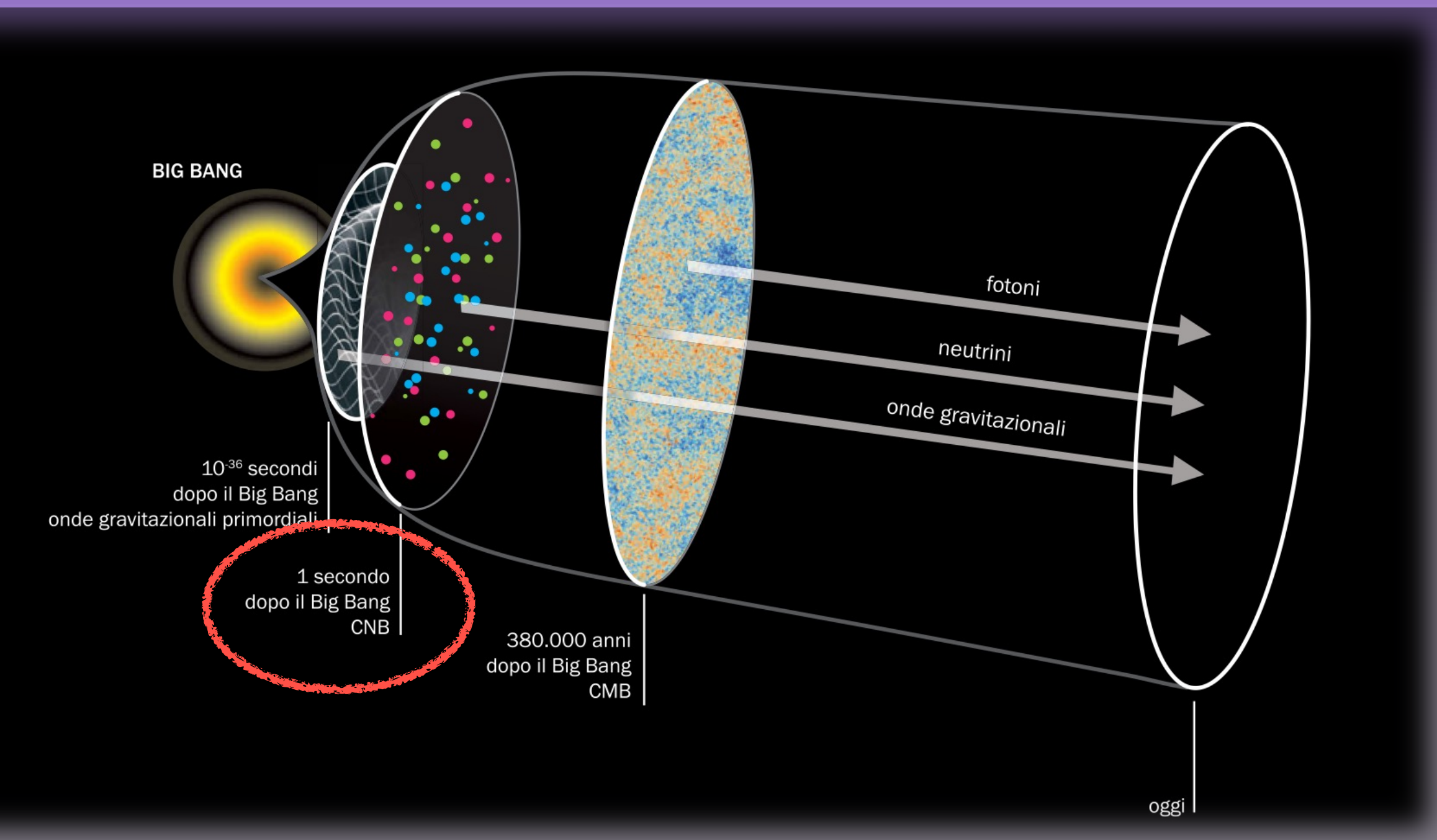


Presentation for the INTERNATIONAL SCHOOL OF NUCLEAR PHYSICS, 47th Course
Erice, Italy, September 16th 2026

Francesca Maria Pofi on the behalf of the PTOLEMY collaboration



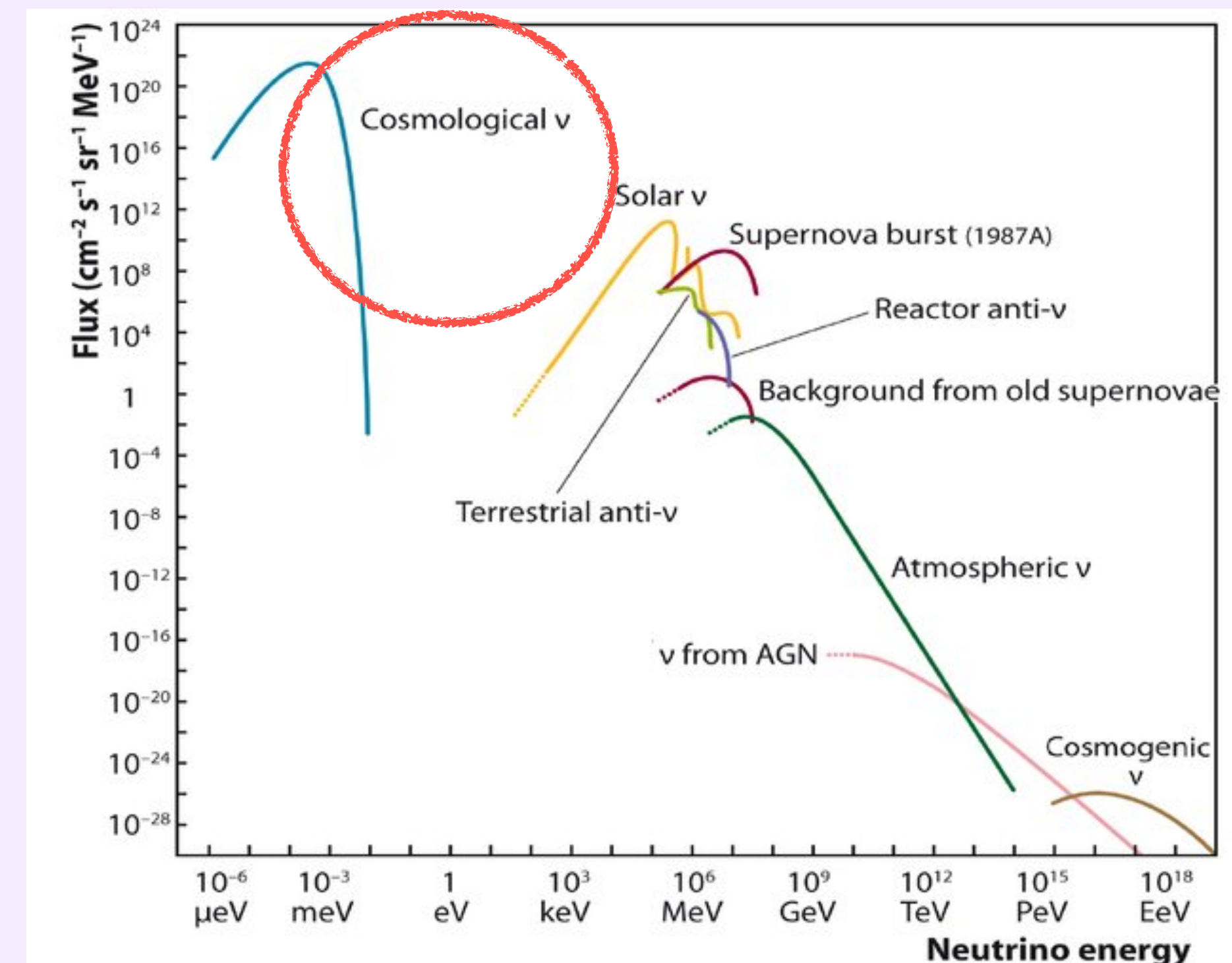
A Sea of 'Still' Neutrinos



- ❖ Most abundant neutrinos' source
- ❖ Extremely low energy $E_\nu \simeq 10^{-4}$ eV
 - ➔ Challenging detection: non-threshold reaction needed

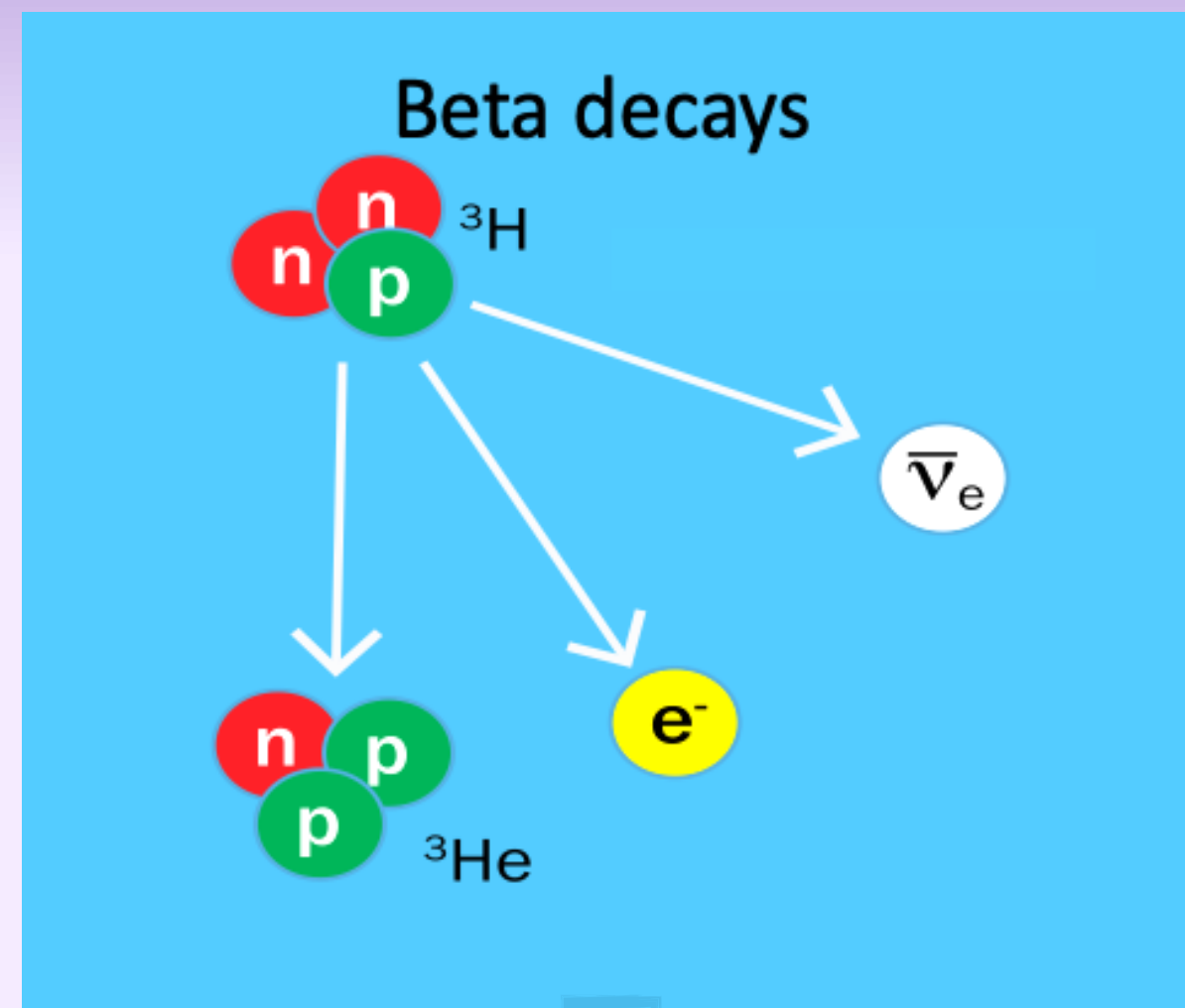
Cosmic Neutrino Background (CNB)

- Identikit:**
- ❖ Decoupling 1 sec after Big Bang
 - ❖ Density $n_\nu \simeq 300/\text{cm}^3$
 - ❖ Temperature $T_\nu \simeq 1.95$ K

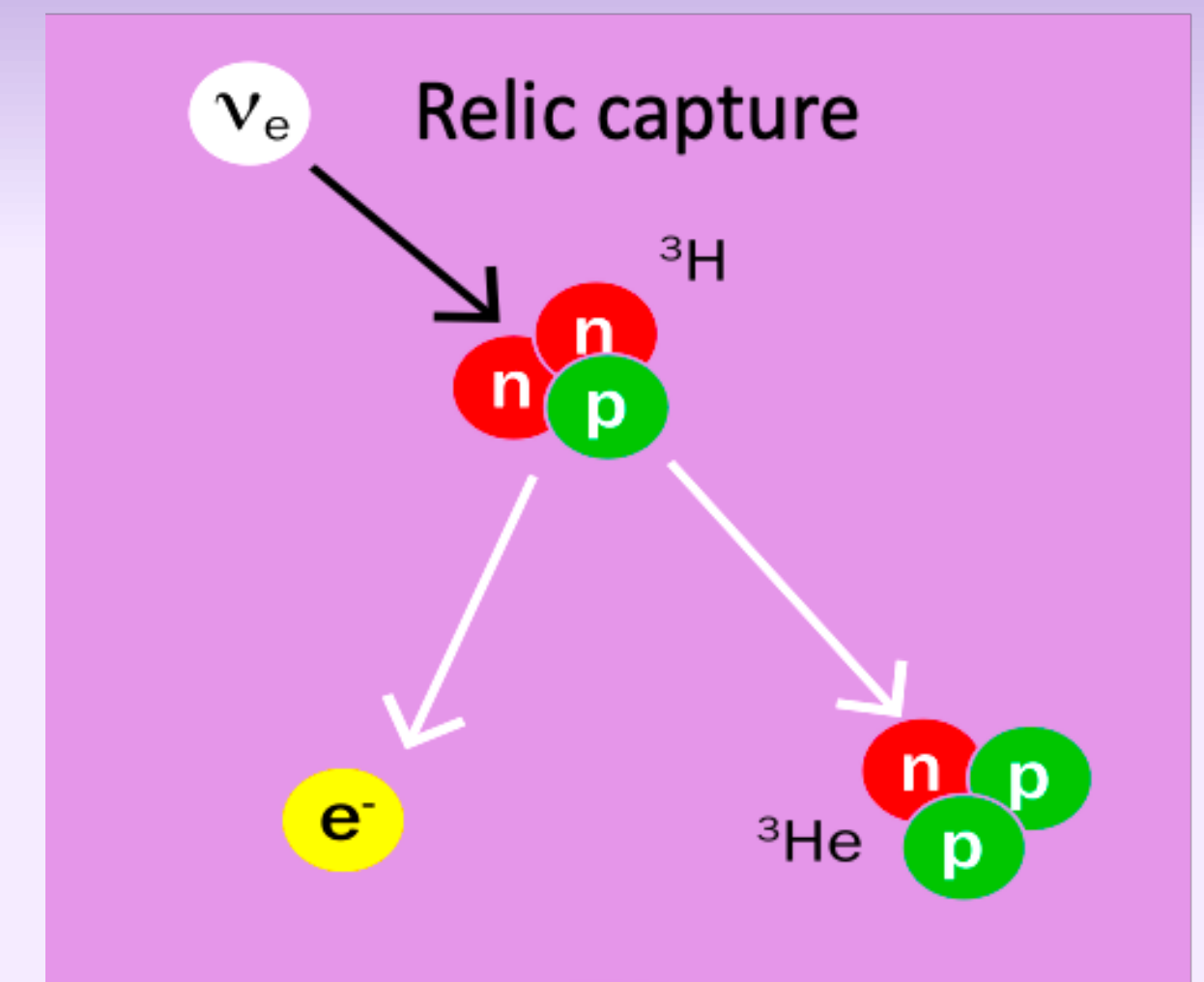
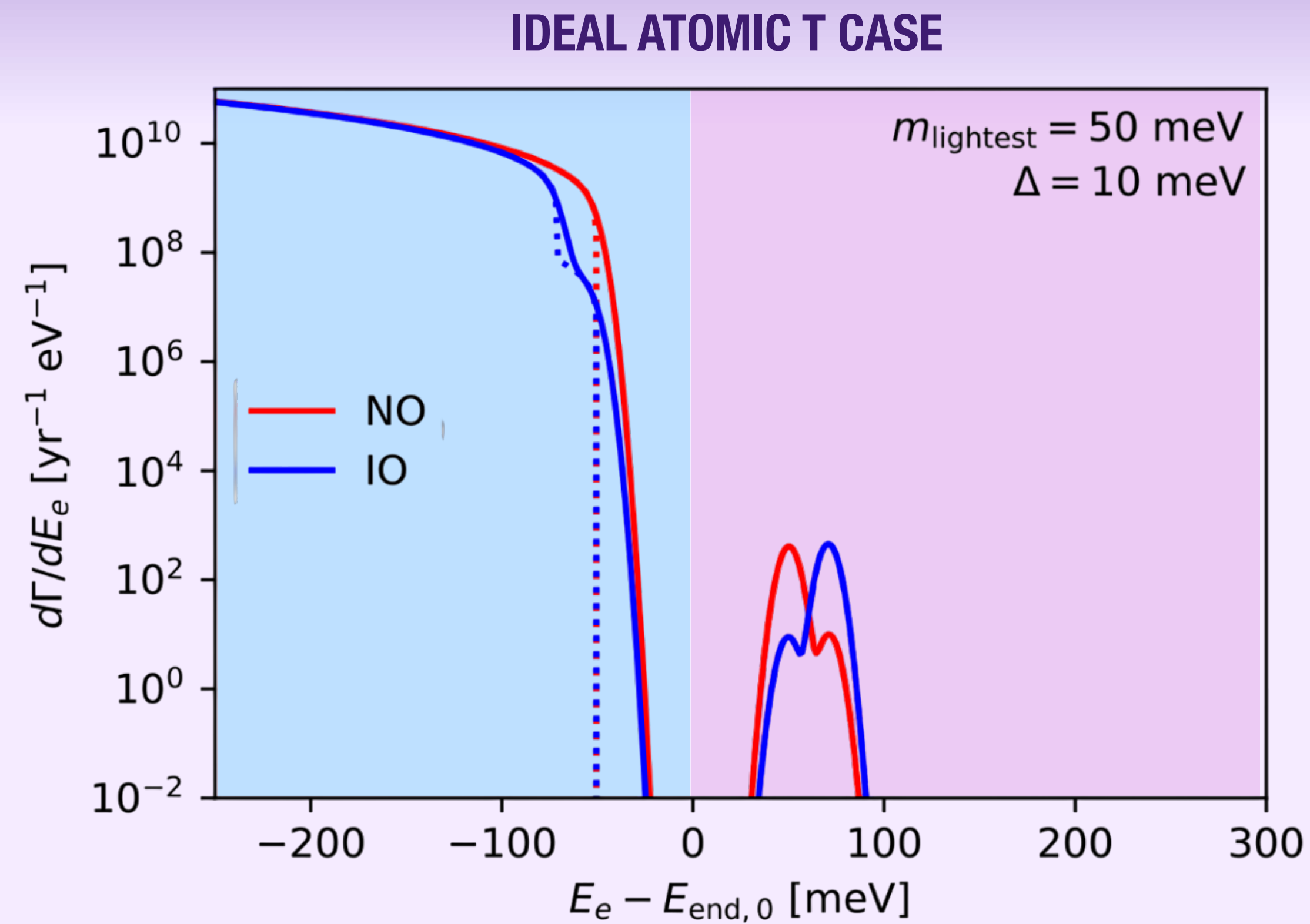


Two Measurements with One Observable

☑ Let's take a β -unstable nucleus eg Tritium (^3H) $\longrightarrow$ What can we obtain *for free*?

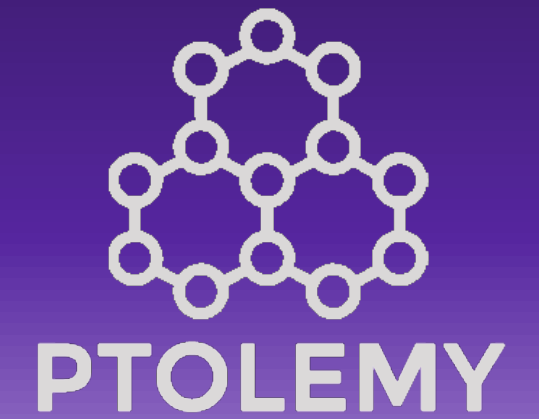


Neutrino Mass Measurement
from endpoint distortion
(1st goal)



First
Relic Neutrinos Detection
(Final goal)

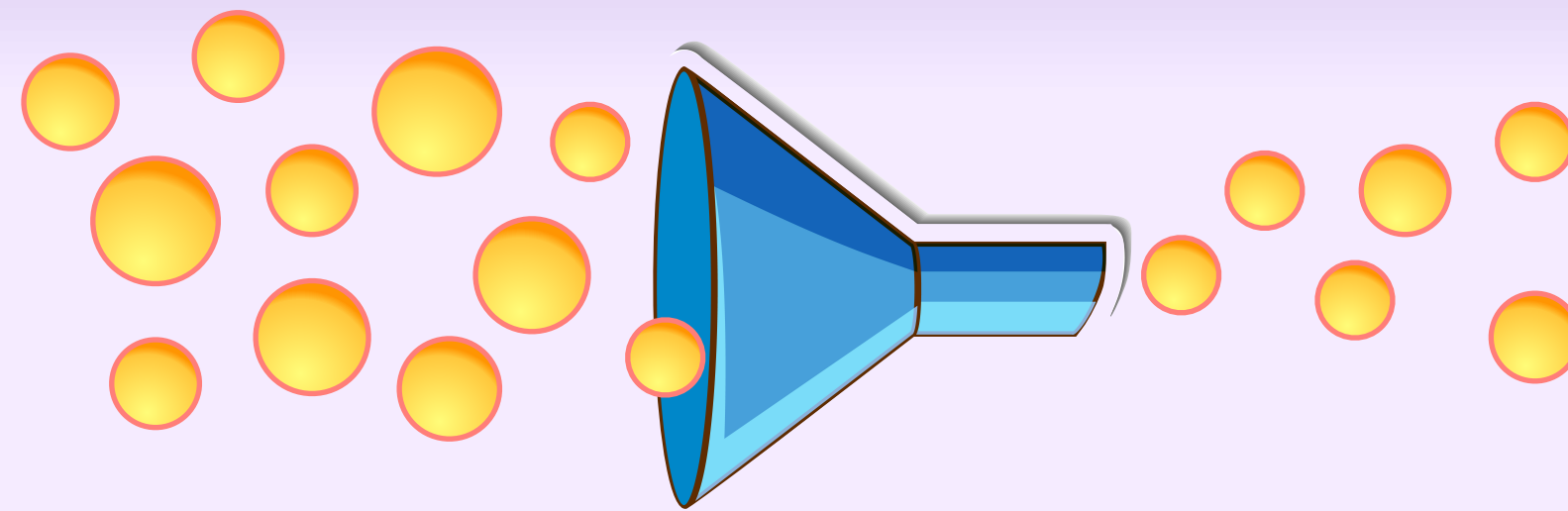
PTOLEMY Ingredients



✓ Extremely accurate measurement of electron energy

- $\mathcal{O}(50 \text{ meV})$ resolution

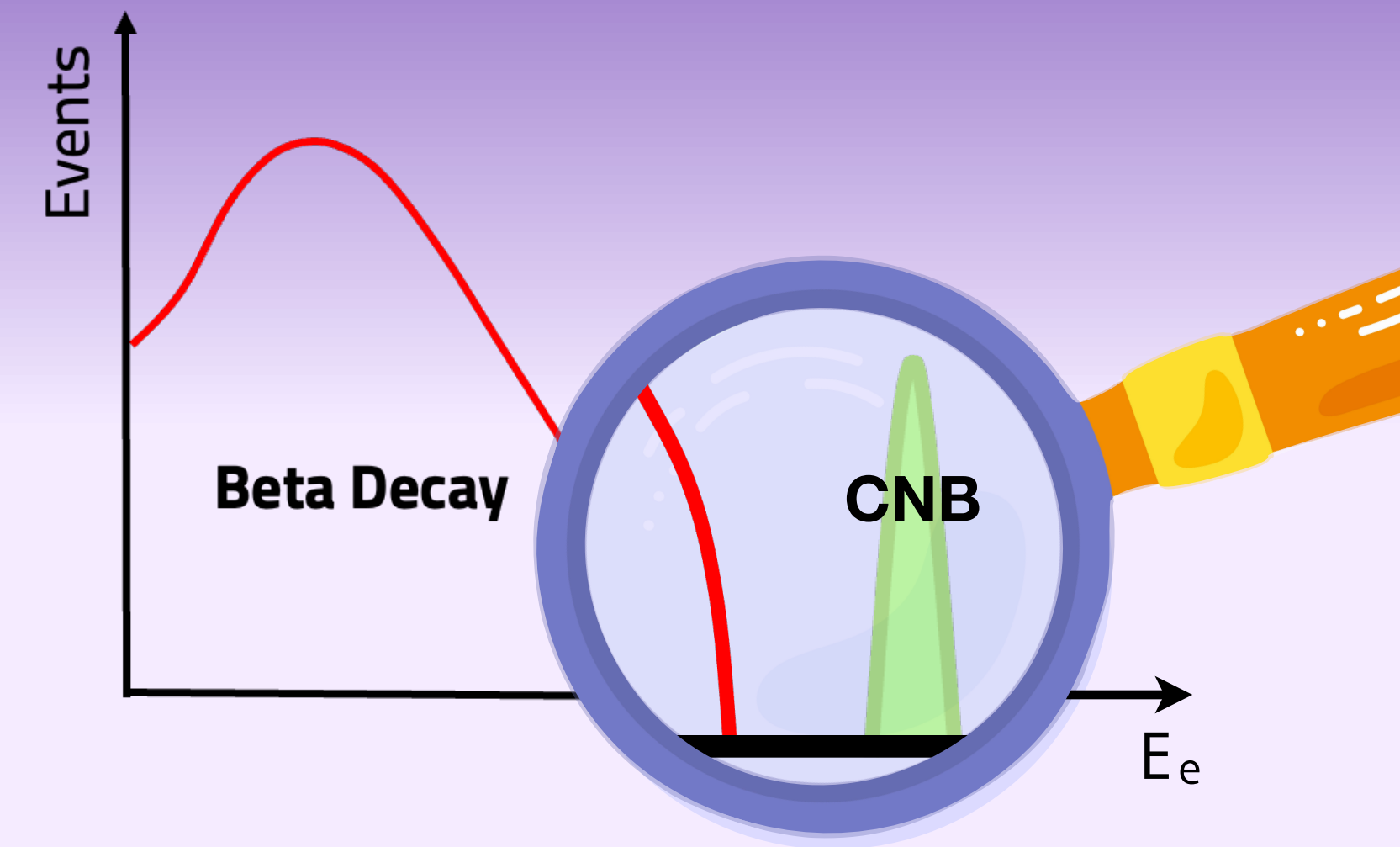
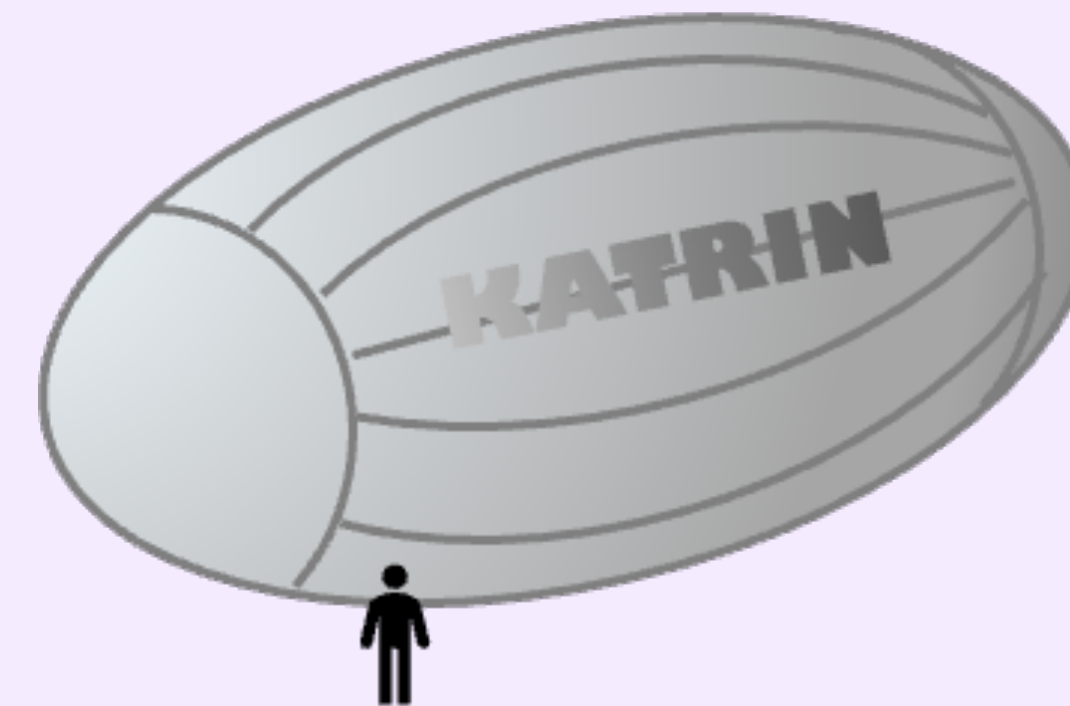
✓ Electron trigger + filtering



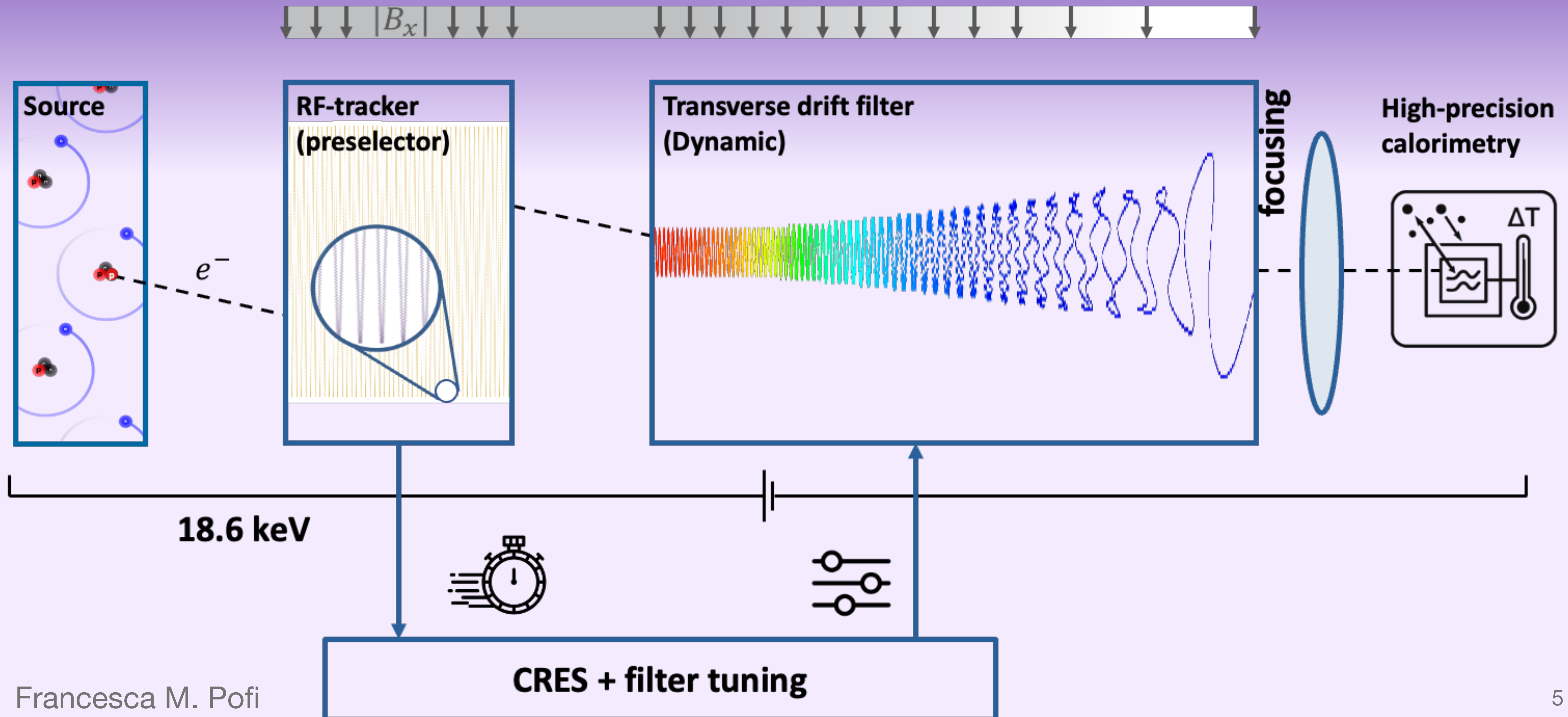
✓ Electron slowdown



✓ Large target mass (very low cross section for ν capture)



A Multi-Disciplinary Detector

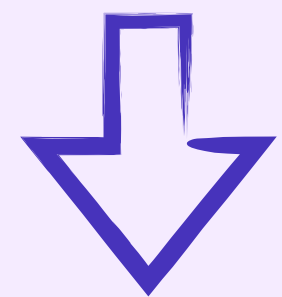


Filter within One Meter

E Field → $\underline{E \times B}$ drift → motion along filter
→ potential hill

B Field → $\underline{\nabla B \times B}$ drift → motion against increasing potential

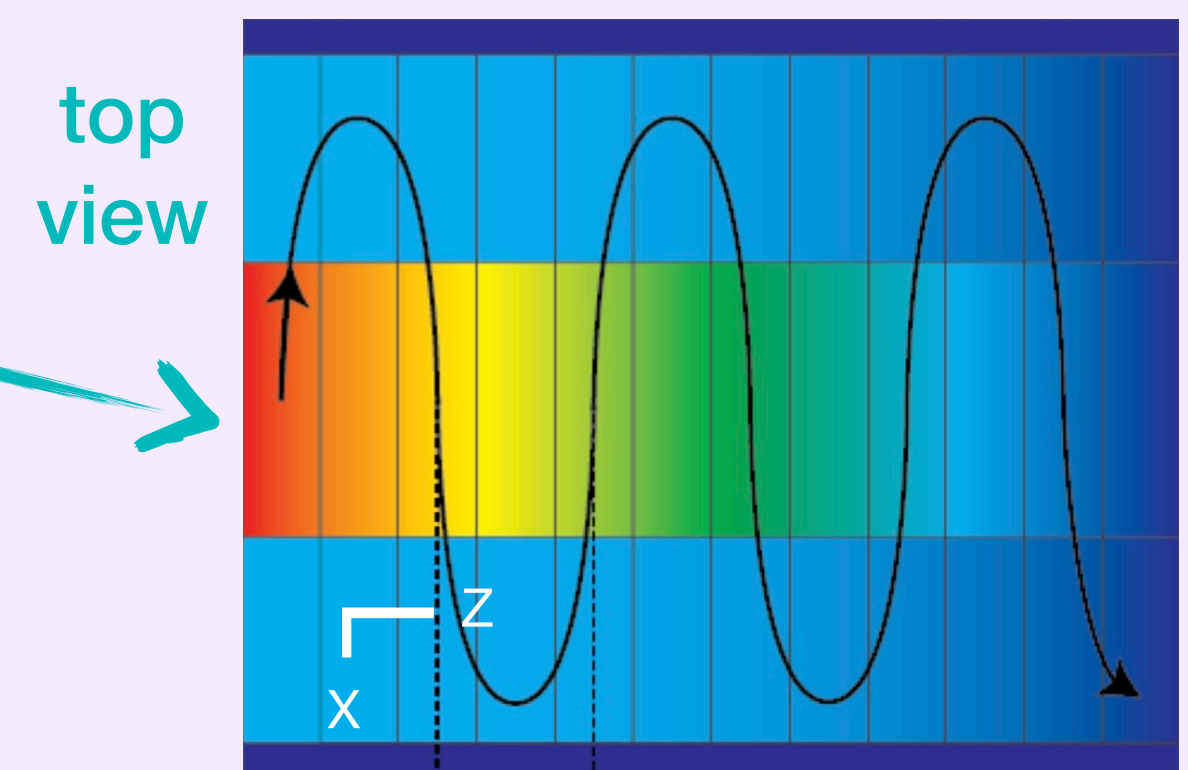
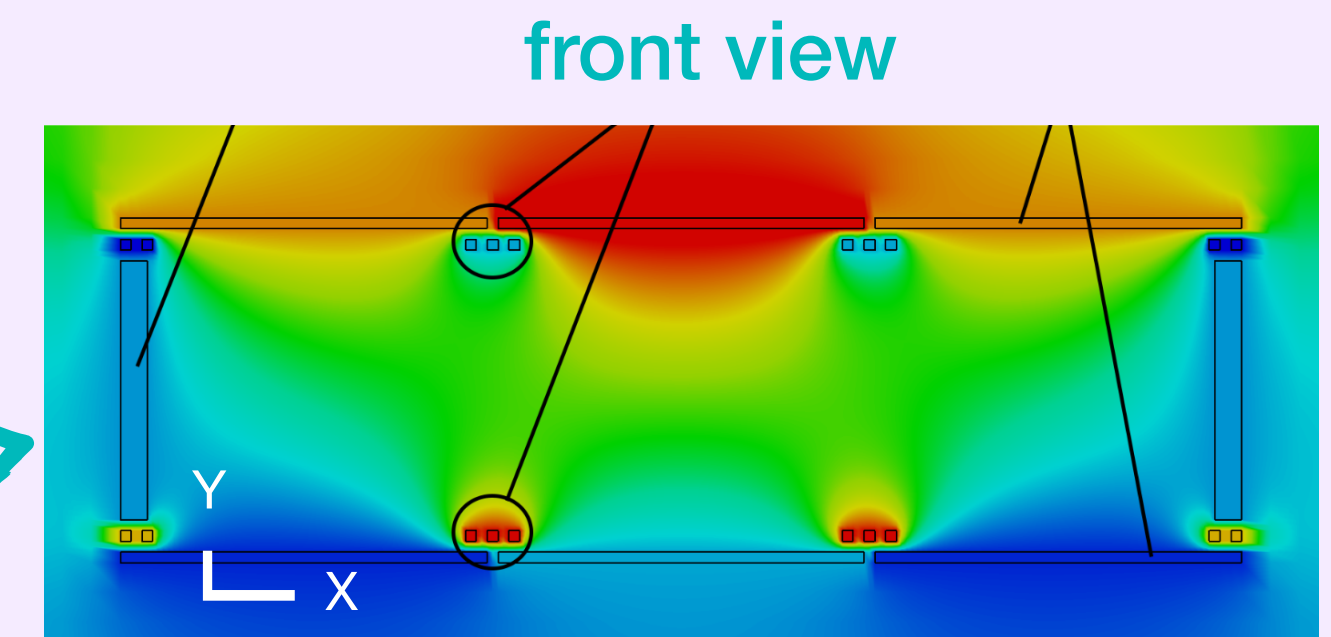
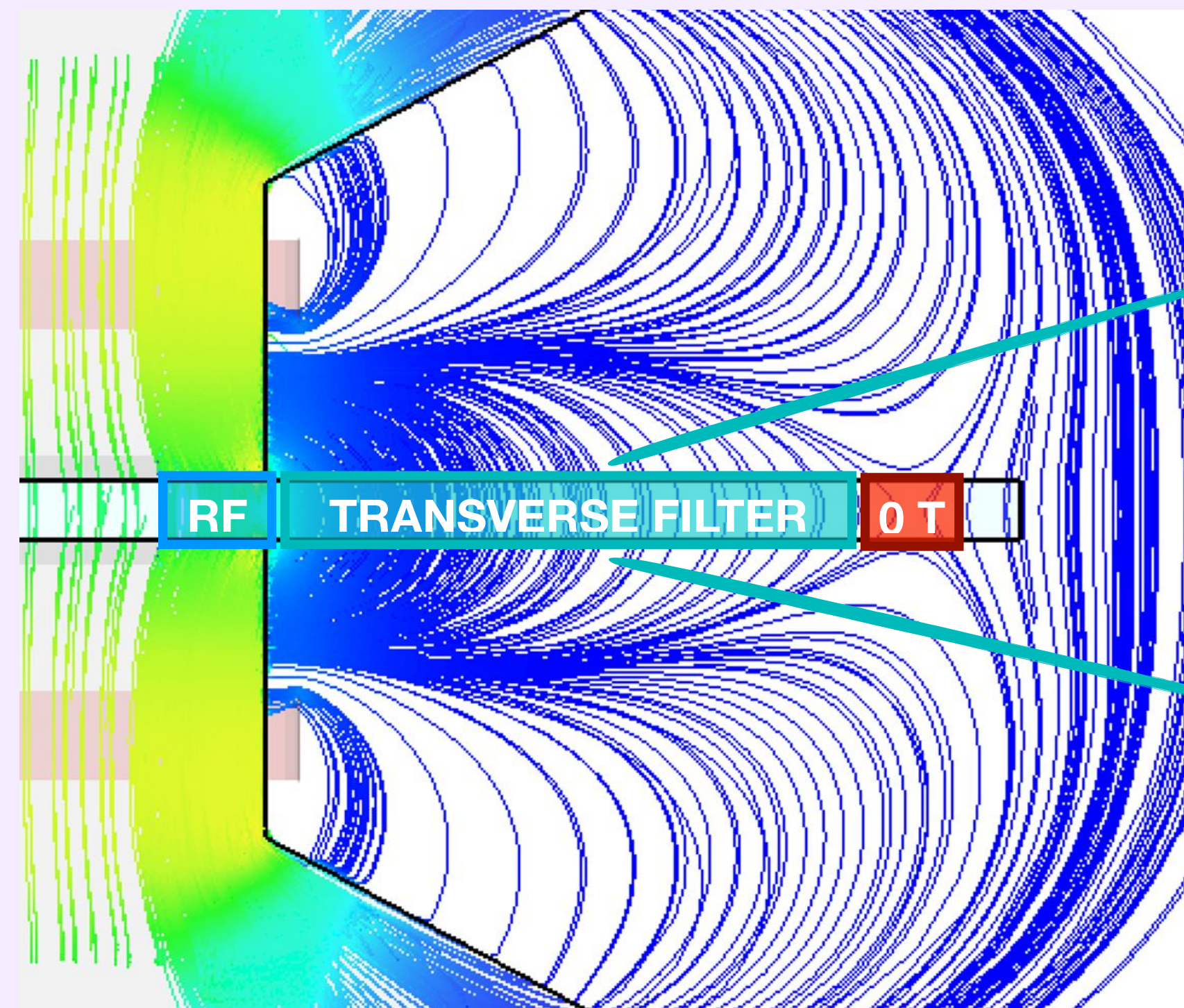
➤ with exponential decay @ same rate → transverse drift balancing



FINAL RESULT:

Electrons' **slowdown + filtering**

- with controlled trajectory
- in short space (~1 m)

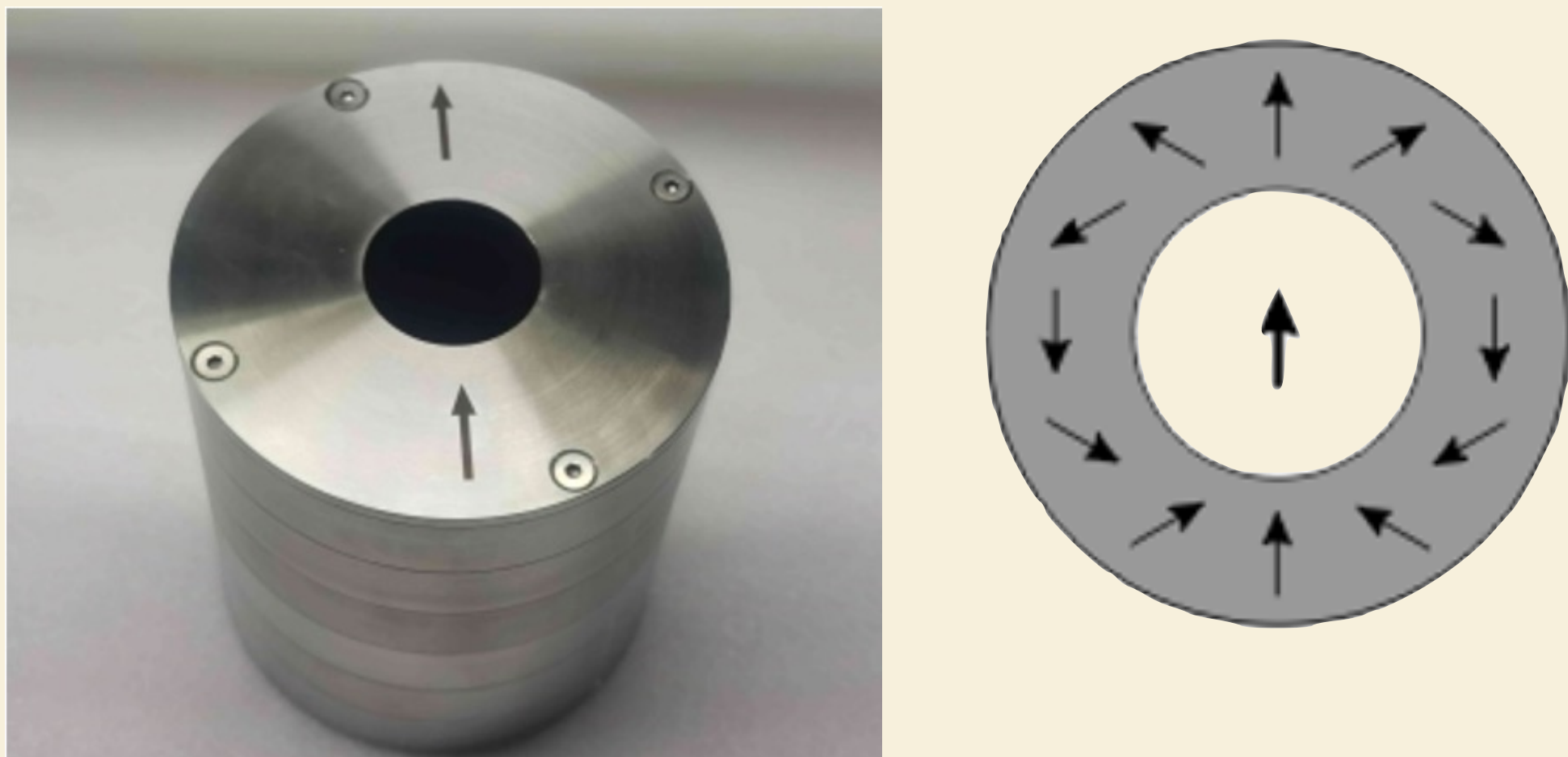


A Compact Setup @ LNGS for Filter Drifts Proof-of-Principle

Introducing the Main Characters

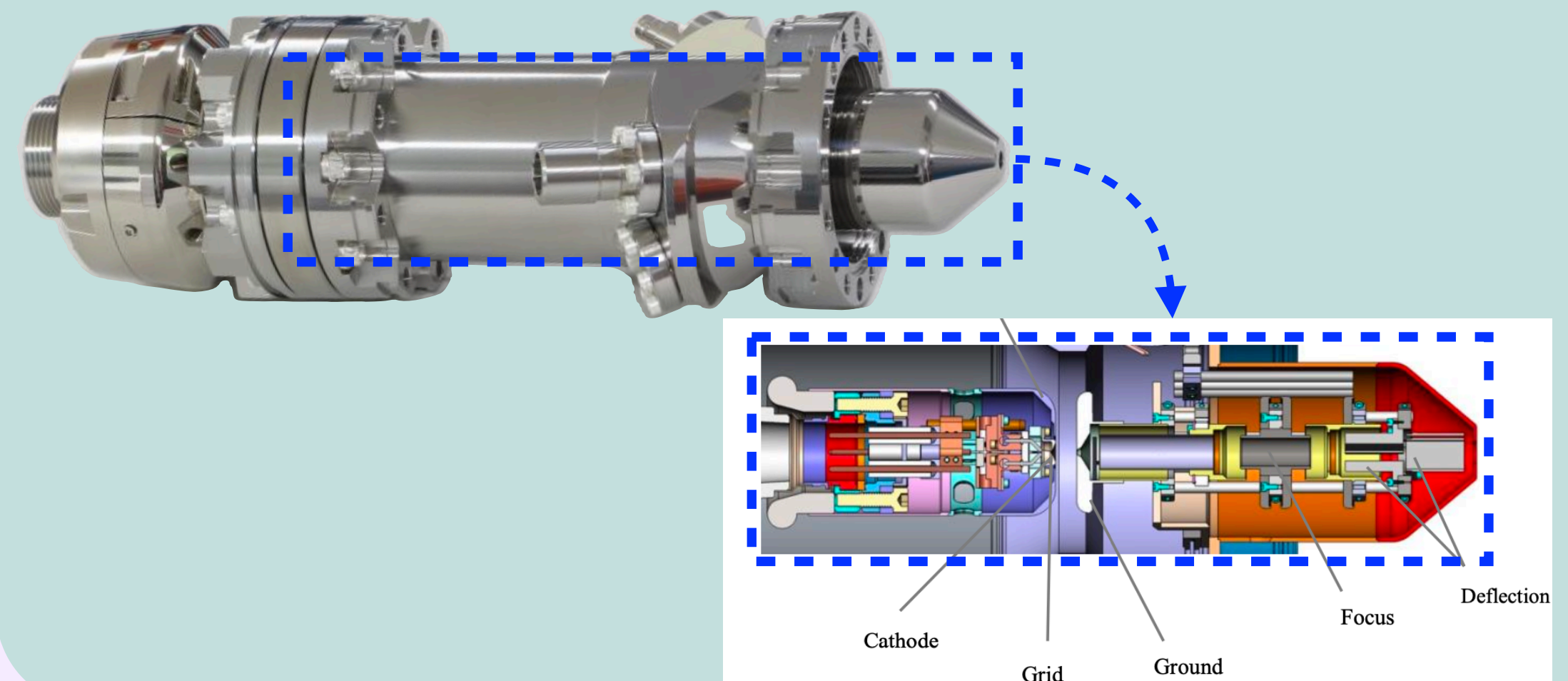
Magnet @ LNGS:

- Halbach cylinder permanent magnet
- 190 mm length, 170 mm external $\varnothing$, 50 mm internal $\varnothing$
- 1 T uniform magnetic field in *limited region inside*



Electron gun:

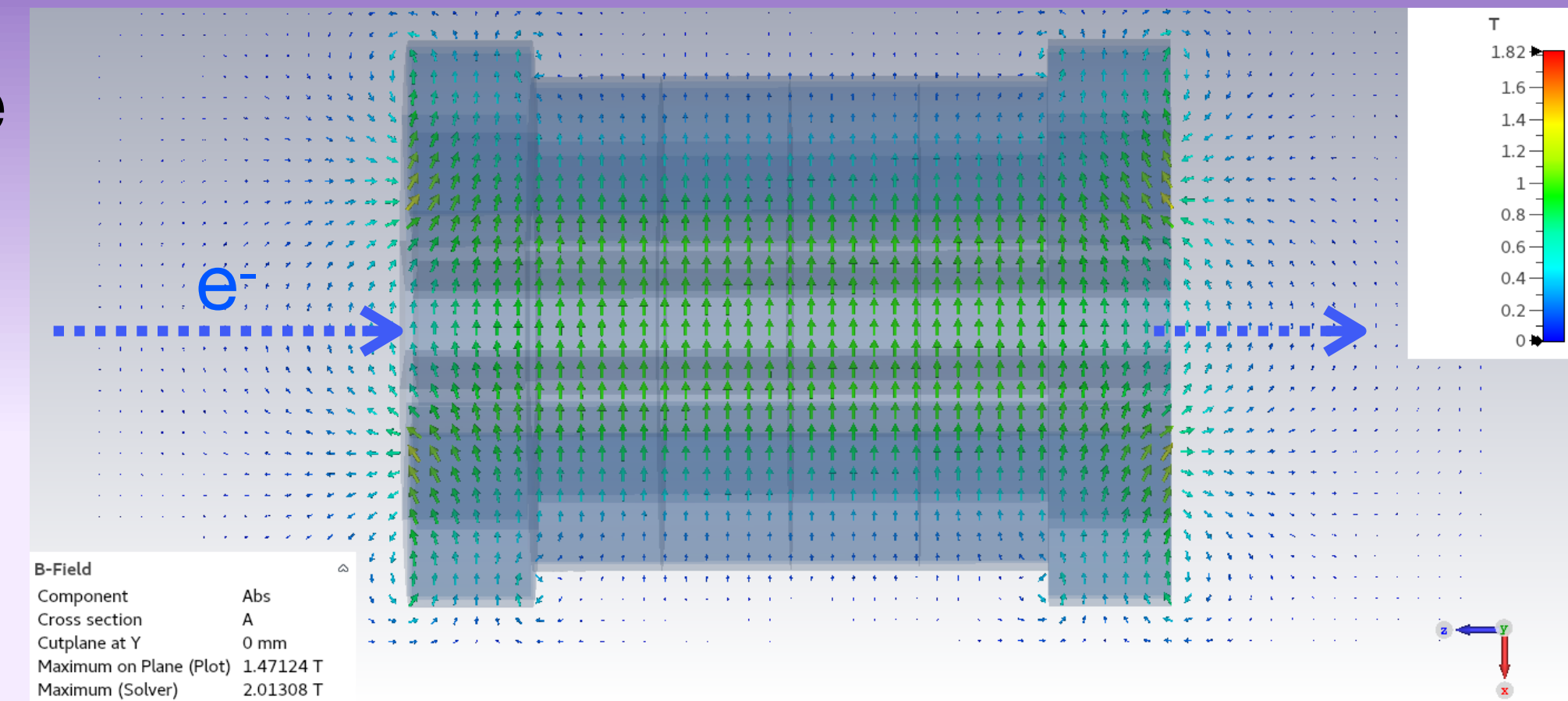
- Kimball Physics EMG-4212A Electron Gun
- 1 to 20 keV electron energy (with guaranteed performances)
- Electrostatic Focus and Deflection
- Tungsten filament source



A Compact version of Accelerator Filter

☀ Idea: e⁻ passage through 1 T magnetic field proof-of-principle

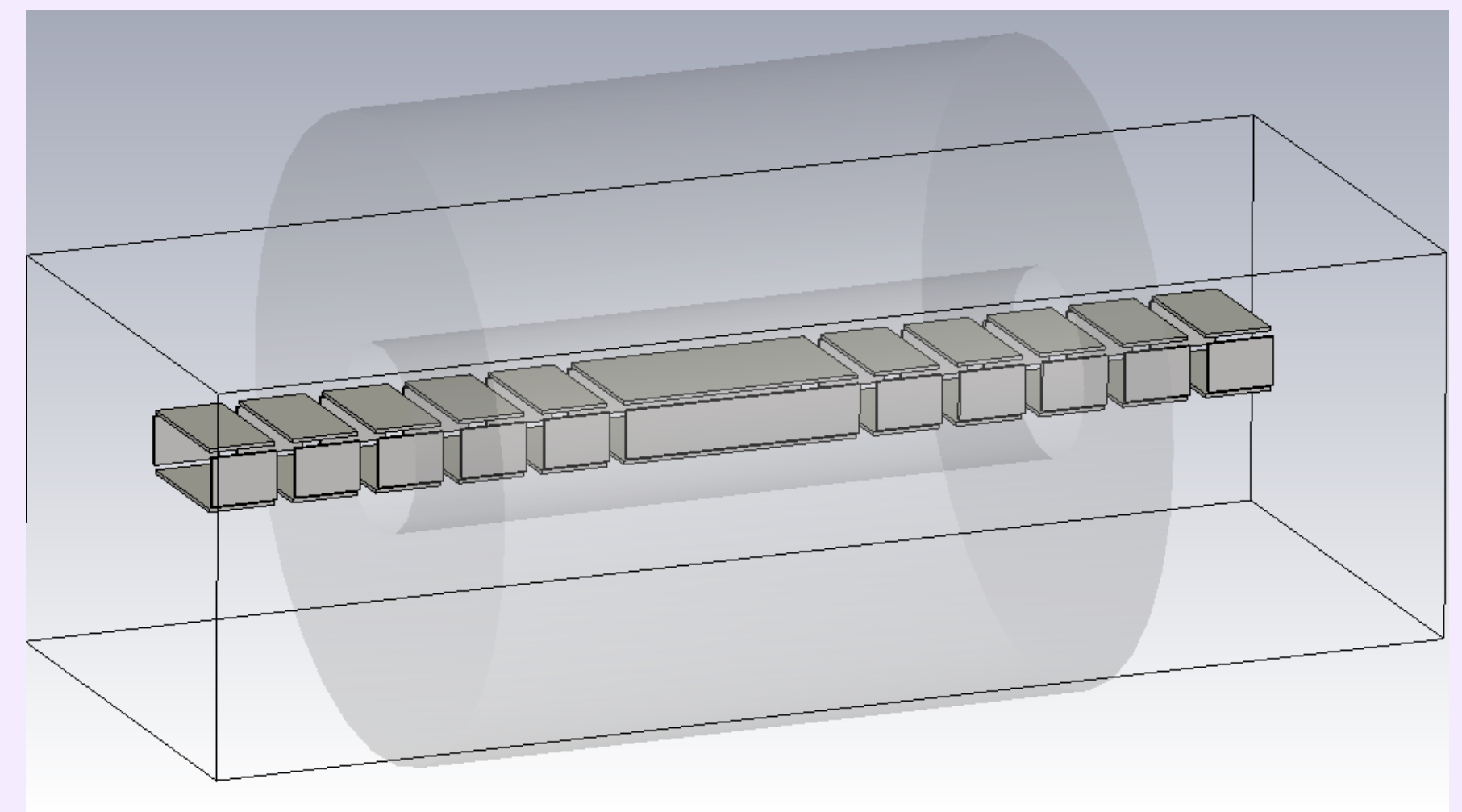
- Become familiar with same drift exploited in filter
- Develop an injection system for
 - ☐ RF R&D setup & ☐ PTOLEMY filter calibration



► How? Very compact *single channel accelerator + decelerator filter*

► Geometry = chain of electrodes' sets
(2 bouncing + 1 top + 1 bottom each)

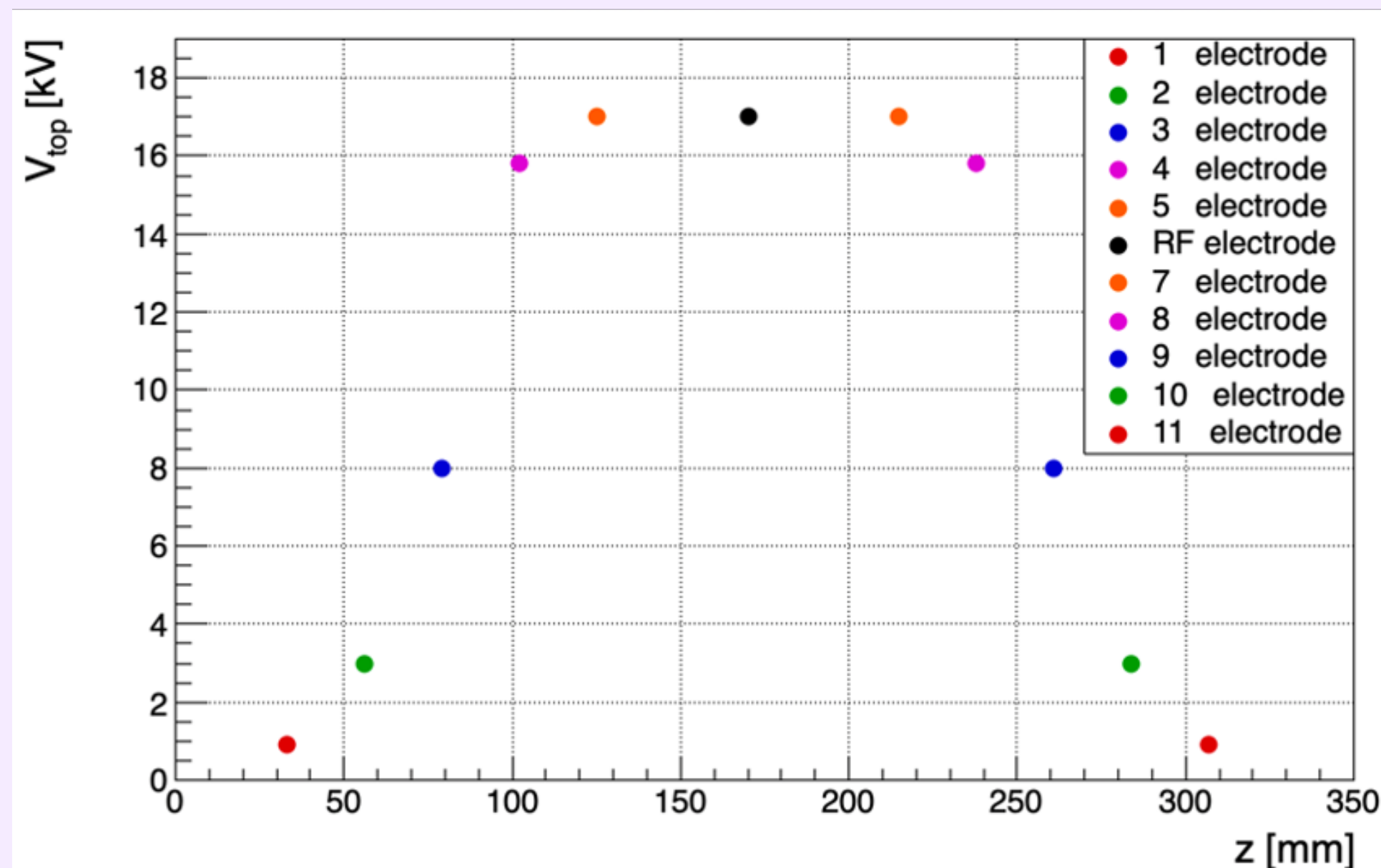
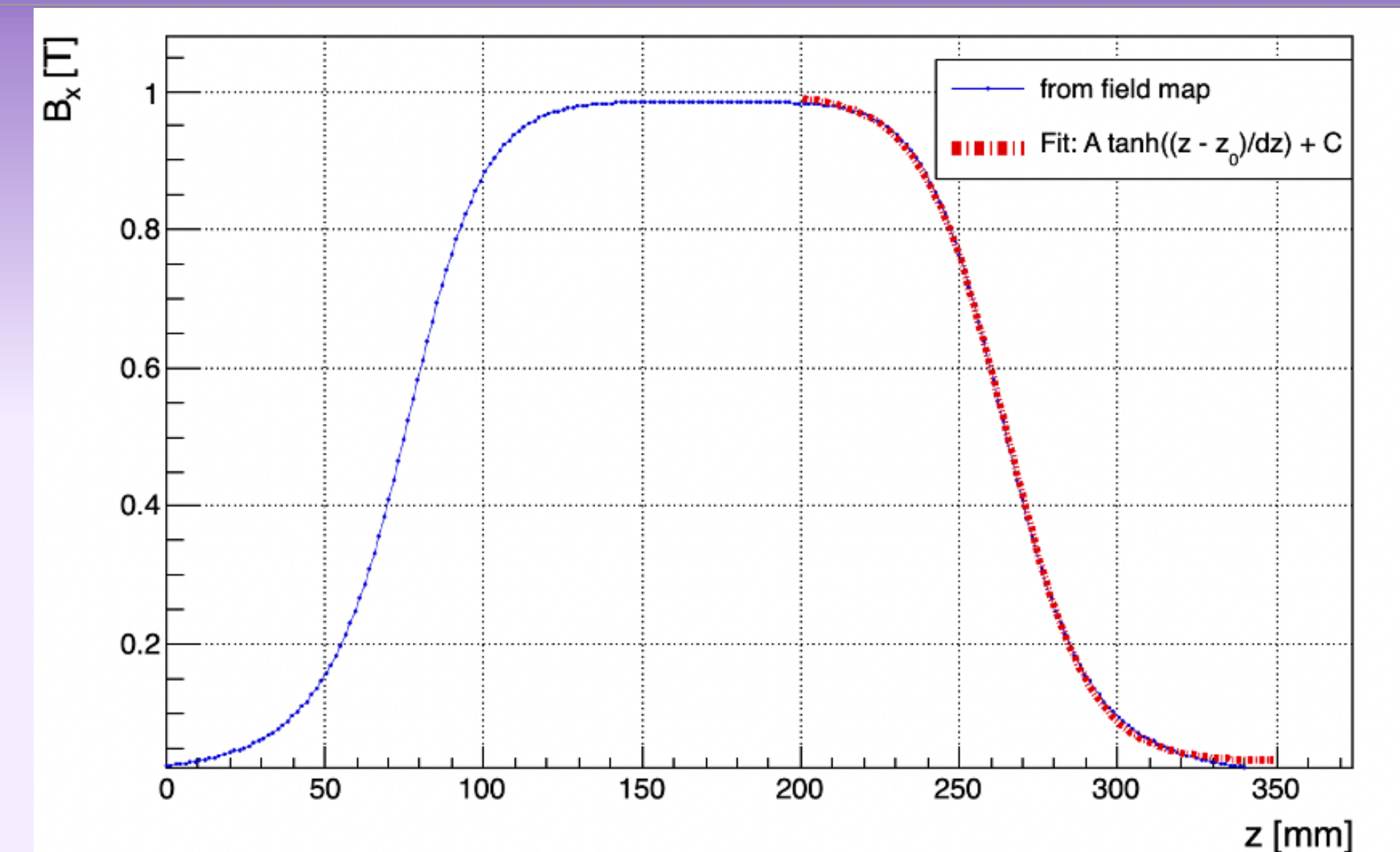
- 5 sets of injection electrodes
- “RF electrodes” (longer set - covering uniform B region)
- 5 sets of ejection electrodes



Sigmoidal Profile for Top Voltages

► Let's have a look to $B_x(x,y=0)$ vs z profile:

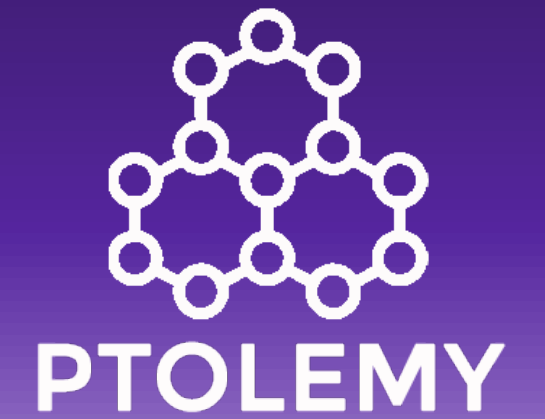
- very steep magnitude increase: from 0 to 1 T in ~15 cm
- Sigmoidal shape, fitted with $\tanh$



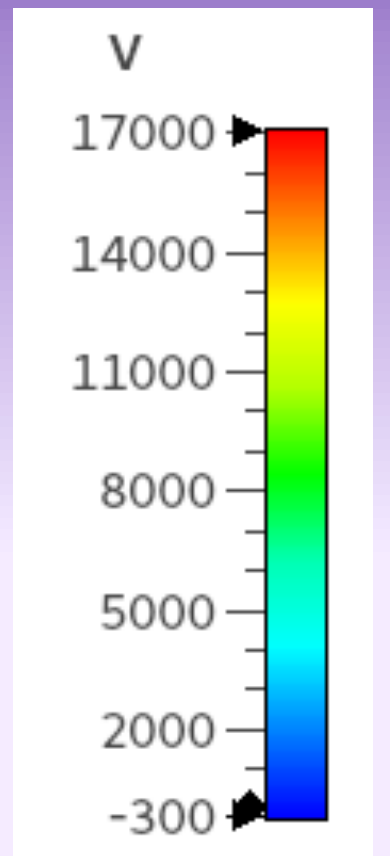
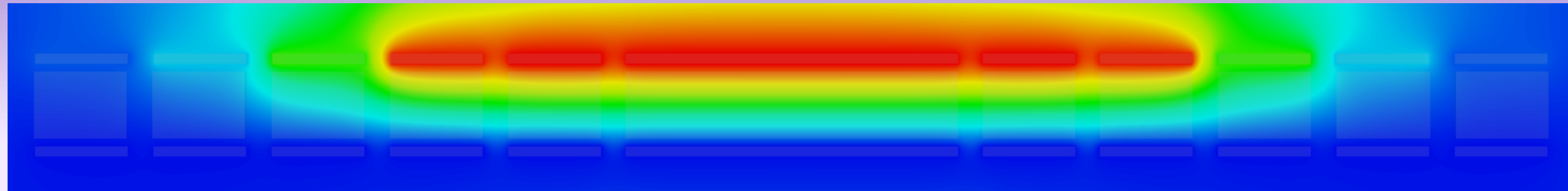
► Voltages applied to top electrodes:

- Injection following a sigmoidal (smoother) profile
- RF voltages matching 5th electrodes' ones
- Ejection with mirrored voltages wrt center (∇B inversion $\rightarrow$ E in $-z$ direction to compensate!)

First Trajectories from CST



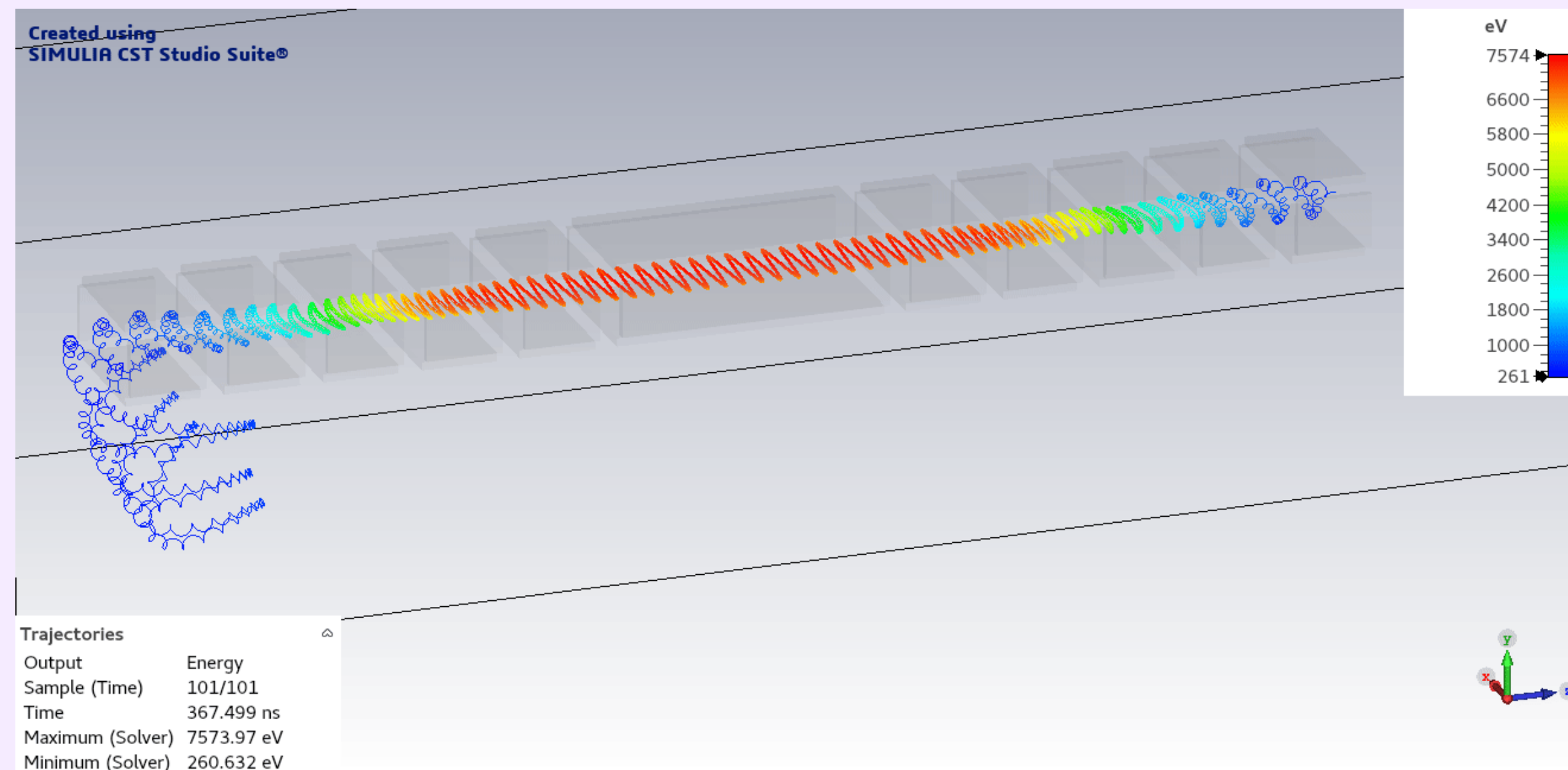
► Potential map



► Particle source:

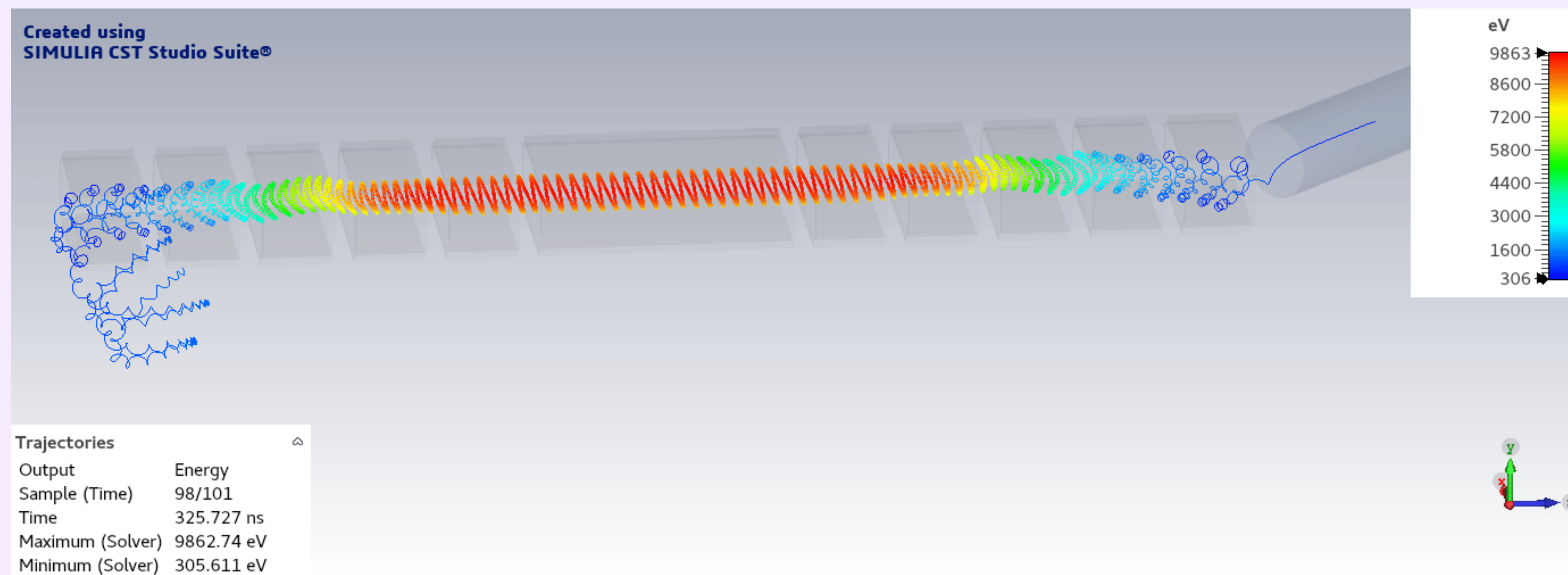
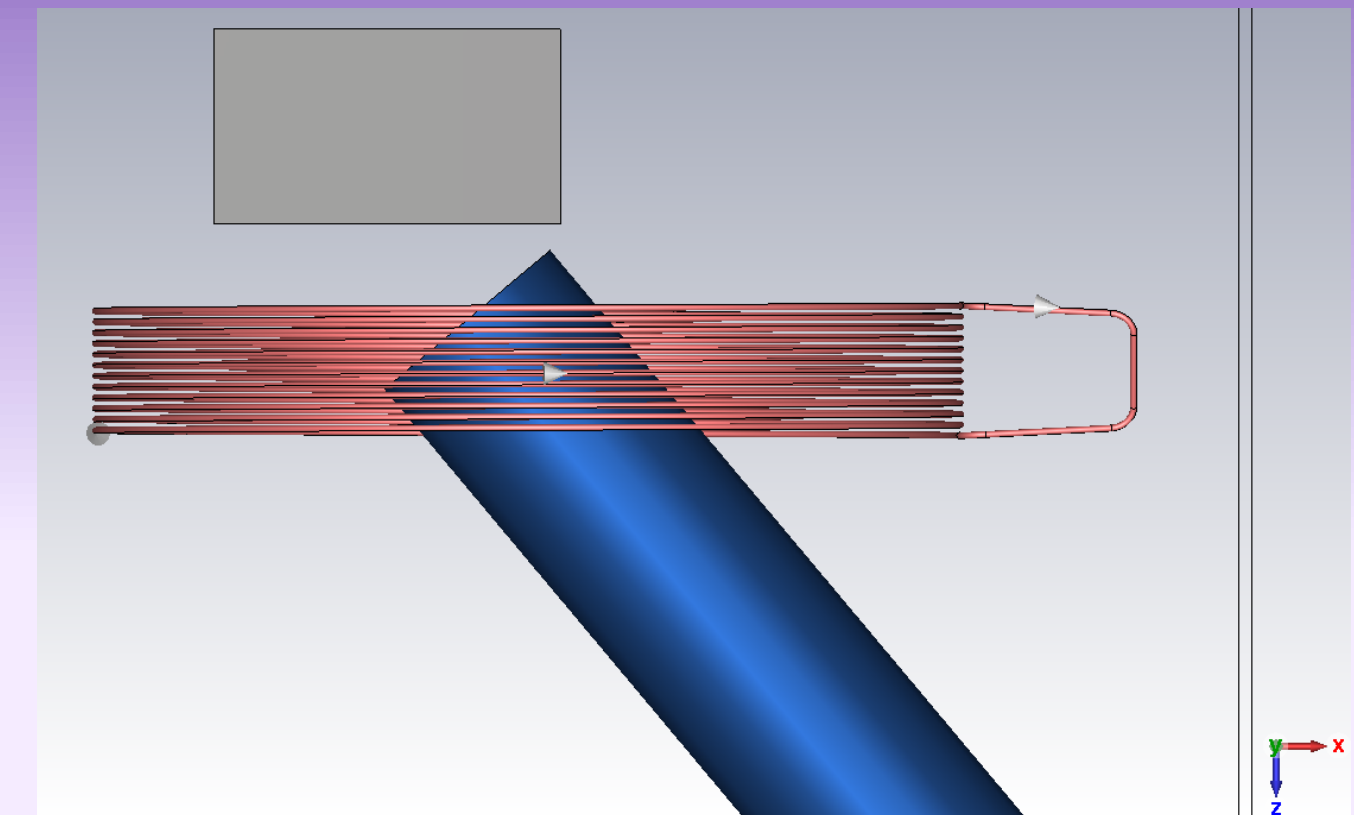
- 700 eV electron
- 6 cm far from magnet ($B_x = 35$ mT)
- Pitch angle of 50°
- Centered in xy plane

► Electric Fields computation & first trajectory on CST Studio Suite

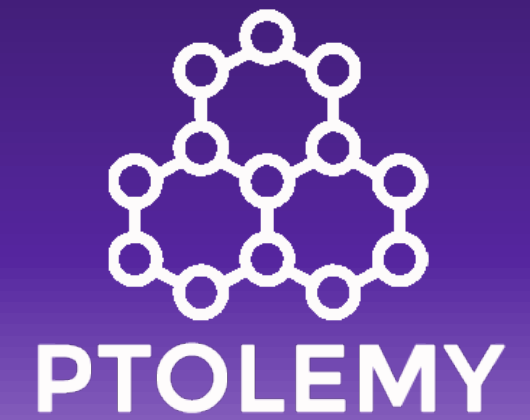


The Real Case: From Electron Source

- ▶ Aim: bring electrons from e-gun to 1st electrode
 - Allowing focusing
 - With convenient entrance angle
- ▶ Possible solution: Focus path screened by mu-metal + coils

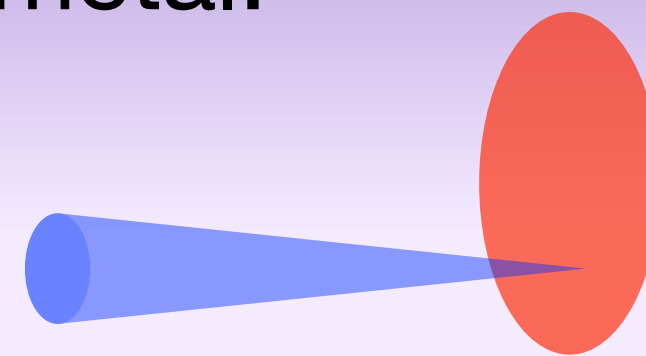


Promising Transport Efficiency



- *Lorentz4* Montecarlo to simulate e-gun focused inside mu-metal:

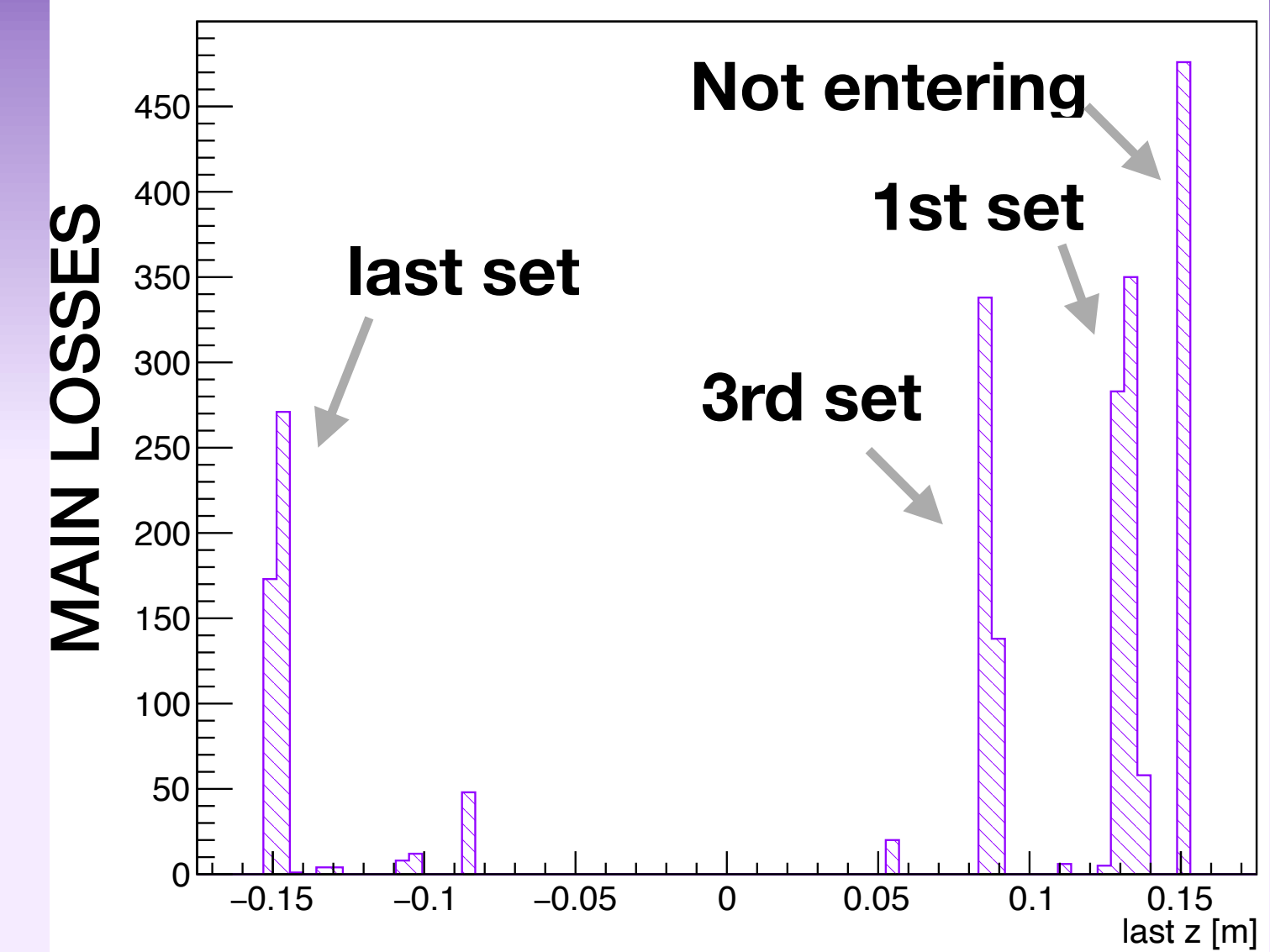
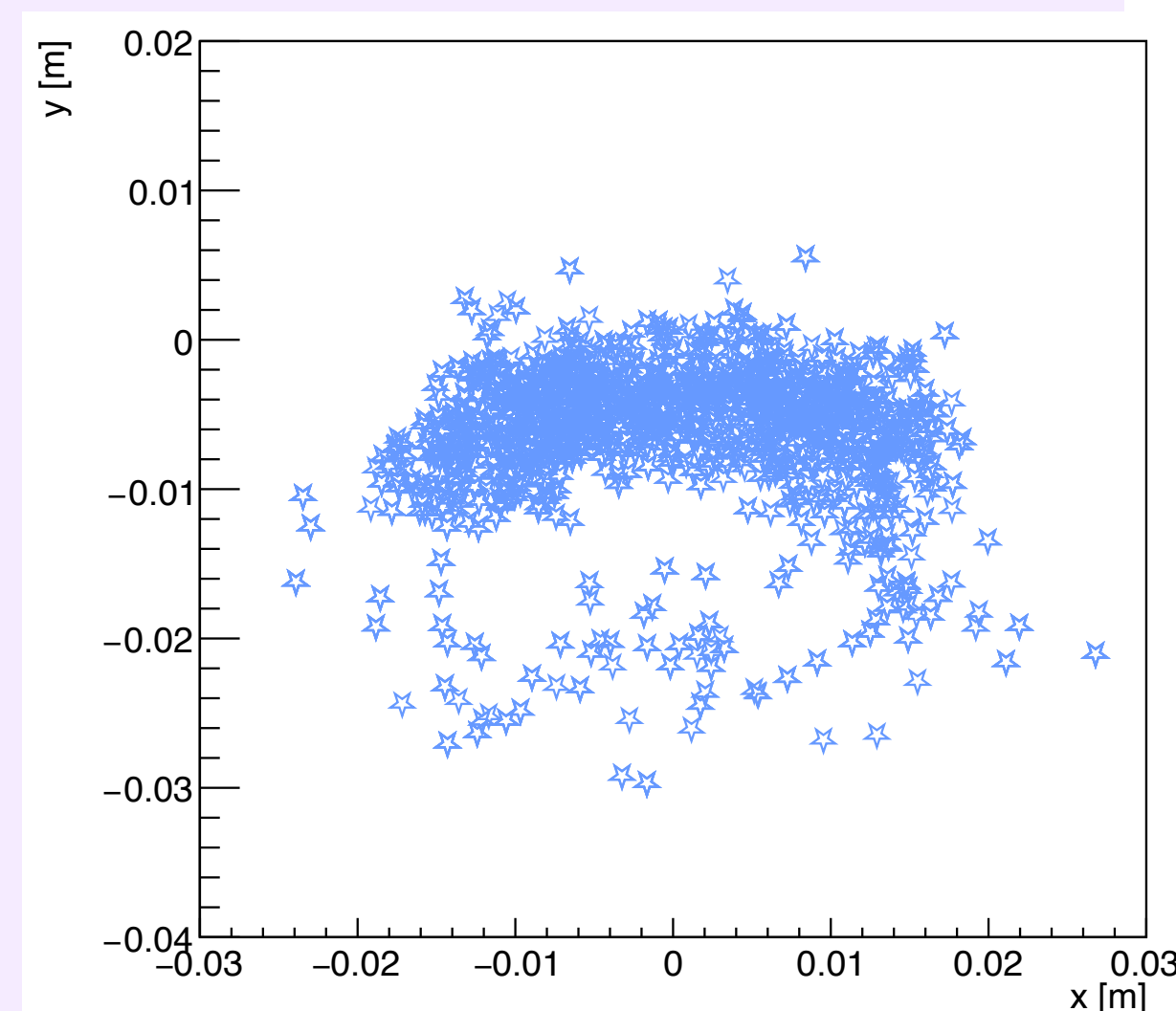
- 2 mm spot size
- 5° angle spread



- Best configuration (till now):

- 3200 over 5000 electrons reaching end of chain!
~60% efficiency
- Main losses on entrance & 1st electrode
- passing through 5 mm distance plane when out → good position for a screen

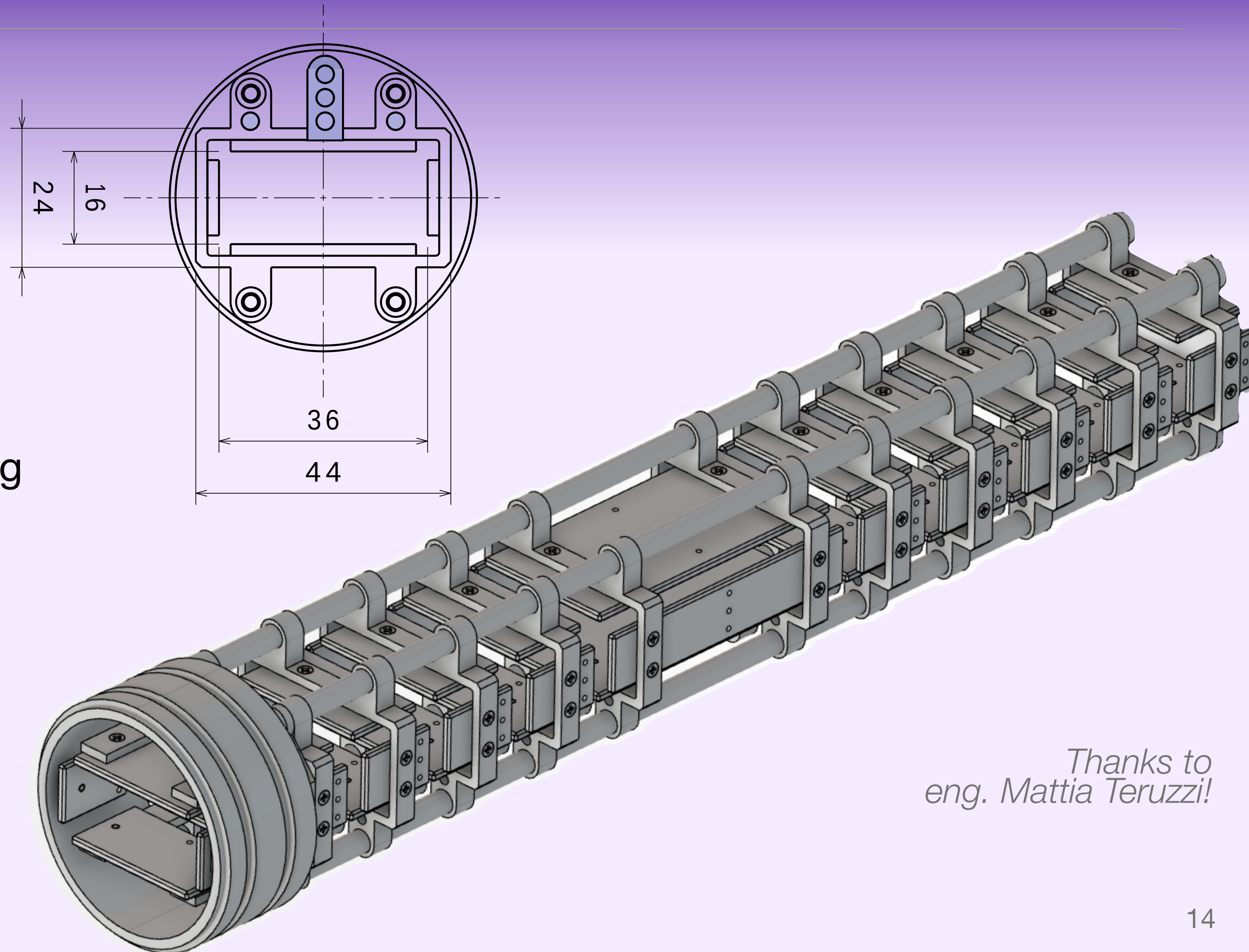
z = 0.15 m



Covering compact region
=
high intensity on screen

From Simulations to an Actual Design

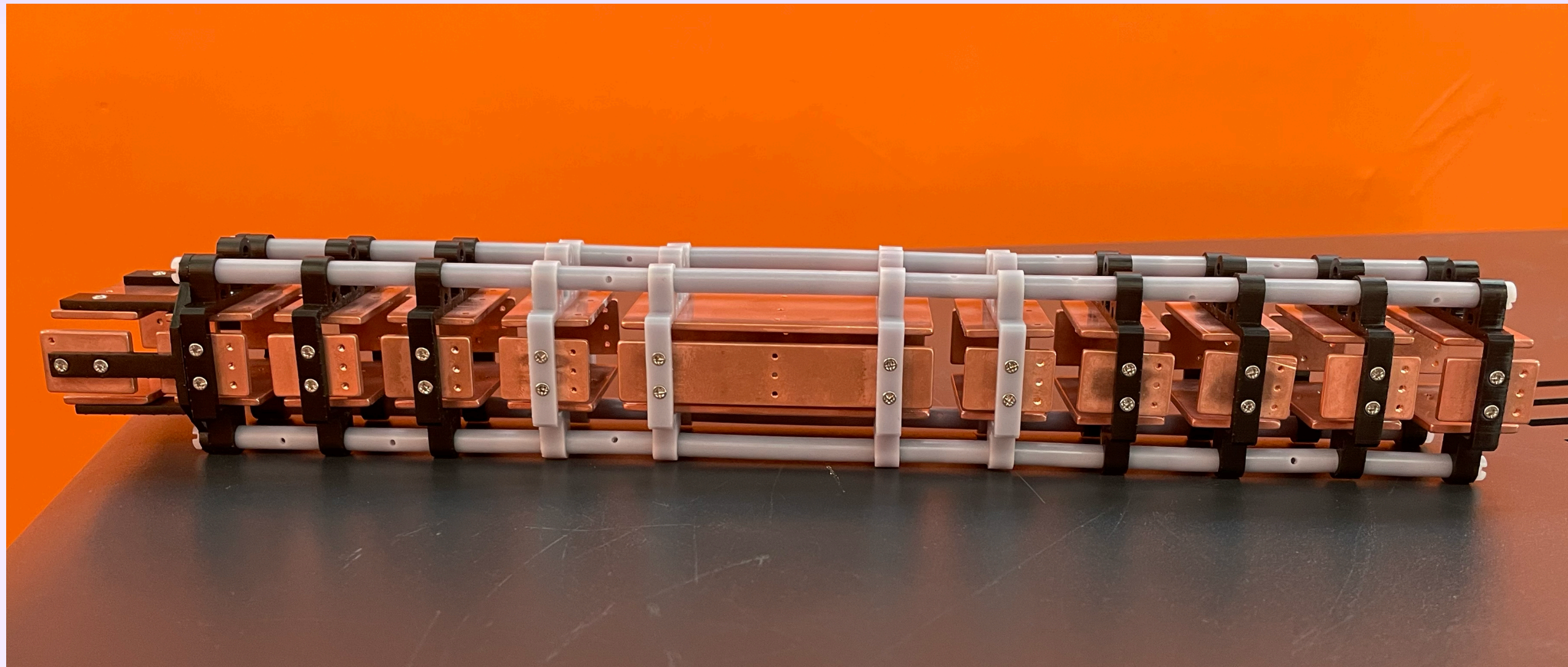
- ▶ Copper electrodes 2 mm thickness
- ▶ Mechanical supports in PEEK
 - lightweight and compact design
 - modular, chain-like assembly
 - through-holes for HV cable routing
 - through-holes to fix electrodes
- ▶ Spacer rods to maintain distances between elements



*Thanks to
eng. Mattia Teruzzi!*

Next Steps

- ▶ Electrodes chain + 3D printed supports just realised by LNGS Mechanical Workshop (thanks!)



▶ ONGOING:

- ▶ MCP, SDD test
- ▶ Setup assembling and voltages connections

▶ Next months:

- ▶ Visualisation on phosphor screen
- ▶ Measurements with MCP & SDD

PTOLEMY

- ## ► Outlook:

Step 3: Electrons detection

