COSMIC NEUTRINO BACKGROUND DETECTION WITH PTOLEMY

EPS-HEP 2023 ★ HAMBURG ★ 20-26 JULY 2023

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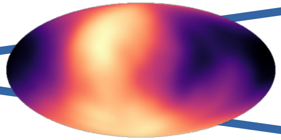
COSMIC NEUTRINO BACKGROUND

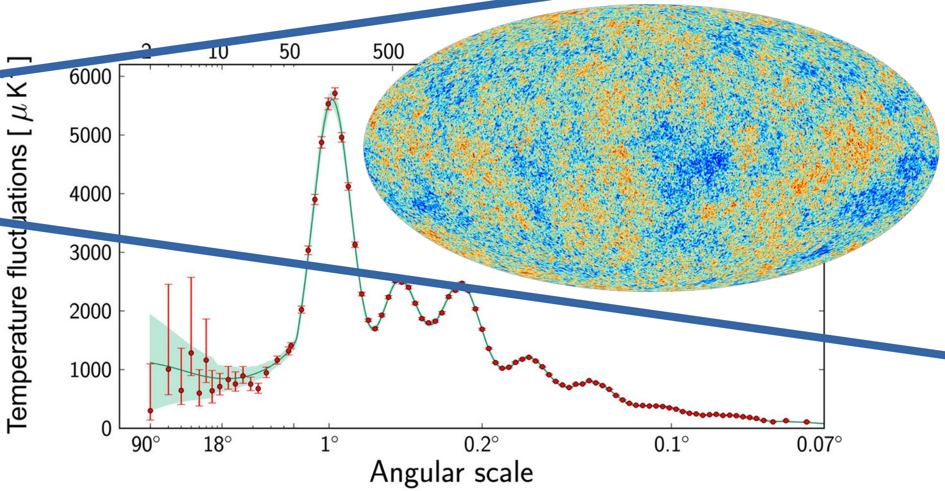
Initial Singularity

COSMIC
NEUTRINO
BACKGROUND

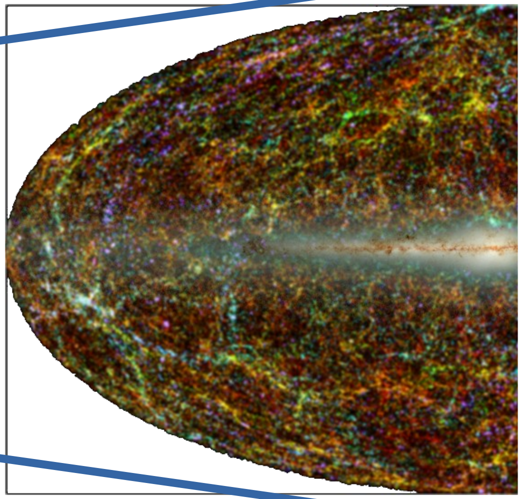


1 second later

COSMIC
MICROWAVE
BACKGROUND

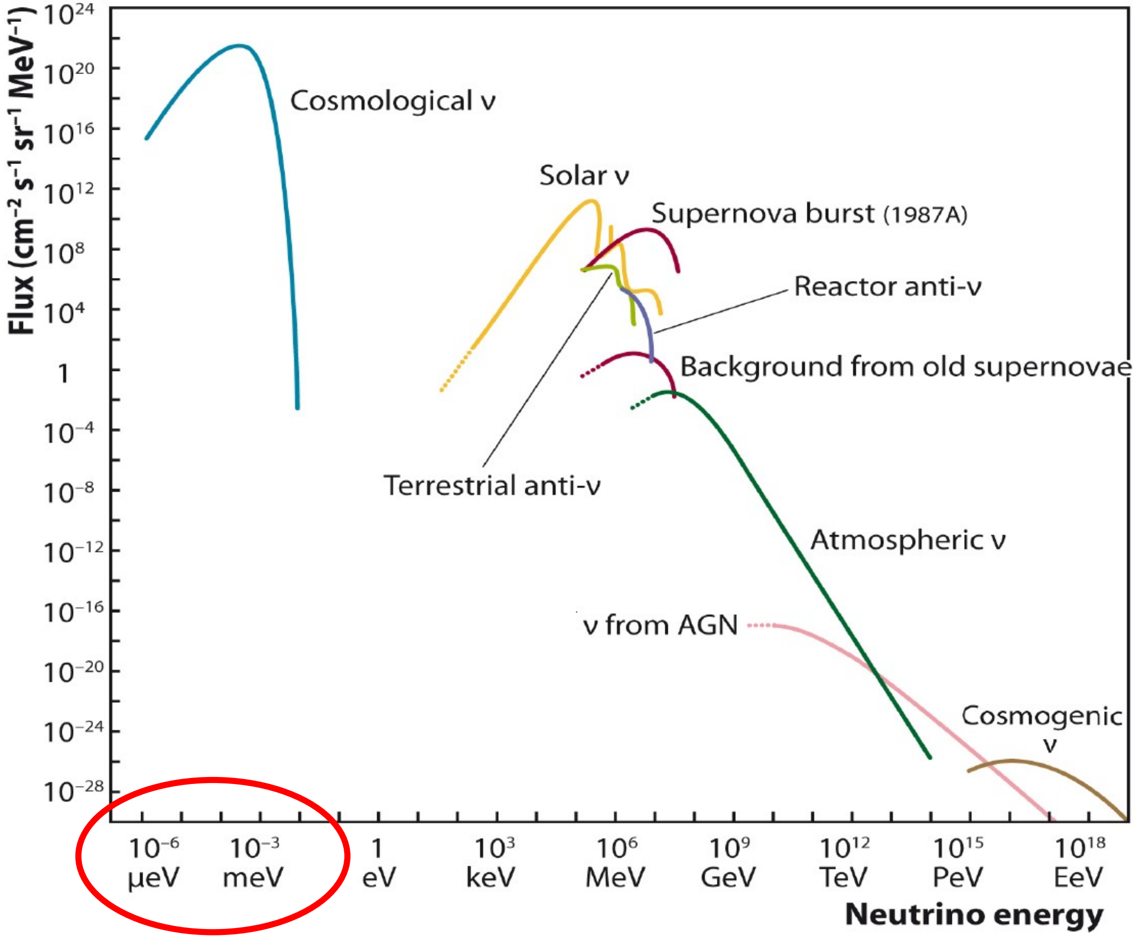


400.000 years
later

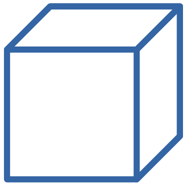


TODAY

THE MOST ABUNDANT ν FLUX



$$T_\nu = \left(\frac{4}{11}\right)^{\frac{1}{3}} T_\gamma \simeq 1.95\,\mathrm{K}$$



~300 cm^{-3}

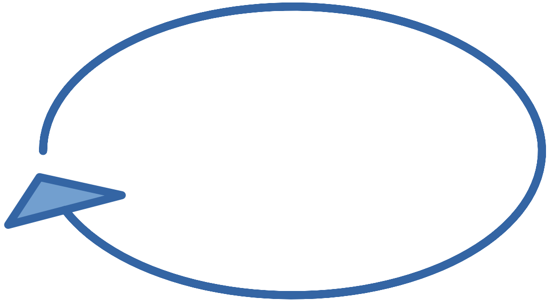
Indirect evidence from Cosmology (CMB, BBN, ...)

No experimental evidence yet!

DIRECT CNB DETECTION (?)

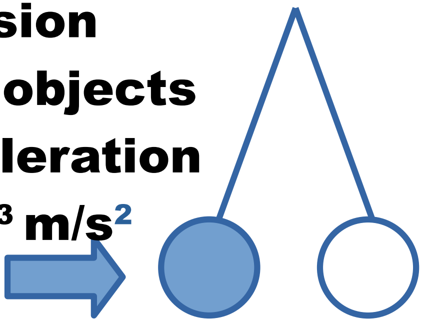
$$\bar{\nu} + p \rightarrow n + e^+$$

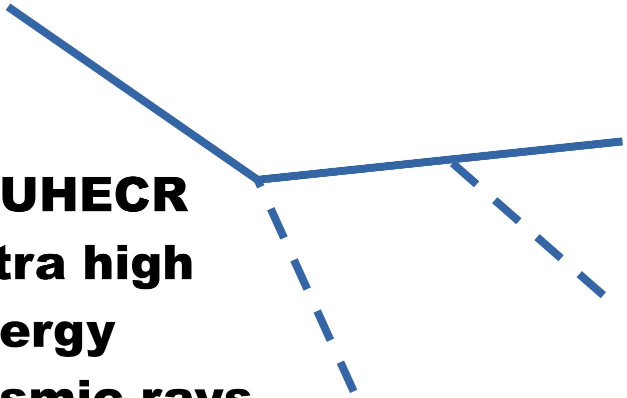
Inverse **beta**



2. ULHC
Ultra high energy accelerator

1. Coherent Collision with objects acceleration ~10^{-23} m/s^2





3. UHECR
Ultra high energy cosmic rays

BUT....

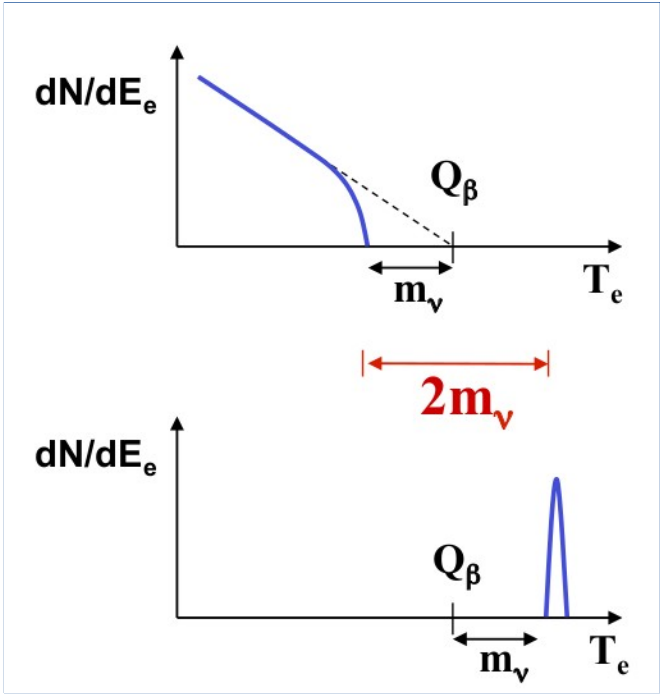
CAPTURE ON β-UNSTABLE NUCLEI

★ **Threshold-less**

$$\nu_e + (A,Z) \rightarrow (A,Z+1) + e^-$$

★ **Monochromatic peak at Q+m**

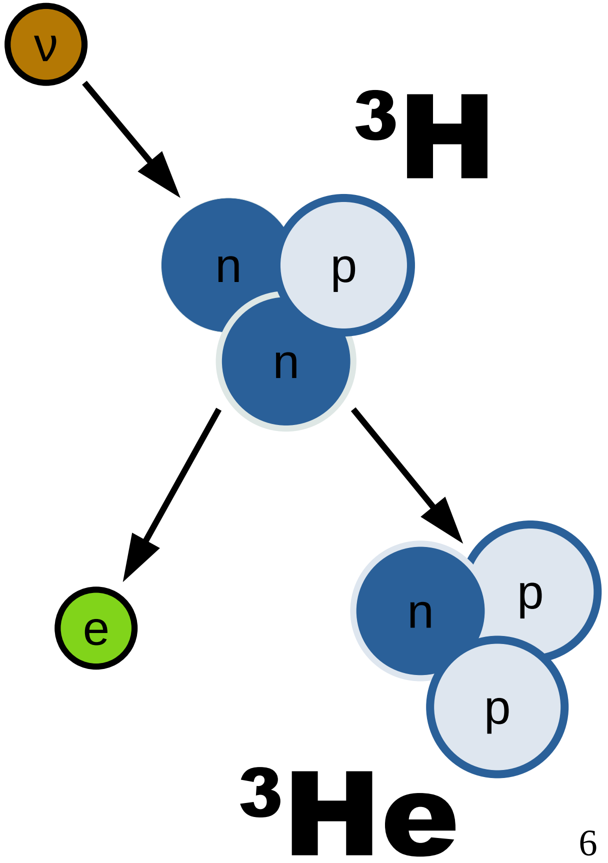
★ **Neutrino mass as by-product**



[A. Cocco et al, 2007]

TRITIUM: THE BEST CANDIDATE

- ★ **Low Q** = 18.6 keV
- ★ **Reasonable halflife** $T_{1/2}$=12.3 y
  (high rate but not that fast)
- ★ **Simple nuclear structure**,
  no nuclear structure corrections
- ★ Relatively **high cross section**
  (constant $\sigma \sim 10^{-44}\ cm^2$)



REQUIREMENTS FOR CNB DETECTION

★ **Large target**, 100 g
8 event/y (Majorana), 4 event/y (Dirac)

★ **Very low** target induced **smearing**

★ **High rate** (~10^{14} Bq) handling

★ **Small filter dimension** (~1m size)

★ **High resolution** electron detection (~50 meV)

THE PTOLEMY PROJECT

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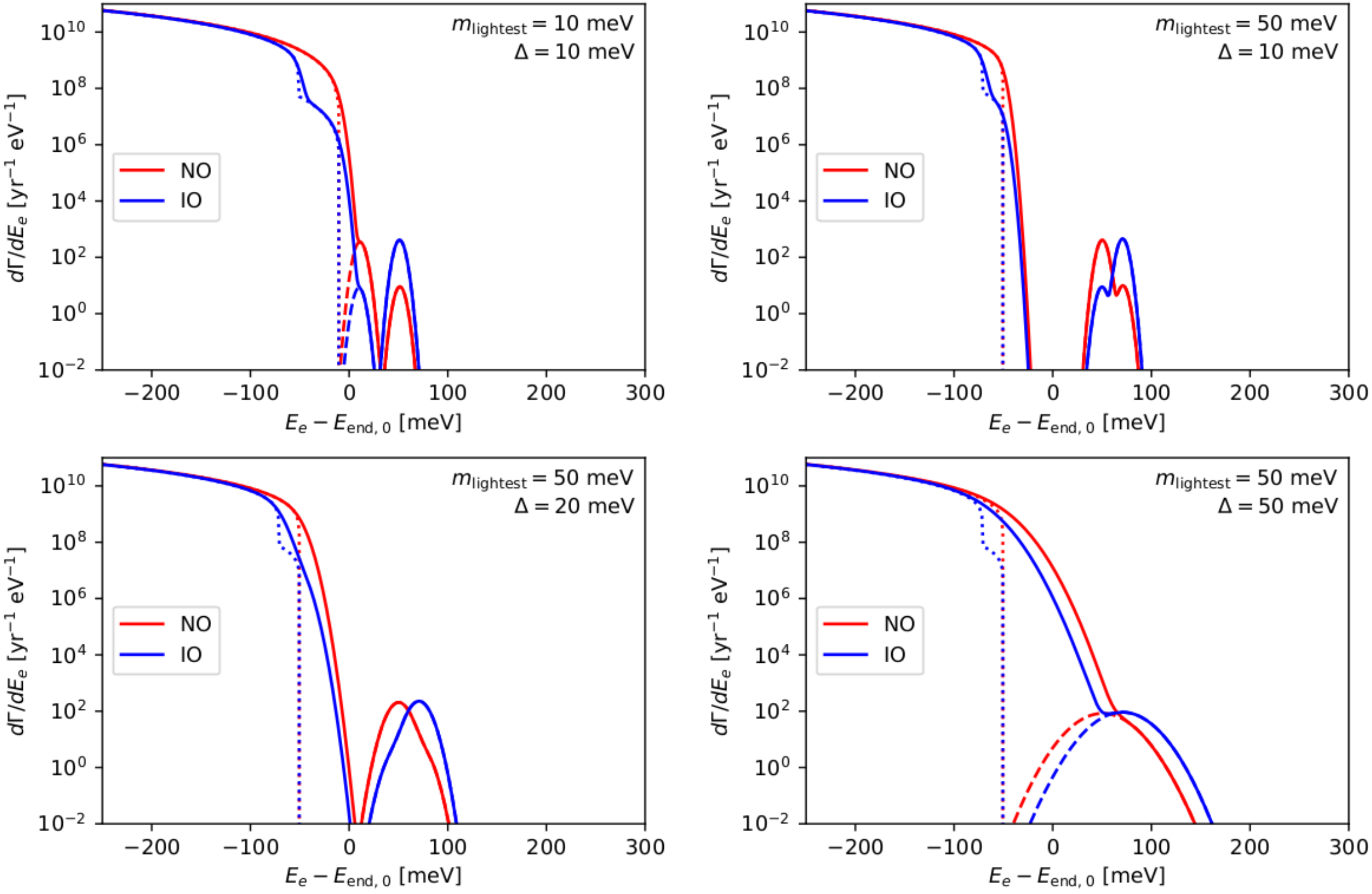
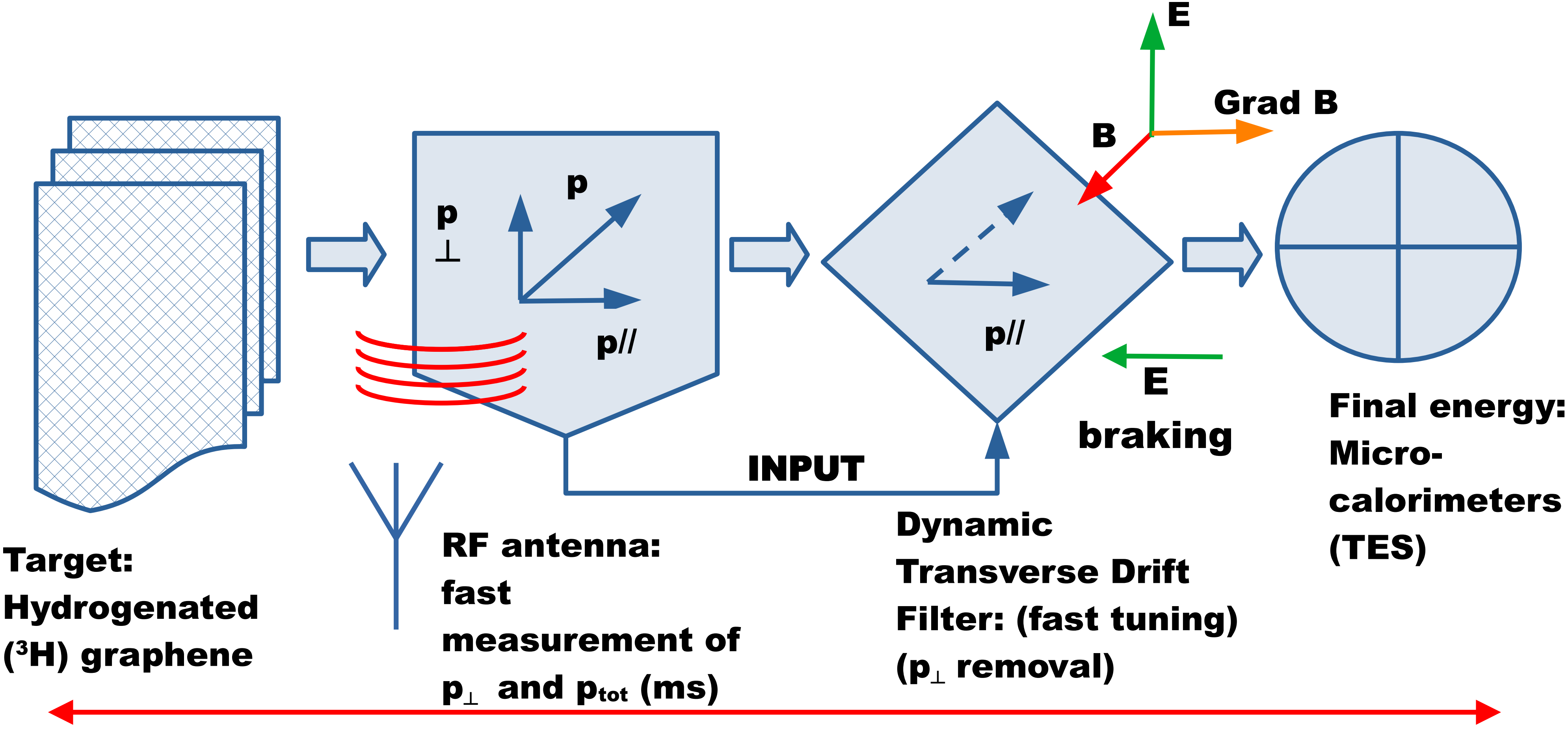
[M.G. Betti et al., 2019]

PTOLEMY SENSITIVITY



[M.G. Betti et al., 2019]

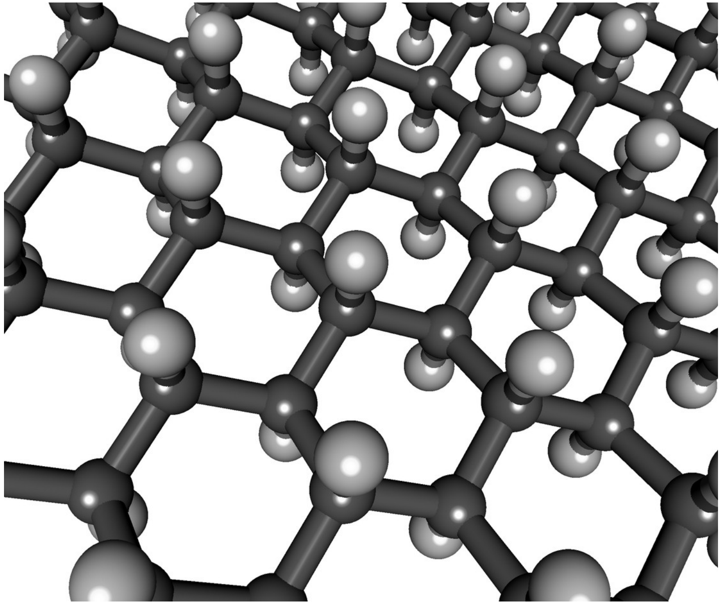
THE DETECTOR CONCEPT



$$E_{tot} = q(V_{TES} - V_{target}) + E_{RFcorr} + E_{TES}$$

HYDROGENATE (^{3}H) GRAPHENE

- ★ Single atomic layer 2D (sp^3)
- ★ Know binding energy (~3 eV)
- ★ Compact: Loading (100%): 0.2 mg/m^2 (2 Ci/m^2)



Loading record:
90 % with hydrogen

@ Univ. "La Sapienza"
Coll. Savannah river Lab (^{3}H)

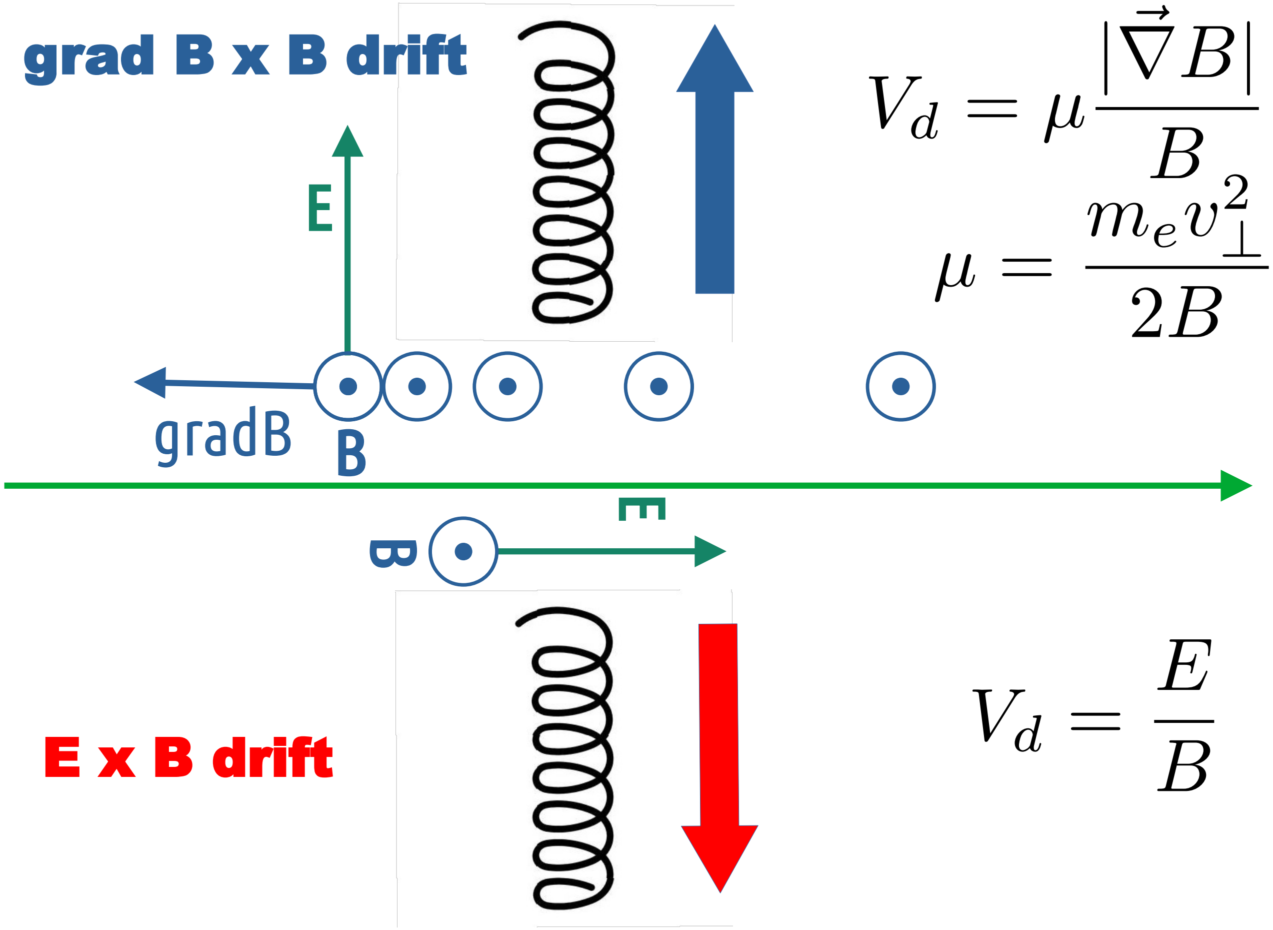
[M.G. Betti et al. 2022]

90% transparency for Low energy electrons

(@ Univ. Roma Tre)

THE FILTER CONCEPT

grad B x B drift



$$V_d = \mu \frac{|\vec{\nabla} B|}{B}$$

$$\mu = \frac{m_e v_\perp^2}{2B}$$

E x B drift

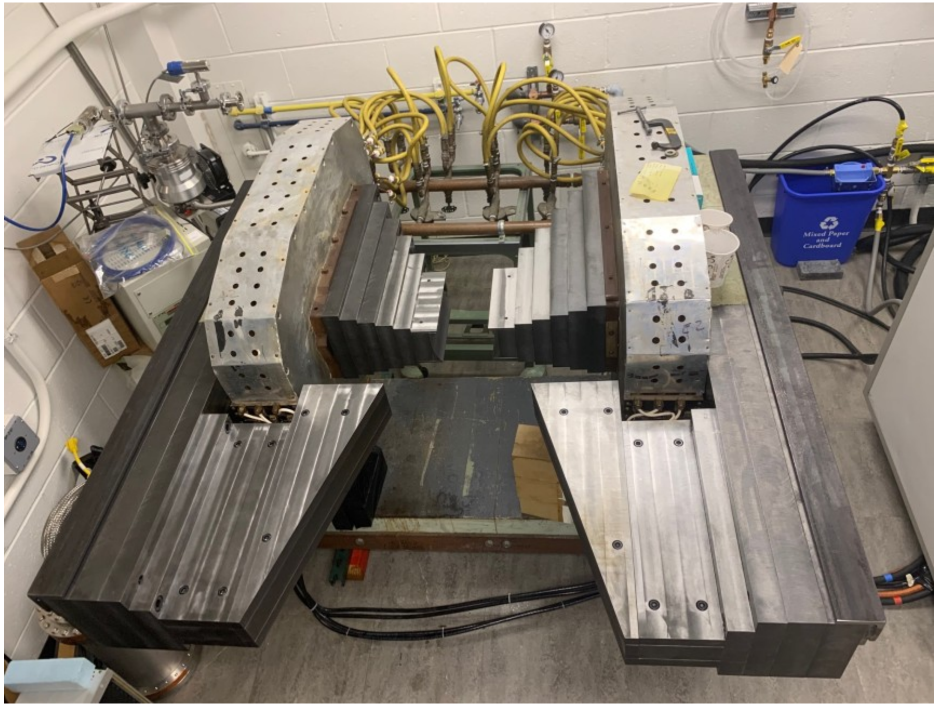
$$V_d = \frac{E}{B}$$

Removal of the Transverse component

$$\frac{dK_\perp}{dt} = e\vec{E} \cdot \vec{V}_d$$

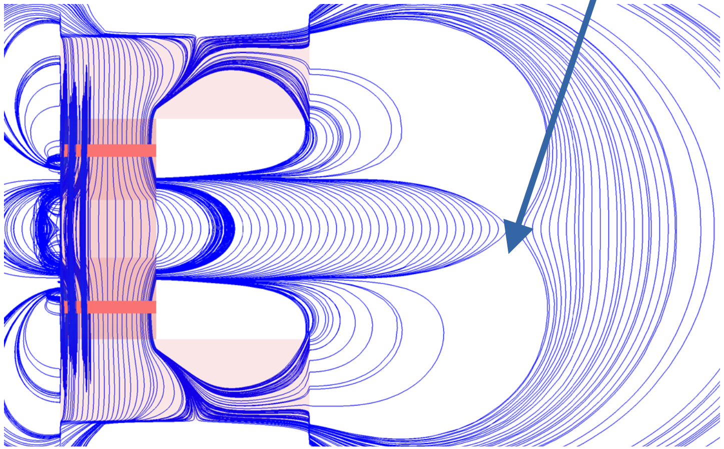
[M. Betti et al., 2019]

THE FILTER PROTOTYPE



Preliminary test of the Filter perfomances at Princeton Univ.

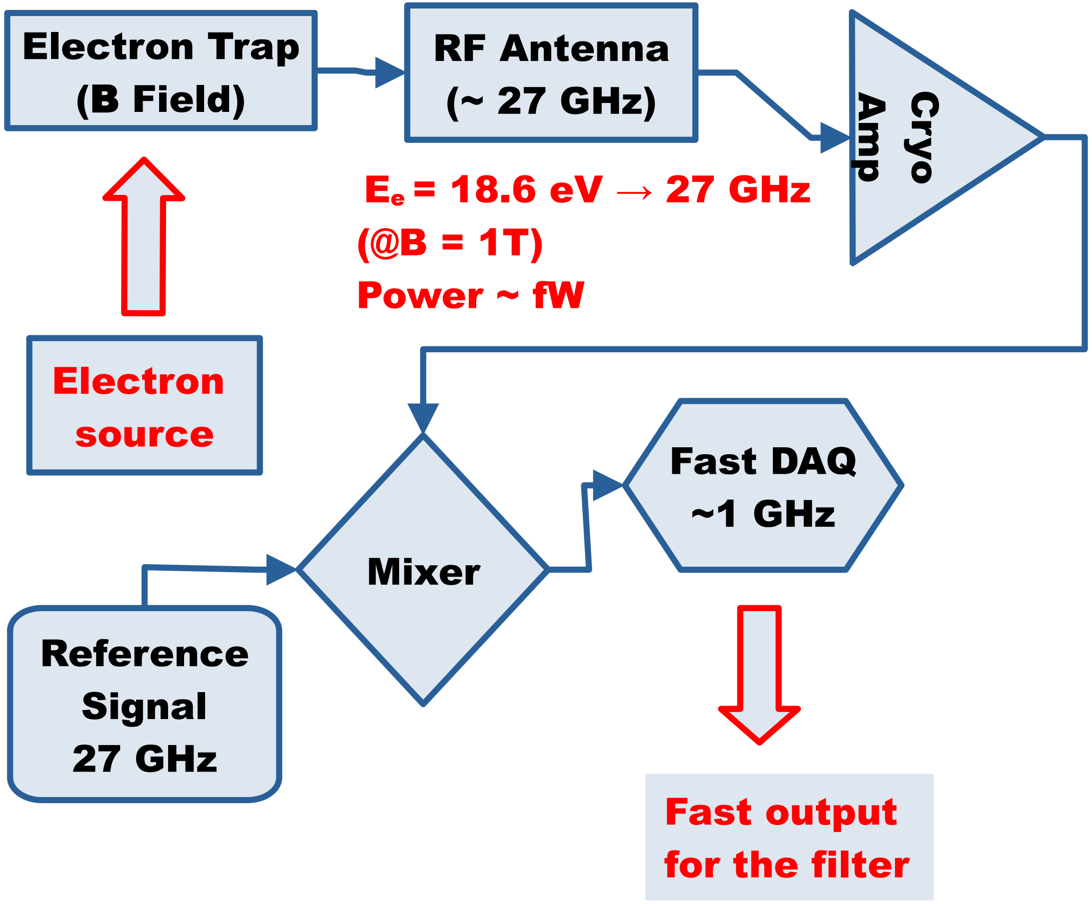
Saddle Point

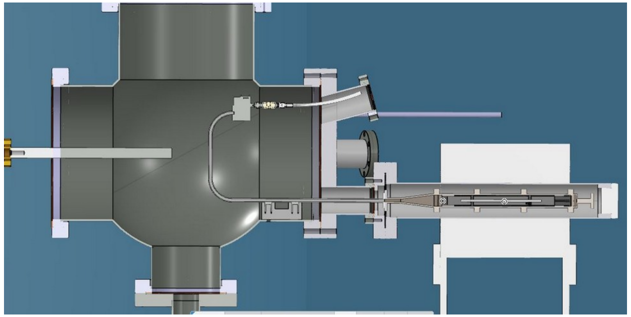


NEW: 1 T conduction-cooled superconducting (ANSALDO Co.) and installation at LNGS

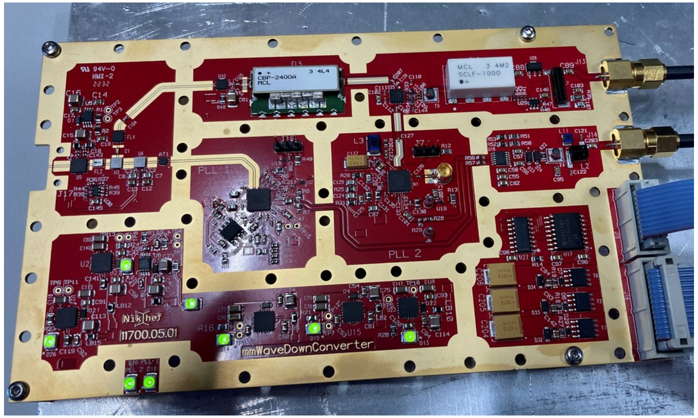
HV precision reference @LNGS

RADIOFREQUENCY ANTENNA



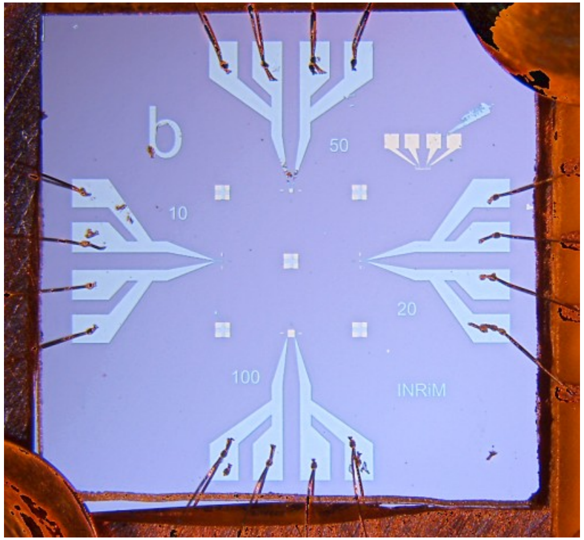


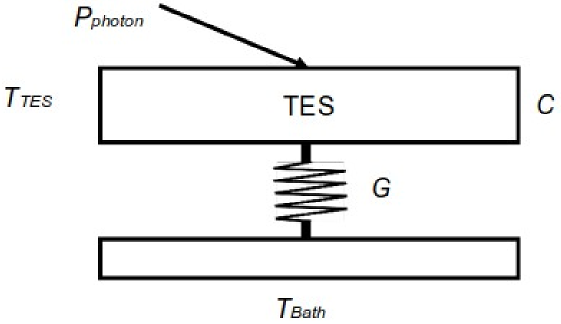
Test at LNGS: Rb-83m source + static B



Electronics and DAQ @ NIKHEF

MICROCALORIMETERS (TES)





★ **Large area (50 x 50 μm²) (pixel)**

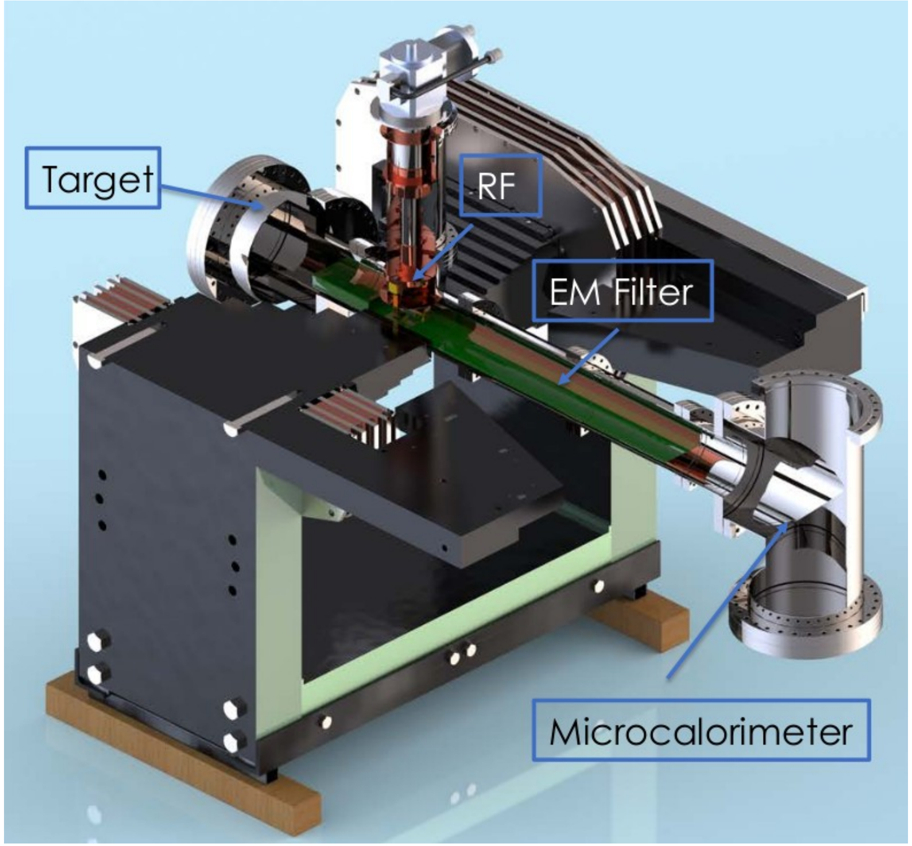
★ **Very small thickness for 10 eV dynamic range**

★ **Resolution better than 50 meV**

ΔE = 0.16 eV already reached for 1540nm IR

@INRIM ISTITUTE

TOWARDS THE DEMONSTRATOR



@LNGS, start at end of 2023

GOAL: proof-of-principle

★**Full electron transport, from the source (target) to the microcalorimeter**

★**Filter efficiency study (electrons near the endpoint)**

★**Detector optimization**

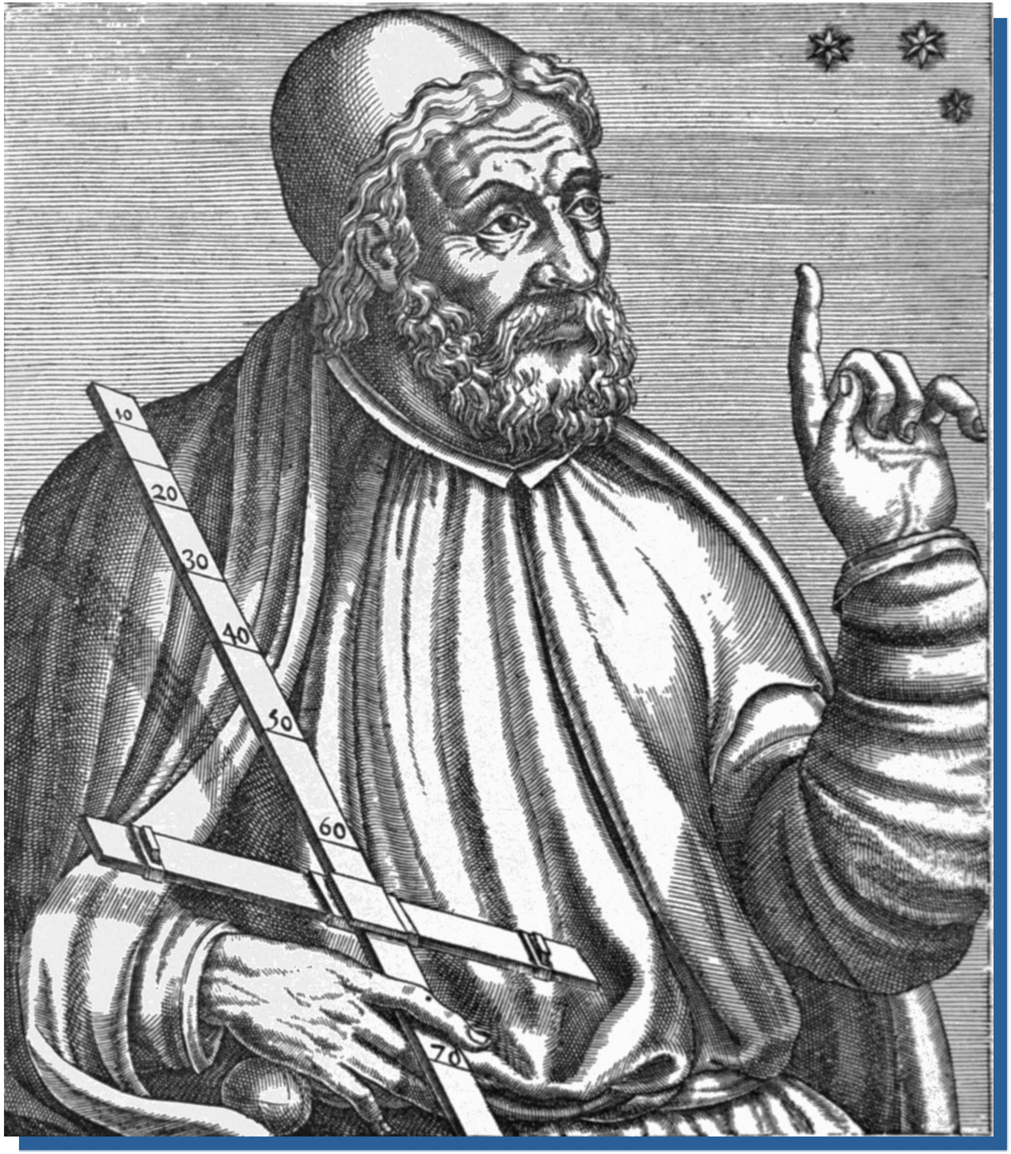
PTOLEMY ROAD MAP

End of 2023: **Demonstrator Phase-I**
Start of installation @LNGS

2024: **Tecnical Design Report**

> 2025: **Demonstrator Phase-II Ptolemy: 1 m^2 graphene Demonstrator**
~0.2 mg source, neutrino mass

> 2030: **Full scale experiment**



Thank you very much!