A concept of a heavy time projection chamber for gamma-ray astronomy in the 100 MeV – 1 TeV energy range

Egor Podlesnyi
Lomonosov Moscow State University, Faculty of Physics;
Skobeltsyn Institute of Nuclear Physics
Dzhatdoev Timur
Skobeltsyn Institute of Nuclear Physics

The presentation is based on our paper

Timur Dzhatdoev, Egor Podlesnyi (2019). *Massive Argon Space Telescope (MAST): a concept of heavy time projection chamber for gamma-ray astronomy in the 100 MeV - 1 TeV energy range*, Astropart. Phys., 112, 1–7

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The earliest papers on the topic:

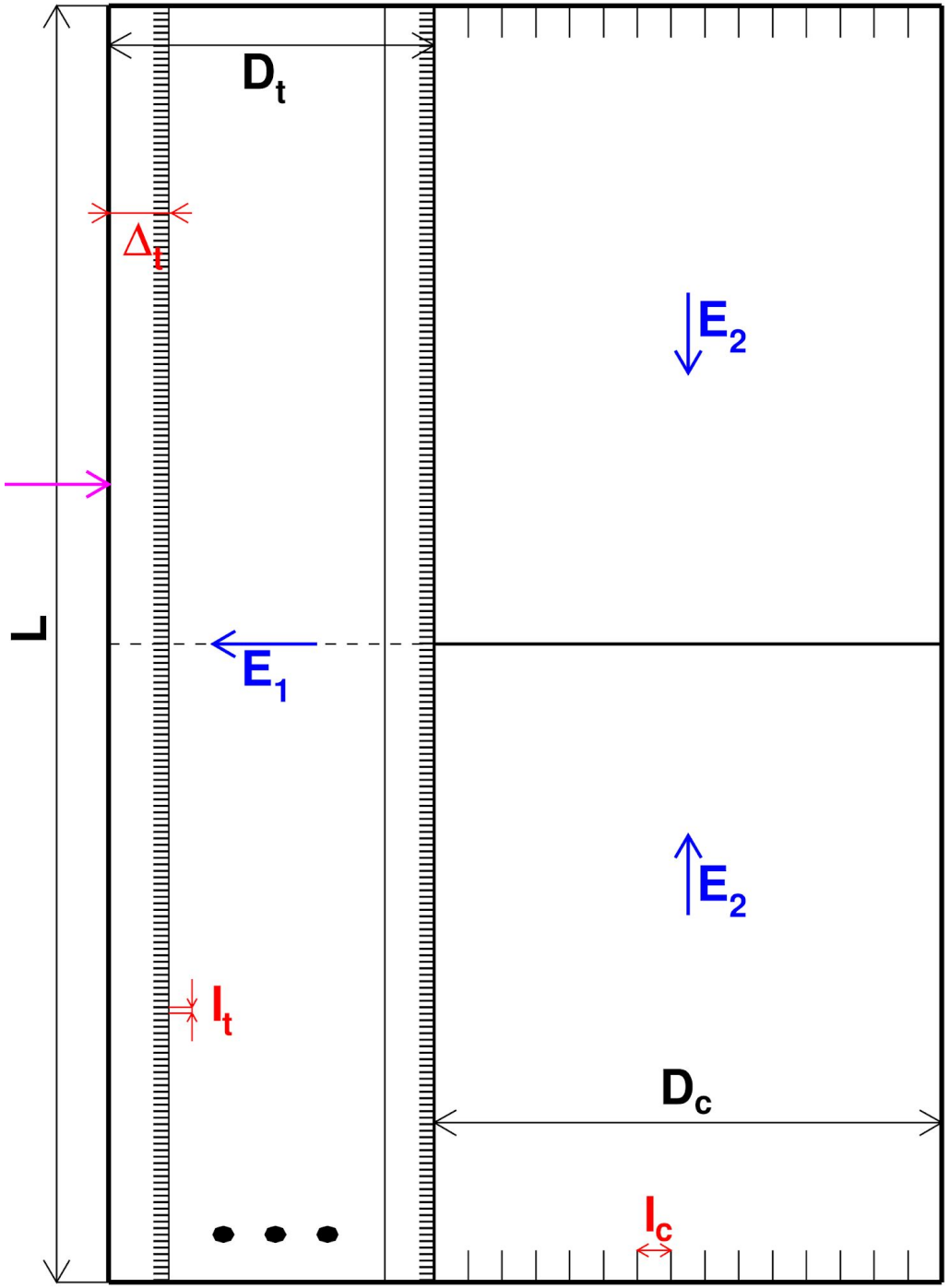
- Two-phase time projection chamber (TPC): Dolgoshein et al. (1970)
- General discussion of the TPC concept: Nygren (1974)
- Liquid Argon TPC: Rubbia (1977)

The state of the art: ICARUS T 600 (600 t of LAr): Rubbia et al. (2011)

Projects of argon gamma-ray space telescopes

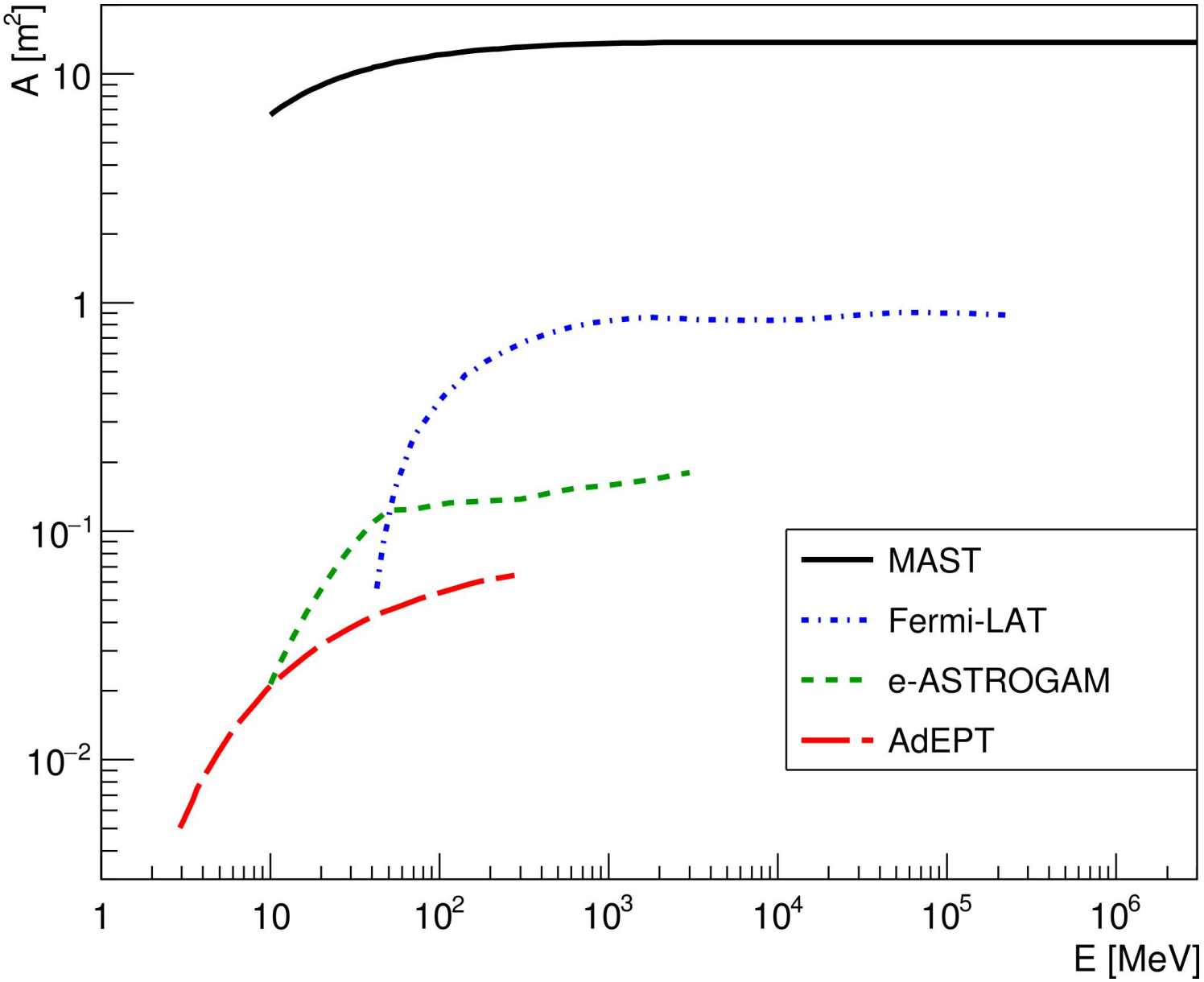
1. AdEPT (Advanced Energetic Pair Telescope) - polarimetry in the energy range 5-200 MeV (gas) (S. D. Hunter et al., Astropart. Phys. 59 (2014) 18–28)
2. HARPO (Hermetic ARgon Polarimeter) - polarimetry in the energy range 3-100 MeV (gas) (P. Gros et al., Astropart. Phys. 97 (2018) 10–18)
3. Theoretical investigation of the application of noble gases for gamma-ray astronomy was carried out by D. Bernard, NIM A 701 (2013) 225–230

Unlike these projects the MAST instrument is aimed at the high energy range (100 MeV - 1 TeV) although it does not provide measurements of polarisation.

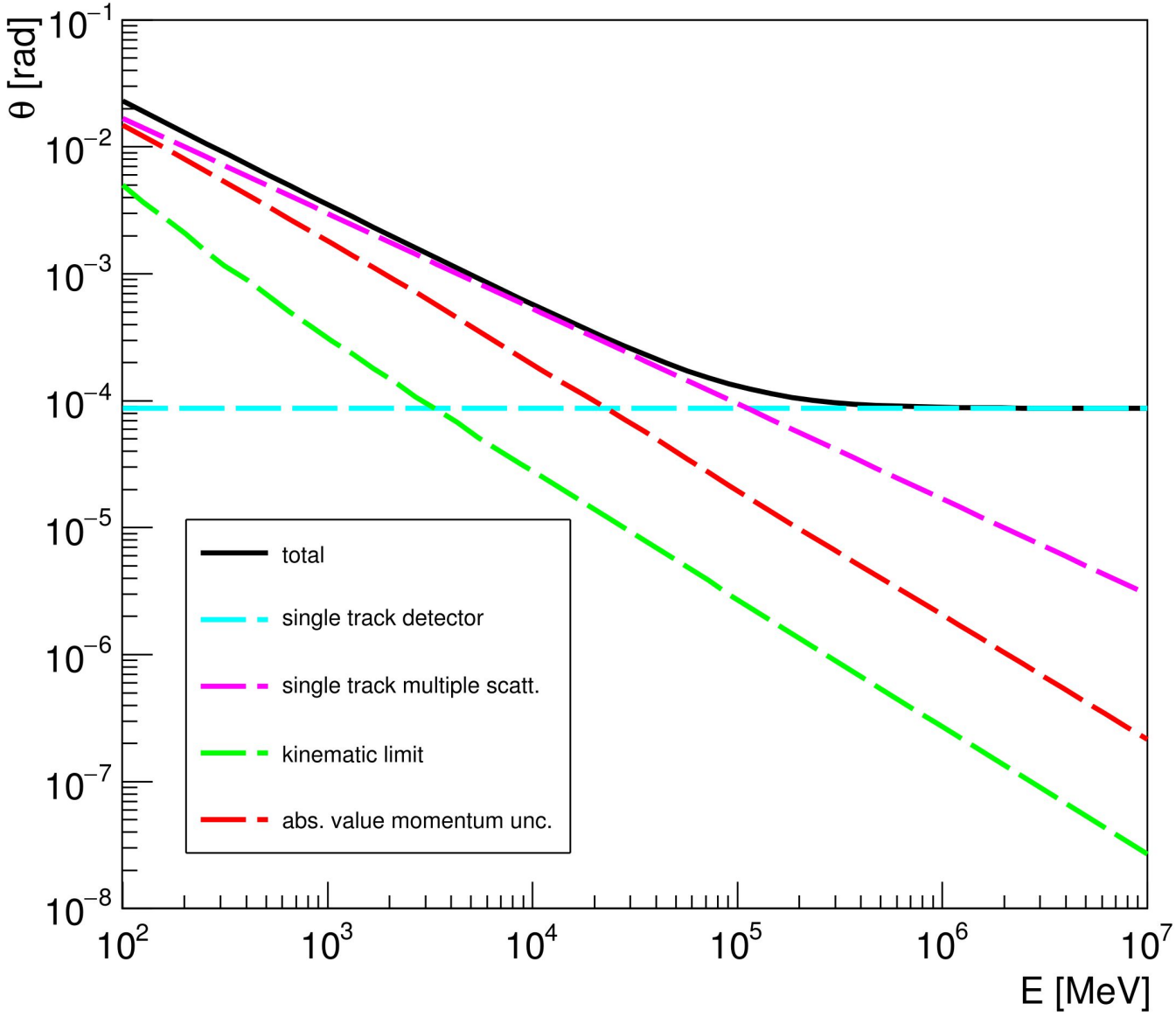


$$M = 36\,\mathrm{t}$$
$$L = 400\,\mathrm{cm}$$
$$D_c = 110\,\mathrm{cm}$$
$$D_t = 50\,\mathrm{cm}$$
$$\Delta_t = 1\,\mathrm{cm}$$
$$l_t = 0.1\,\mathrm{mm}$$
$$l_c = 1\,\mathrm{mm}$$
$$E_t = 3\,\mathrm{kV/cm}$$
$$E_c = 500\,\mathrm{kV/cm}$$

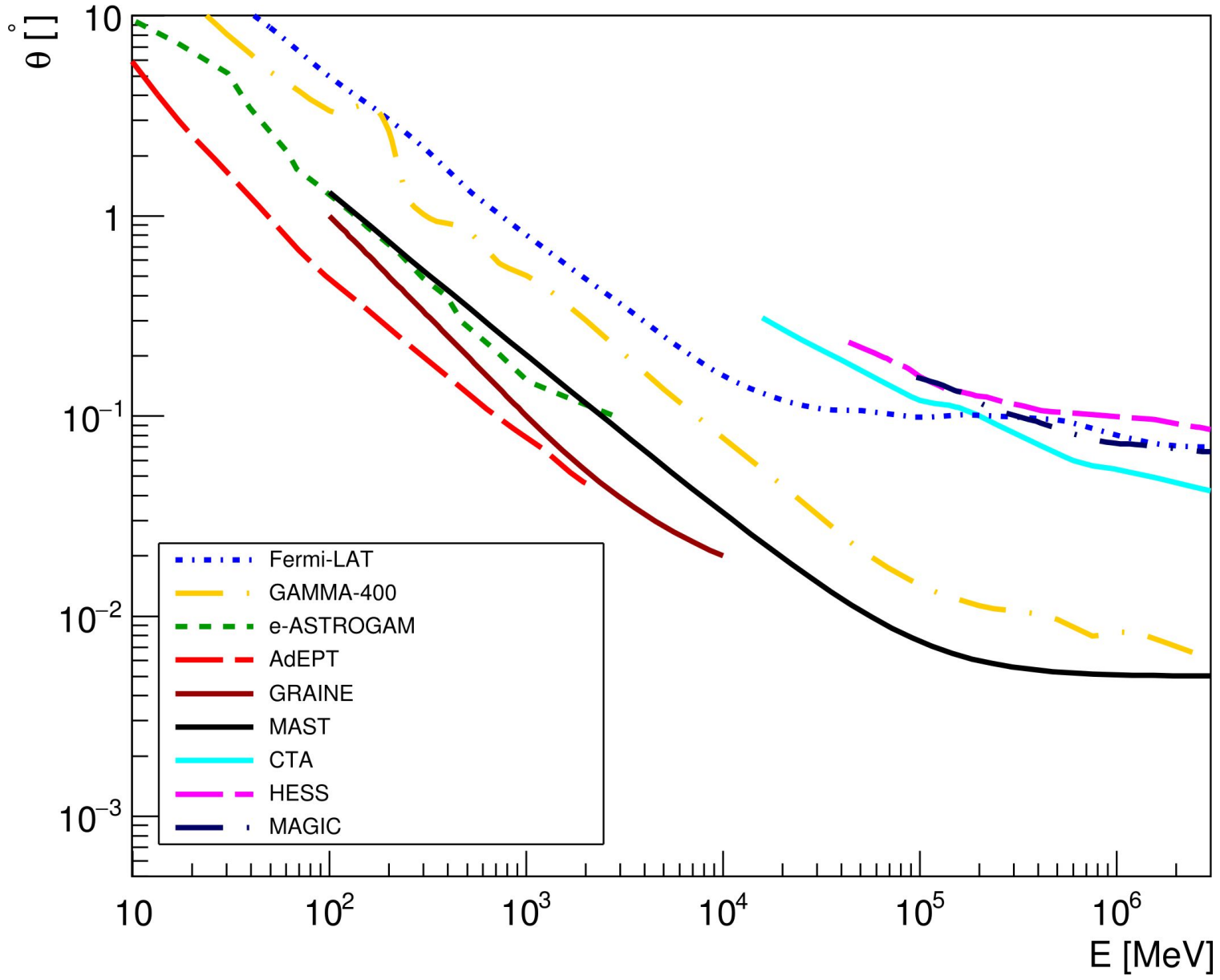
MAST is supposed to be launched by *Falcon Heavy*



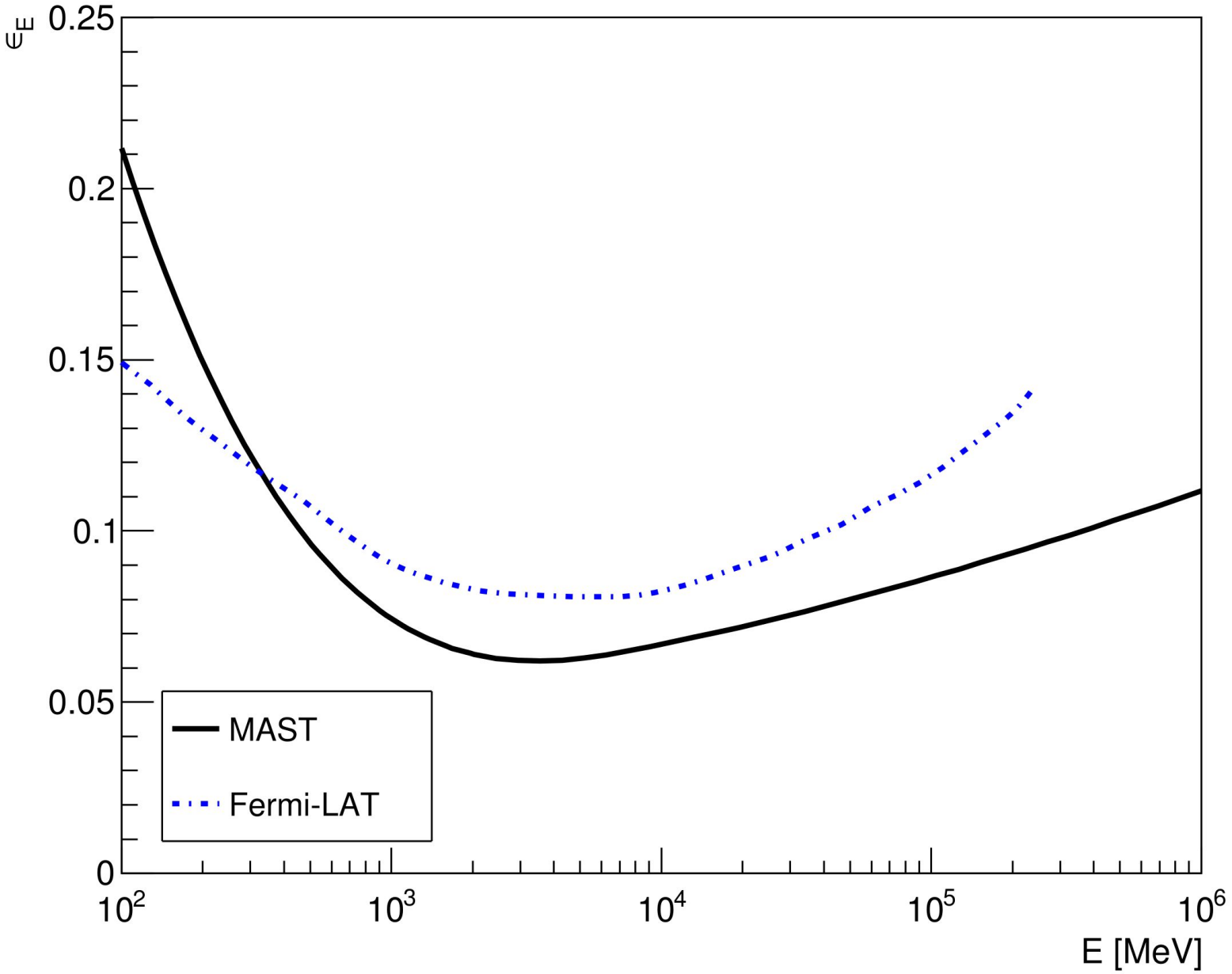
Effective area



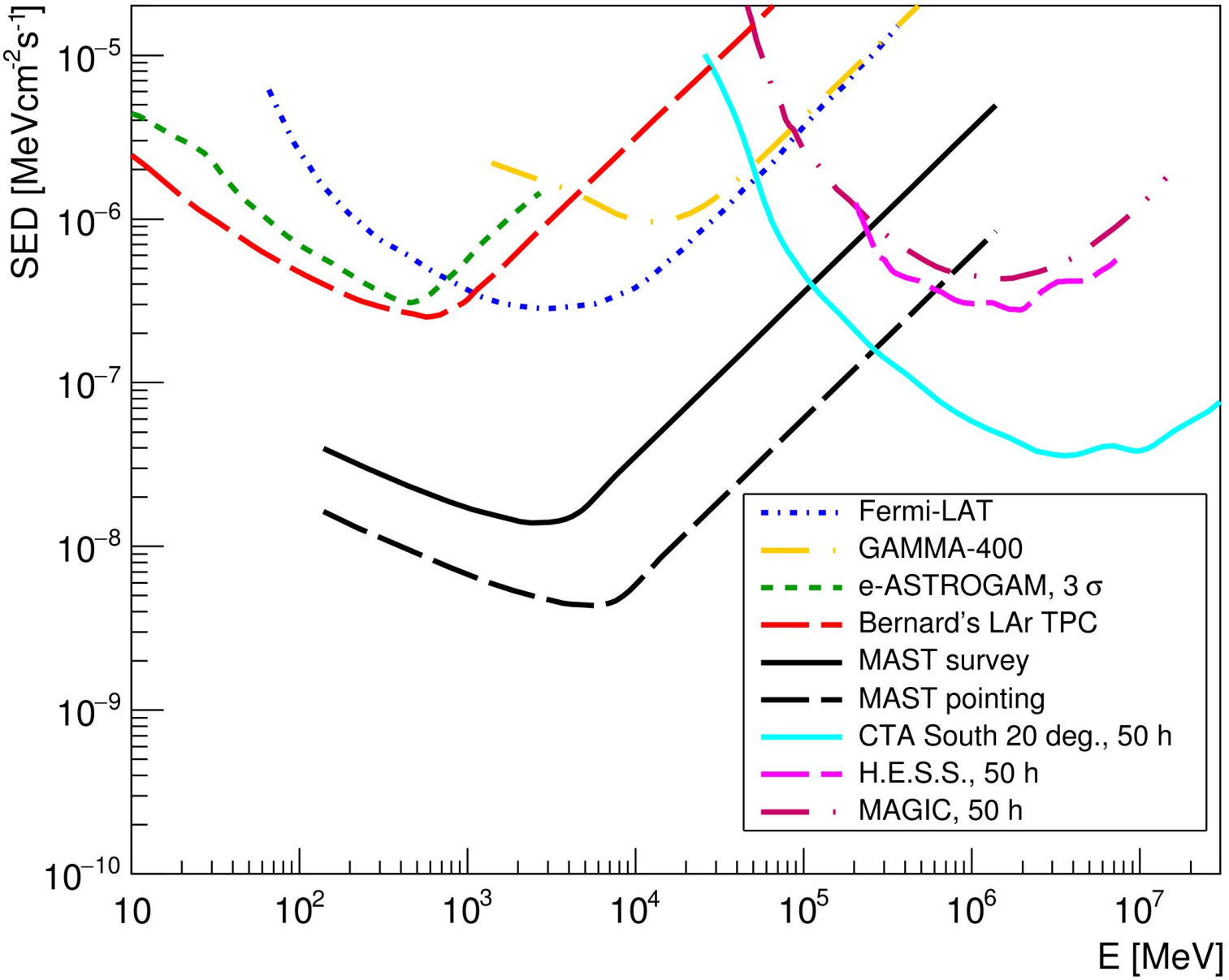
Components of the MAST angular resolution



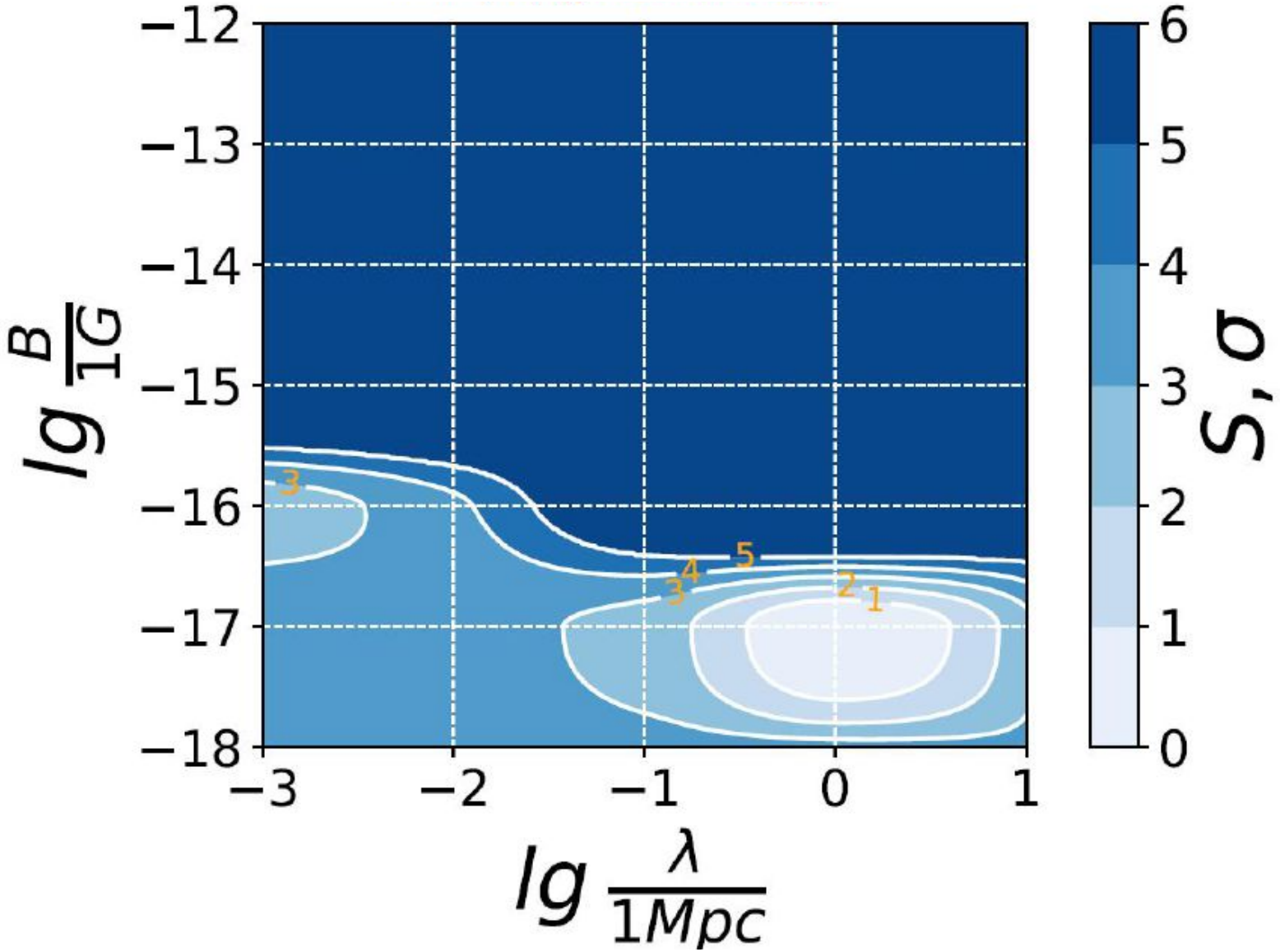
The MAST angular resolution in comparison with other instruments



Energy resolution



Differential sensitivity



Sensitivity to the parameters of the extragalactic magnetic field (EGMF) for 1ES 0347−121 (spectrum + ang. distribution, 3 years in survey mode, MC true field is 10 aG, 1 Mpc) (preliminary)

Conclusions

- The MAST instrument would have:
  1. one order of magnitude greater effective area than Fermi-LAT has
  2. 3-10 times better angular resolution than Fermi-LAT has
  3. more than one order of magnitude better differential sensitivity than Fermi-LAT has
  4. energy resolution similar to Fermi-LAT's one

- The project would provide an effective connection between ground based and space based gamma-ray observations.

- Thanks to its performance the MAST instrument will be able to:

1. Discover plenty of new faint gamma-ray sources
2. Measure the extragalactic gamma-ray background (EGRB) with high precision
3. Improve constraints on annihilation (decay) processes of dark matter (or discover these processes)
4. Investigate objects associated with IceCube astrophysical neutrinos and sources of gravitational waves (GW) registered by LIGO, VIRGO, etc.
5. Reduce uncertainty of parameters of the EGMF

Thank you for your attention!

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Additional slides

$$\sigma_{\theta 1} = \frac{2\sigma_d}{x}\sqrt{\frac{3}{N+3}}$$

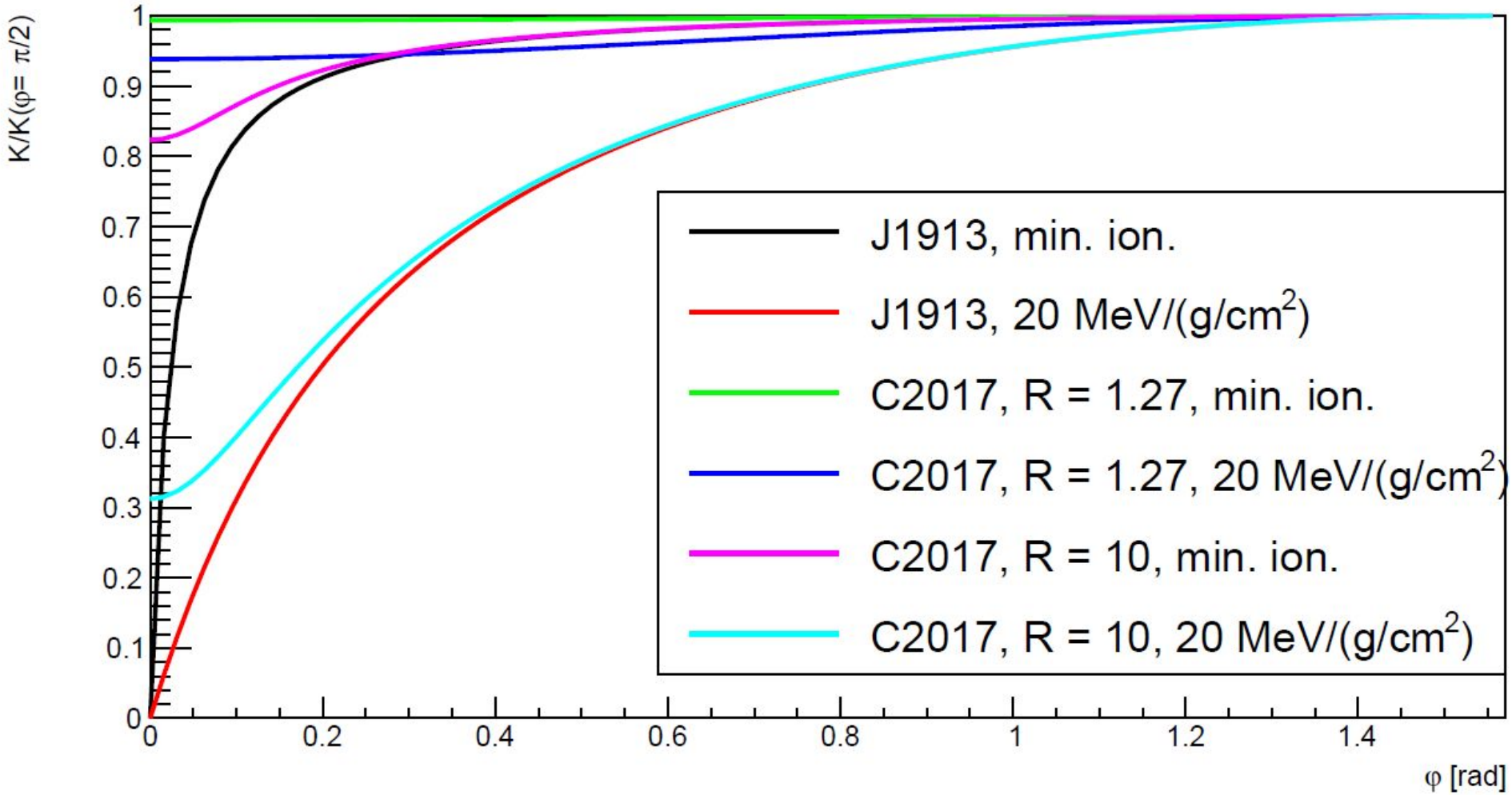
uncertainty due to the finite size of the readout layers

$$\sigma_{\theta 2} = \frac{(2\sigma_d)^{1/4} l_t^{1/8}}{X_0^{3/8}} \left(\frac{p_0}{p}\right)^{3/4}$$

uncertainty due to the multiple scattering of electrons

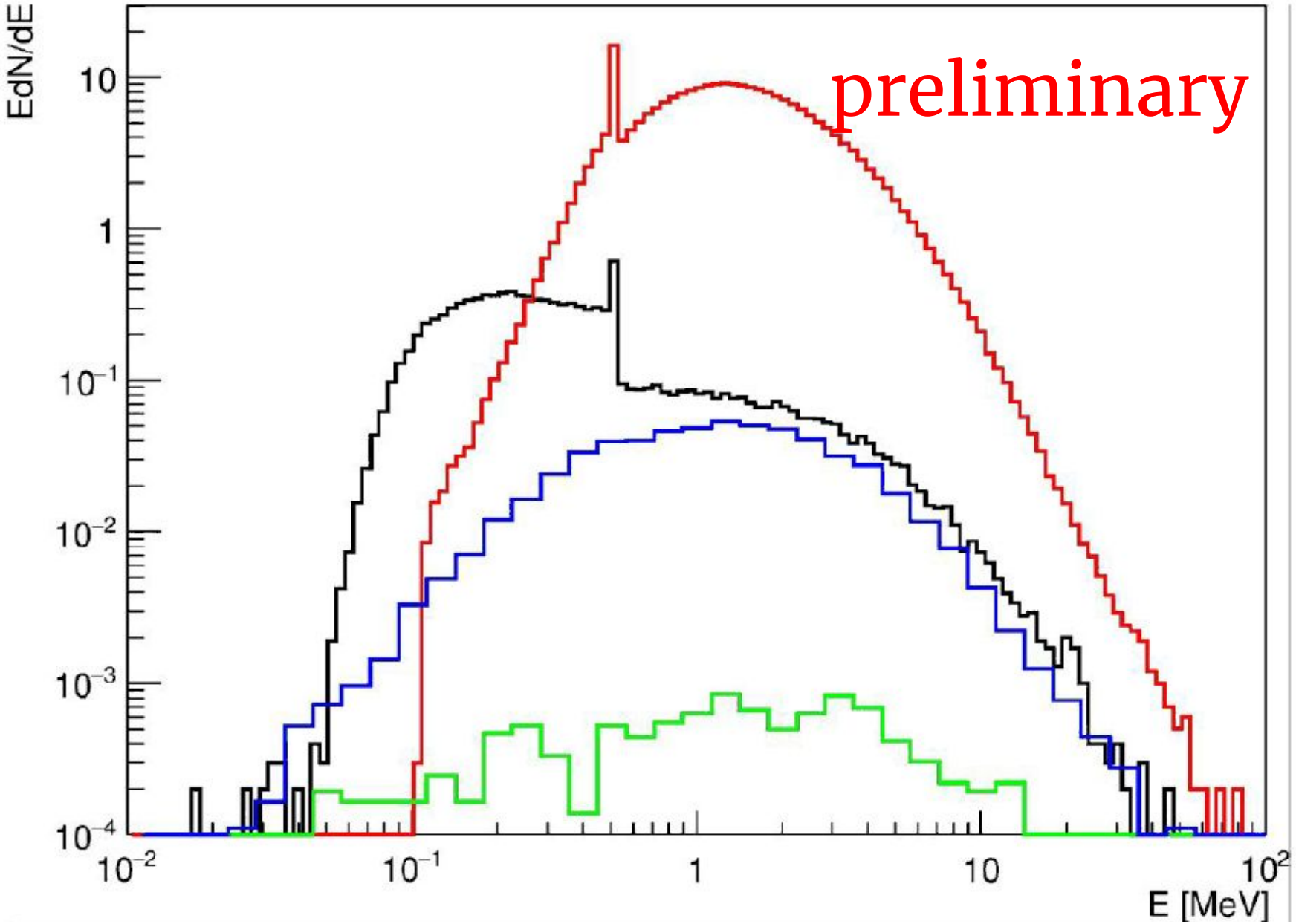
$$\sigma_d = \sqrt{\frac{l_t^2}{12} + \frac{K_D \Delta_t}{v_d}}$$

minimal space distance to separate two different tracks



Recombination efficiency

The flux of "backsplash" ("reverse current") for Argon (γ-rays: black; e^++e^-: green) and Tungsten (γ-rays: red; e^++e^-: blue)

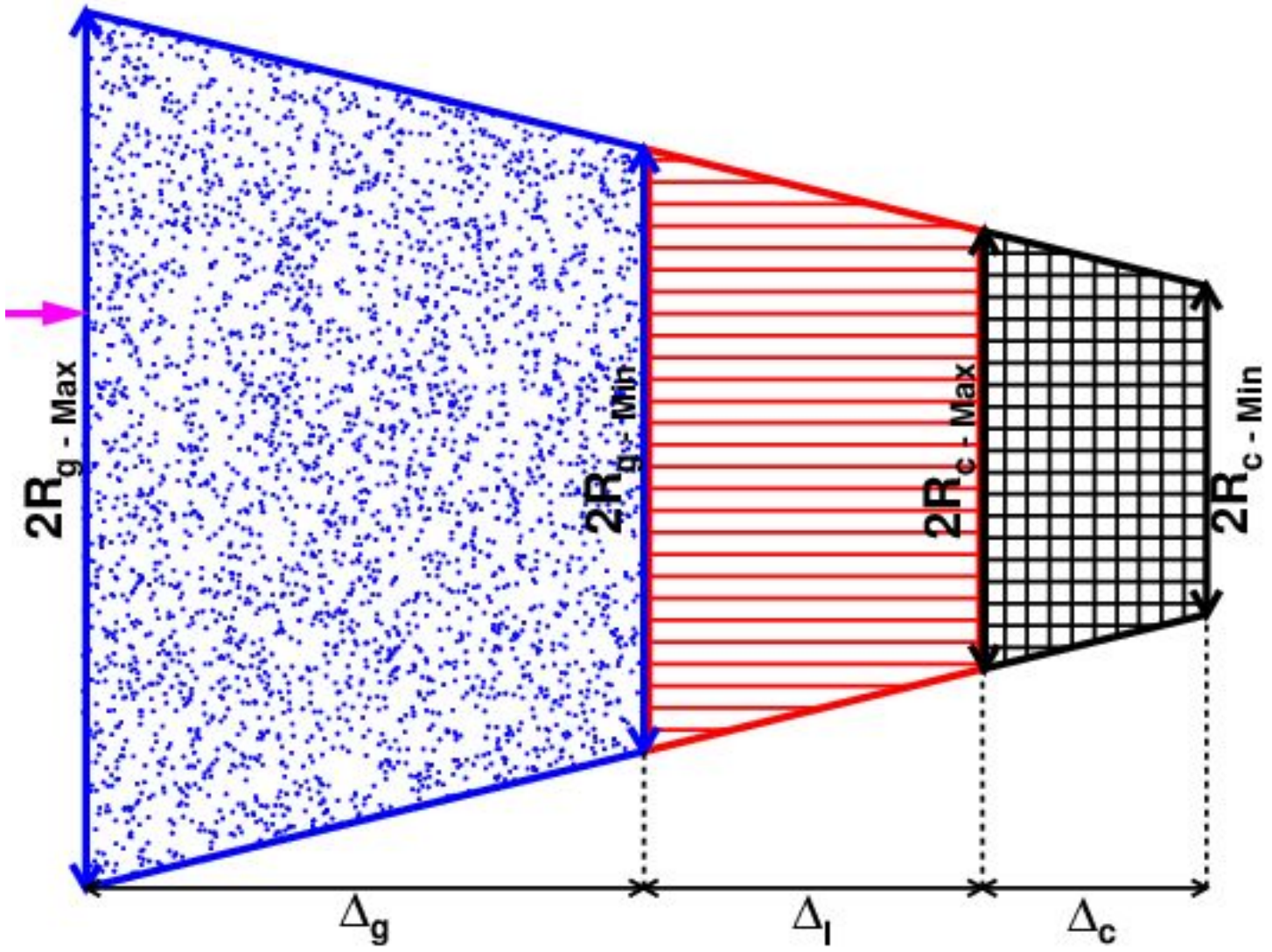


Background signals

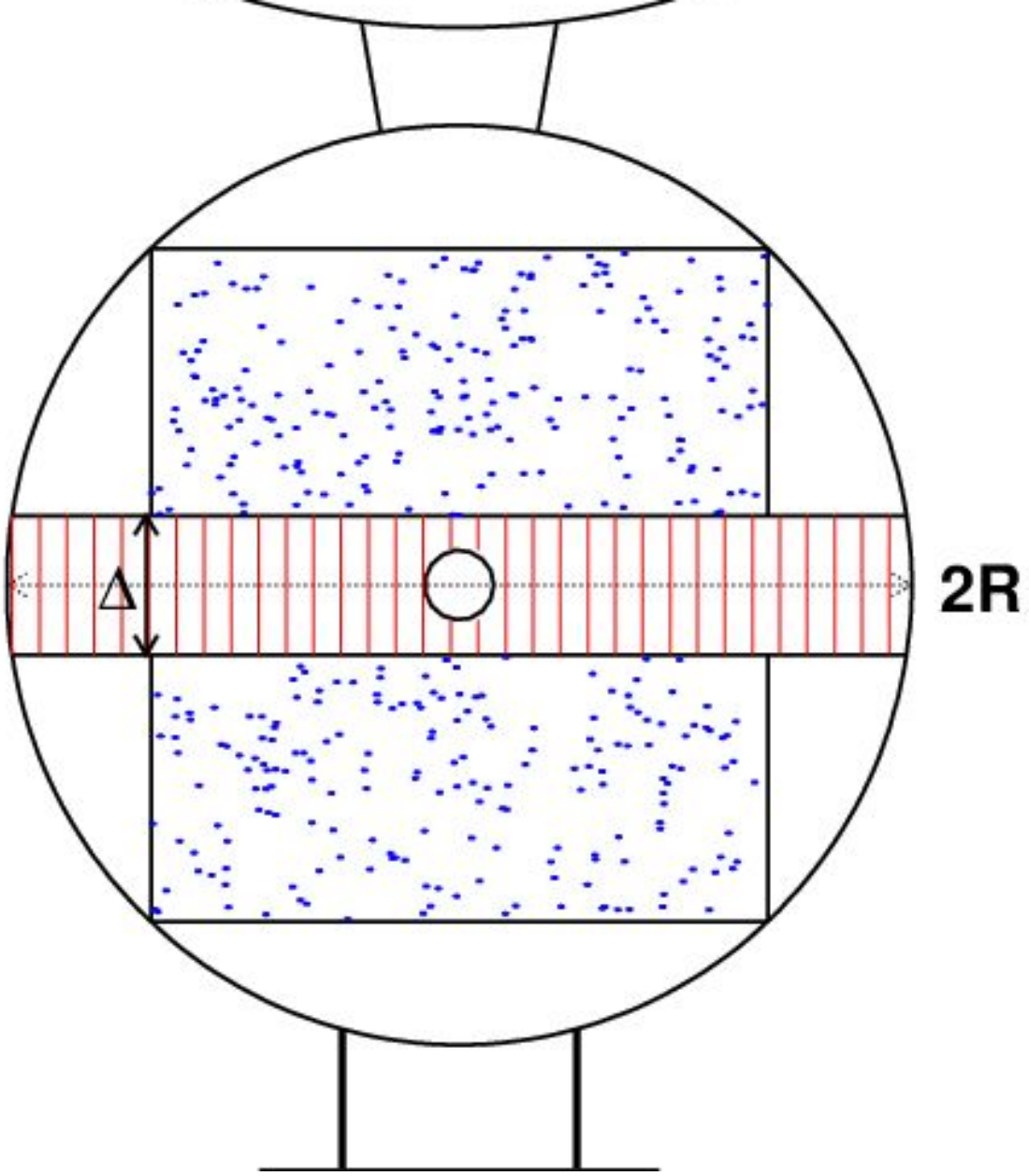
The ACD could be similar to the Fermi-LAT one (plastic scintillator, inefficiency $\delta = 3 \times 10^{-4}$ (Moiseev et al., 2007))

Trigger condition: $(S_{ACD}=0)\&(E_{dep}>30\ MeV)$
Expected rates (background model according to Fermi-LAT Atwood et al., 2009):

- Charged particles - 30 Hz
- Background gamma-rays - <500 Hz
- Neutrons - 500 Hz



Scheme of Non La



Scheme of TACT (Thin Argon Conversion Telescope)