OSTraD: Opaque Scintillating Tracking Detectors

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Outline

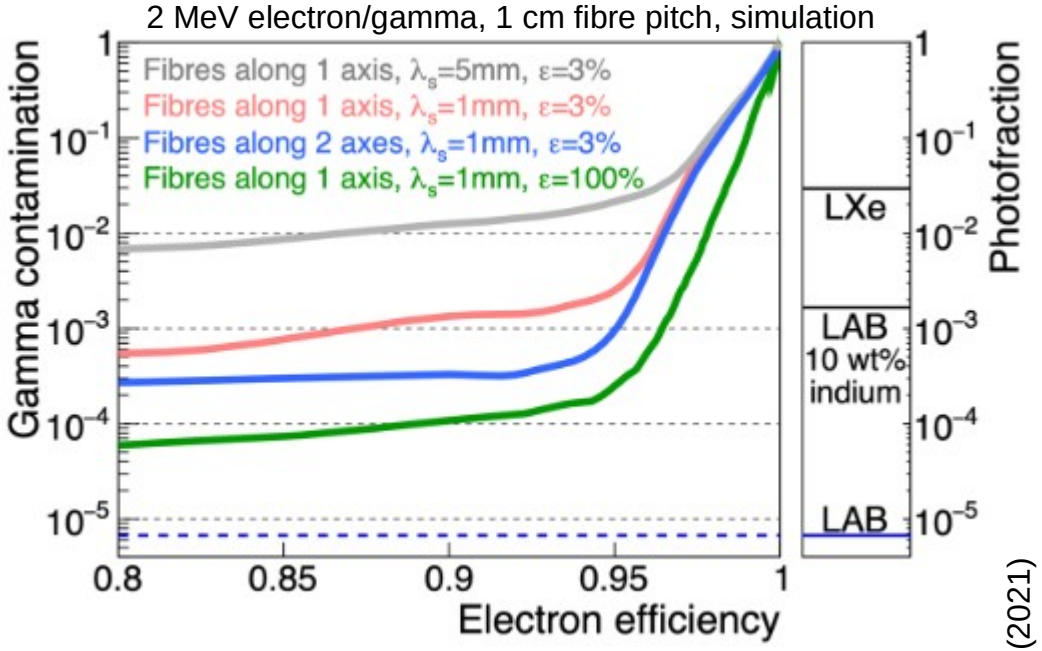
- Motivation for Opaque Scintillation Detectors
- Opaque scintillation trackers
- Deliverables / Conclusion

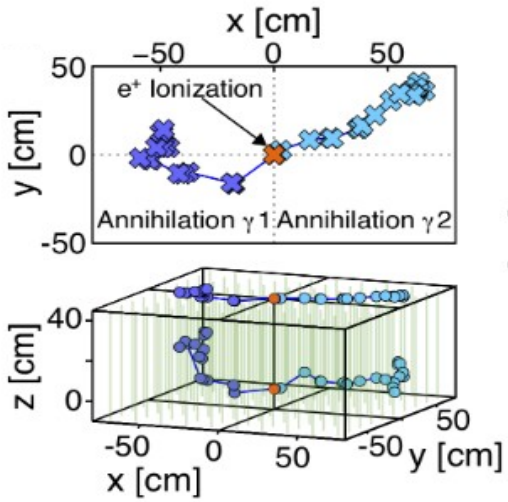
The Origin of Opaque Scintillators

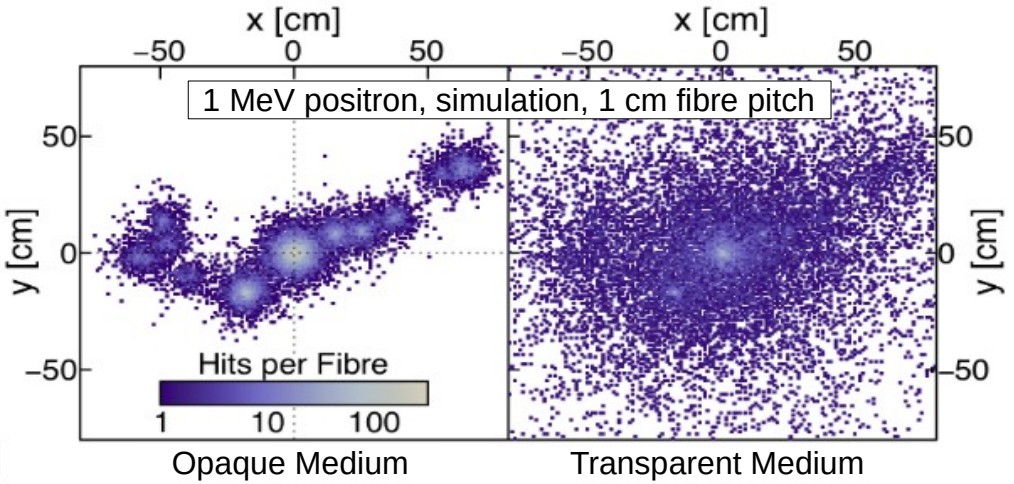
Technology developed in context of low energy O(1 MeV) astroparticle physics (neutrinos)

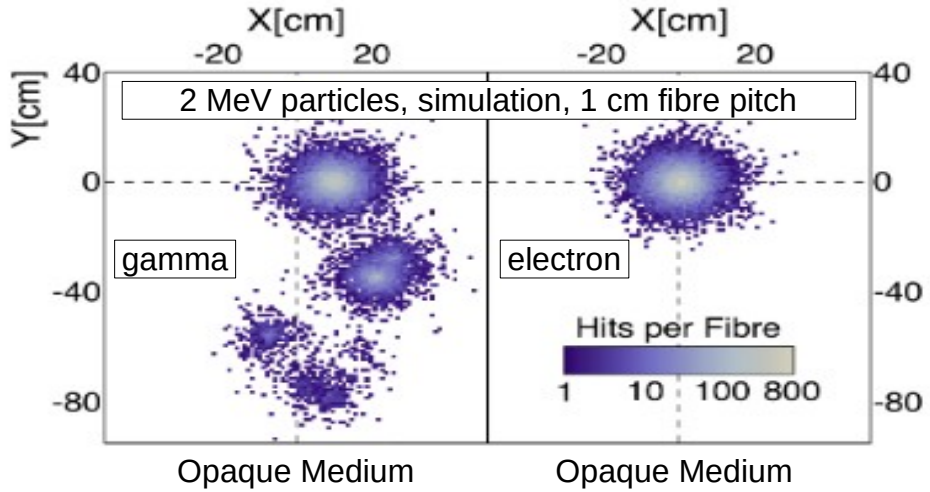
Energy depositions happen on O(10 cm) scale
- → opaque medium confines scintillation light to its point of creation
- → light-readout via grid of wavelength-shifting fibres
- → particle-ID through spacial resolution of less than 1 cm
- → e.g. electron/gamma discrimination of 1000/1 possible

Opaque scintillator medium is composed from liquid scintillator and wax
- → Mie-Lorentz scattering/optical scattering









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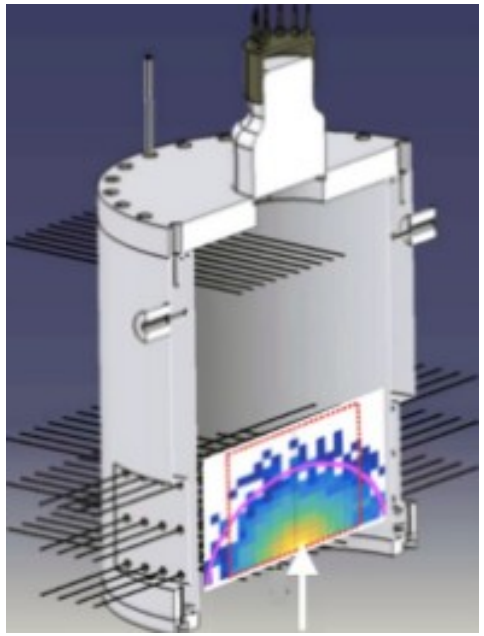
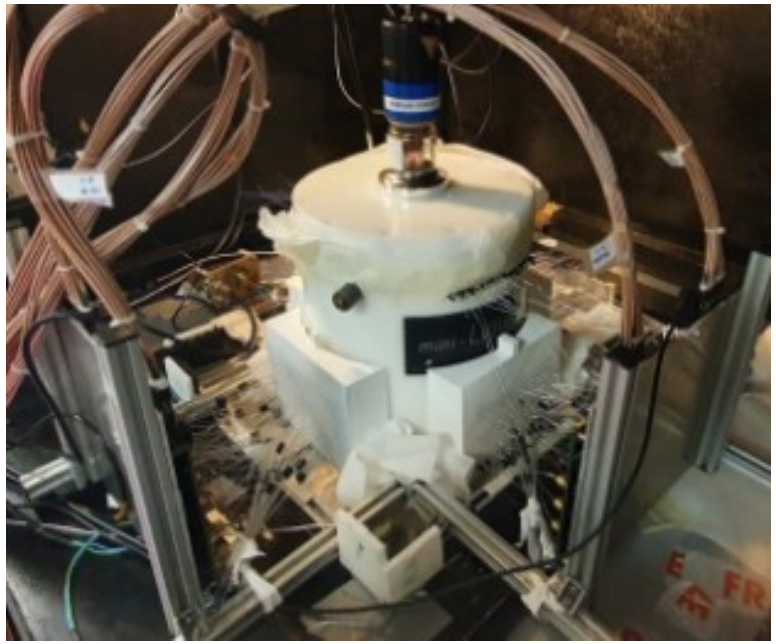
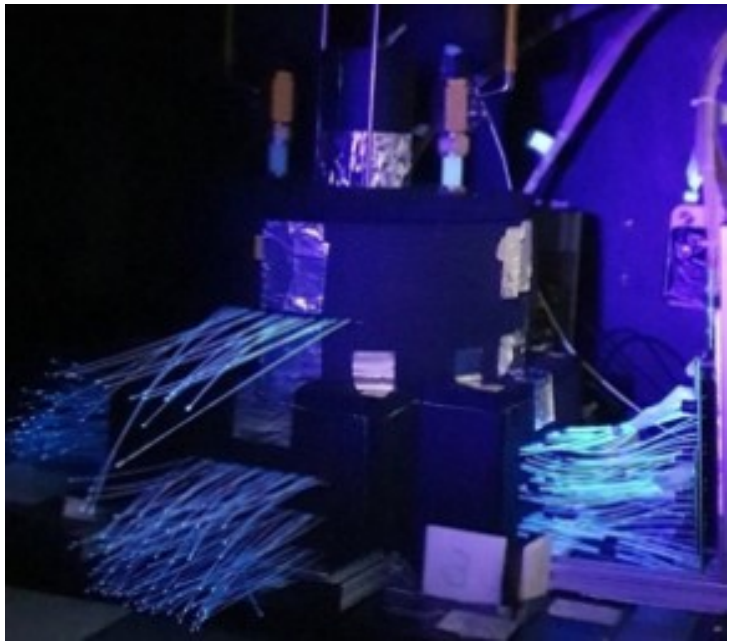
Experimental Demonstration of Light Confinement







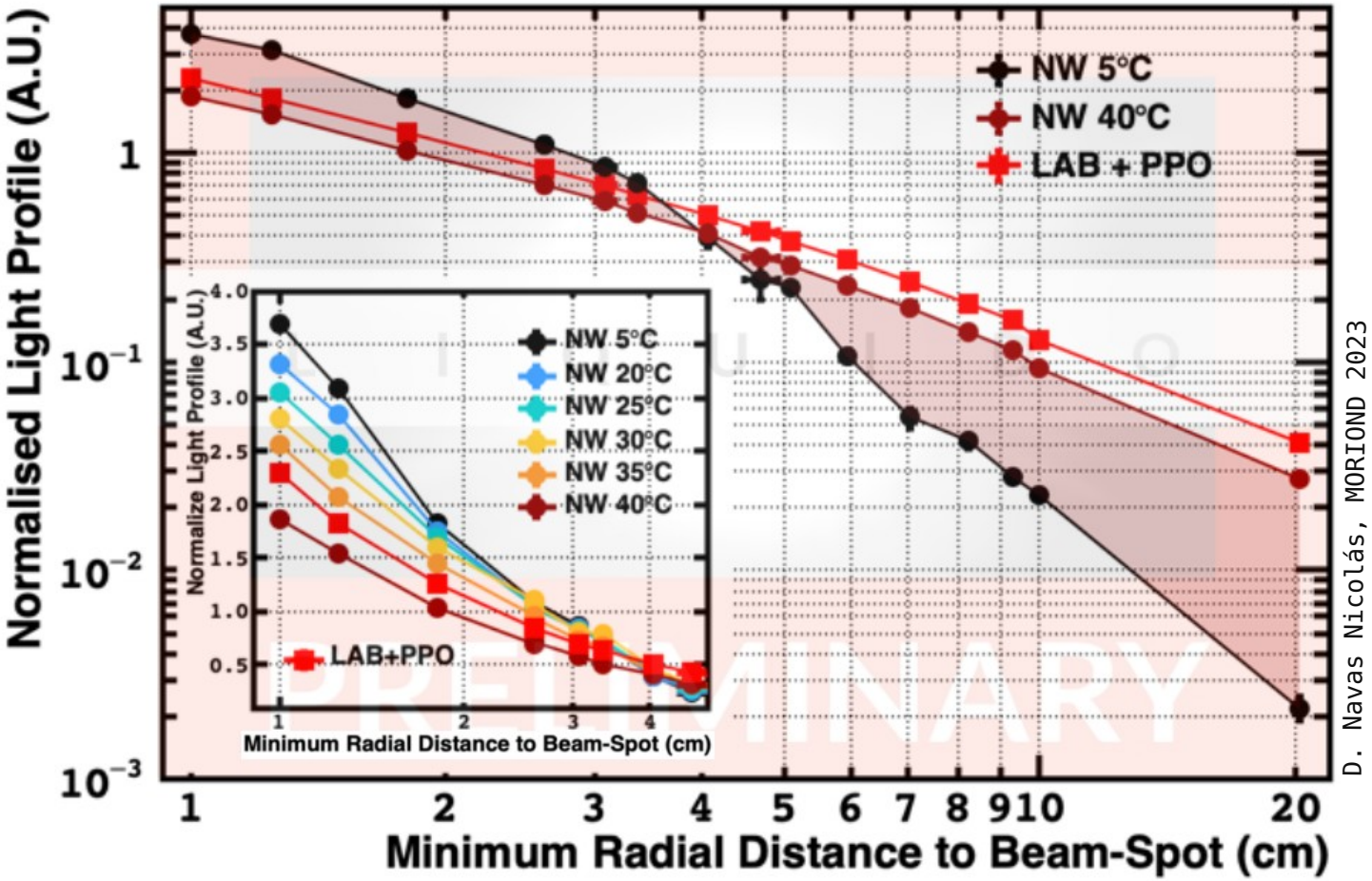
→ 10 litres detector
→ 56 wavelength-shifting fibres in 2 orthogonal directions
→ mono-energetic electron beam from ^{90}Sr source tunable between 0.4 and 1.8 MeV
→ operated @ LP2i Bordeaux, France

data taking since 2021 including runs with:
→ wax-based liquid scintillator: NoWaSH-20 in transparent and opaque mode (temperature dependent, 5 to 40°C)
→ transparent scintillator
→ water (transparent / non-scintillating)

Light Confinement Confirmed

Temperature dependent opacity of scintillator leads to confinement of light

90% of light confined within 5 cm radius



Interest Group

R&D development driven mostly within LiquidO collaboration:
~100 scientists
~25 institutions
~10 countries

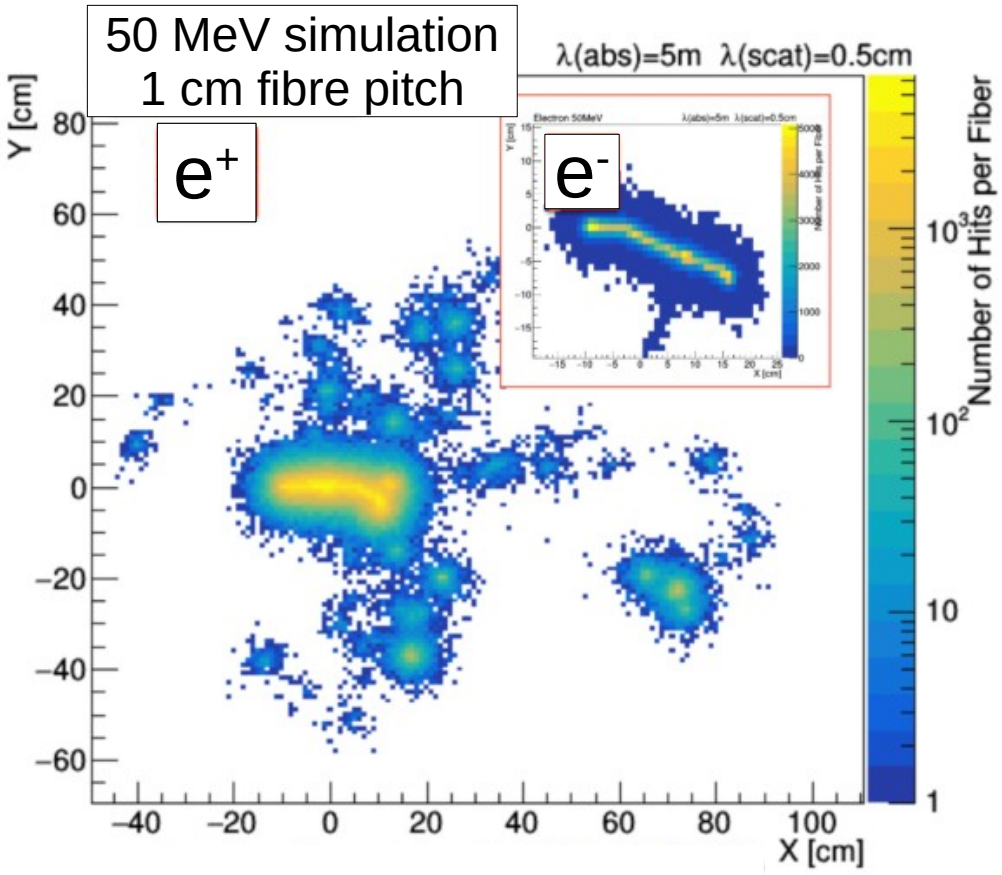
Broad field of application:
→ particle physics
→ astrophysics
→ nuclear/hadron physics
→ medical physics
→ geophysics

Interest in hadron/nuclear physics mostly by European partners
→ Mainz
→ Barcelona
→ Paris
→ Rutherford Lab
→ Sussex

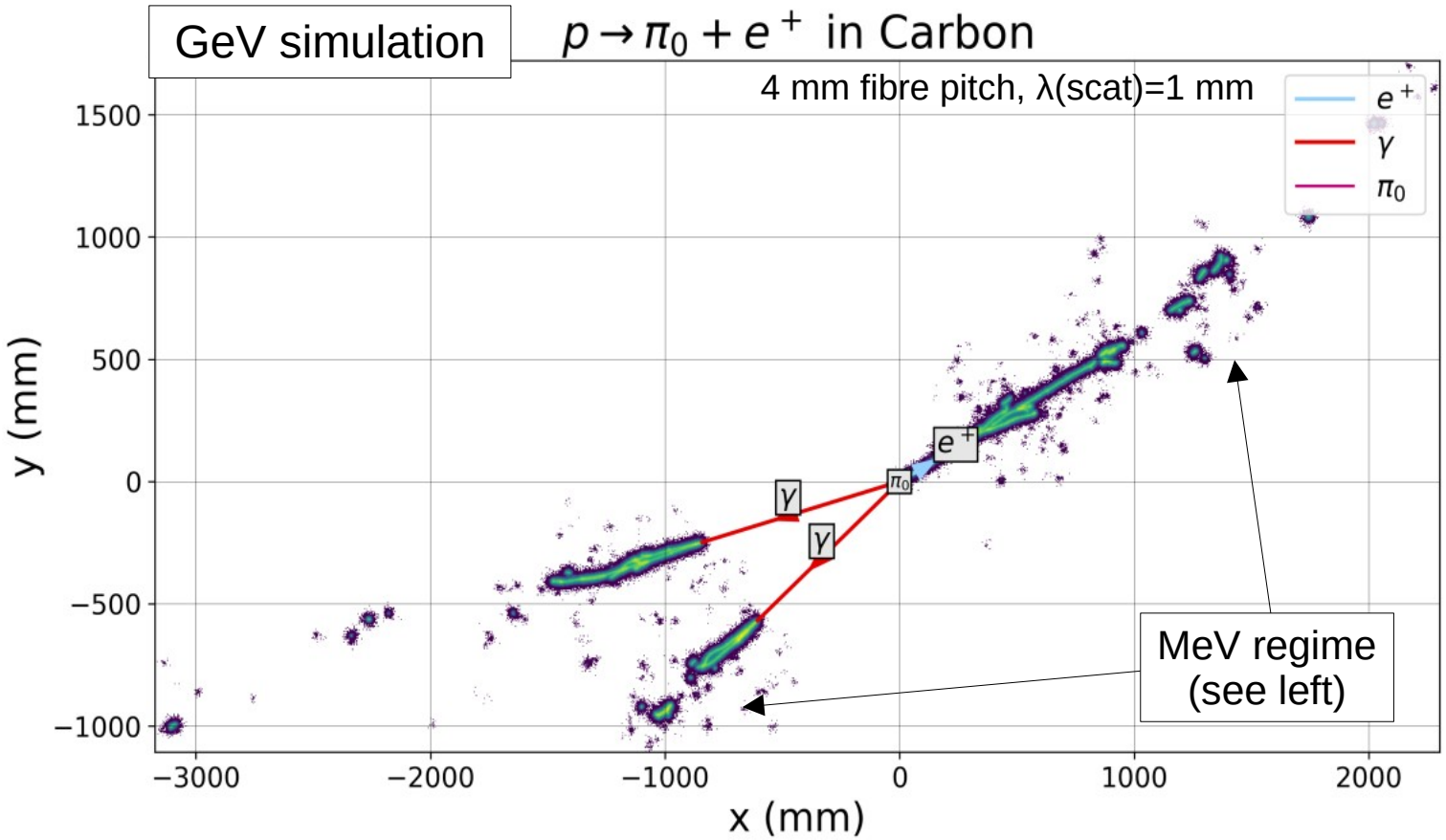
Community interest also from:
→ DarkMESA
→ NuDoubt
→ BDX@JLAB
collaborations

Potential for Hadron Physics Community

tracking
→ directionality
→ dE/dx



proton decay
→ event tagging trough tracking
→ higher abundance of protons per fiducial mass
→ 10% in water
→ up to 20% in scintillator



Potential for Hadron Physics Community

4 mm fibre pitch, λ(scat)=1 mm

simulation of 1 GeV neutrino-neutron coherent pion production

electrical charge via missing annihilation gammas: negative

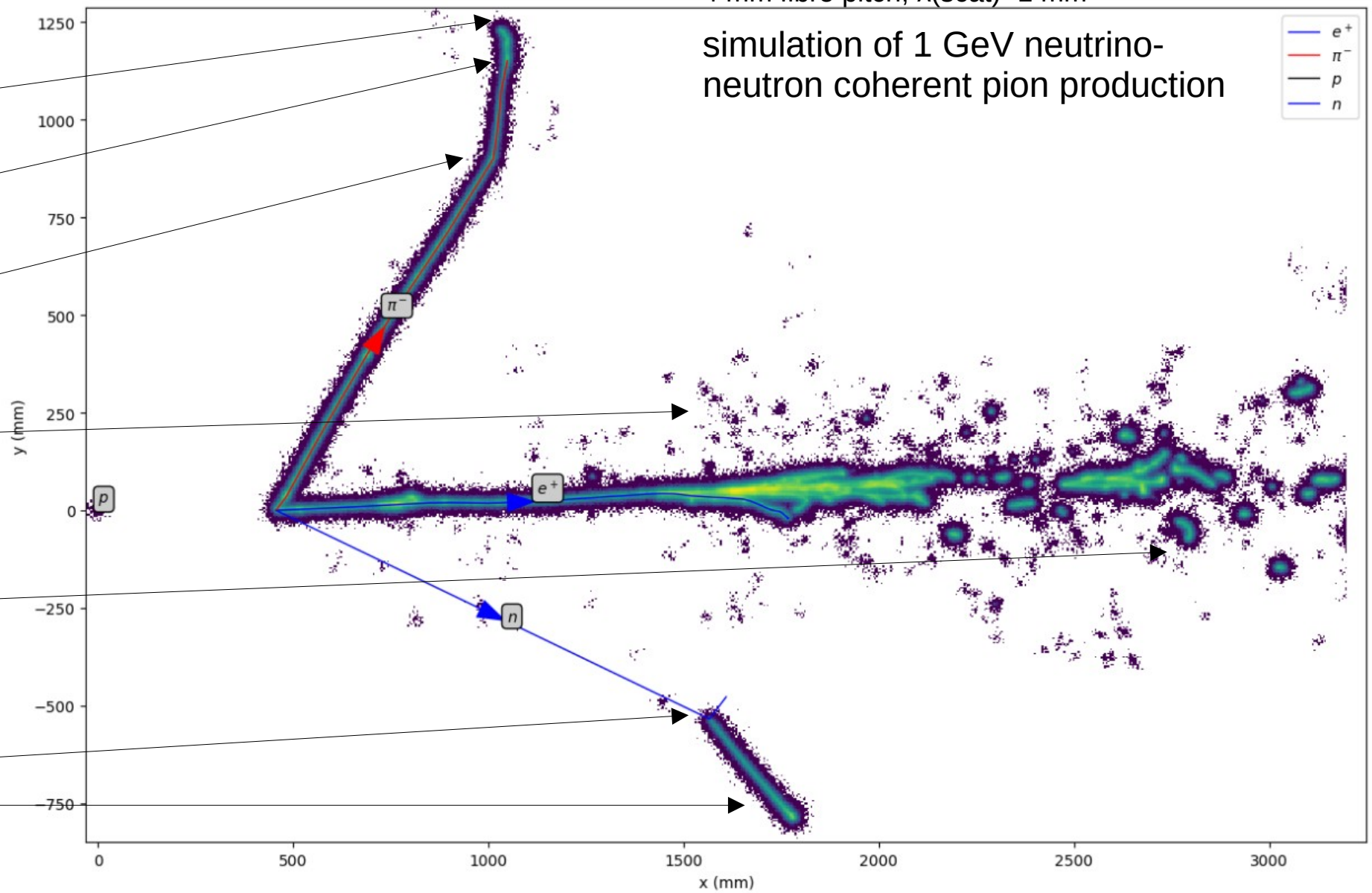
muon to Michel electron/positron

pion to muon

EM-shower

MeV regime

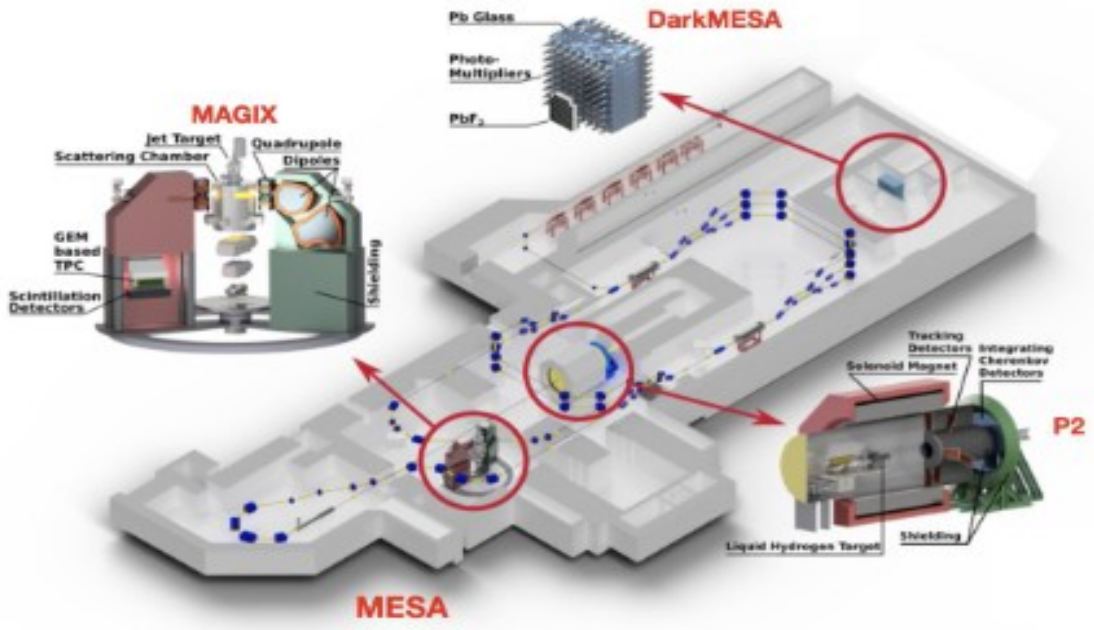
neutron momentum via time of flight and proton recoil



Opaque scintillation trackers at MAMI/MESA

The MESA Accelerator

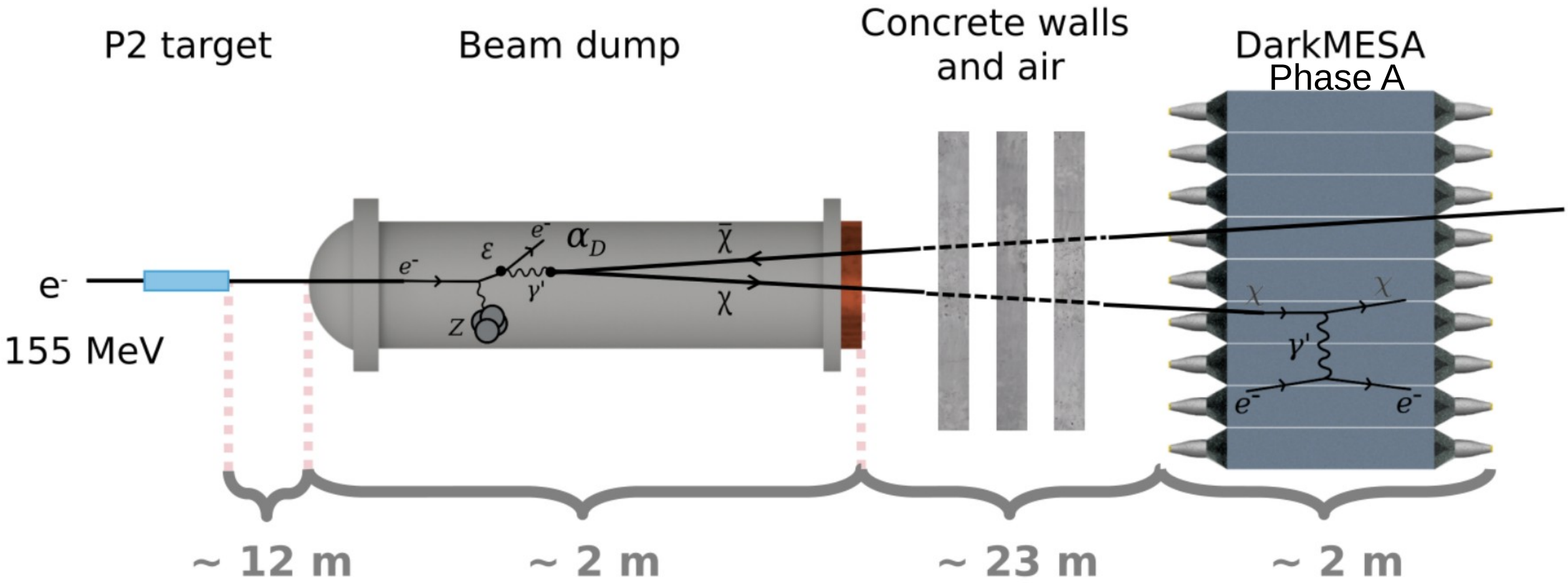
- Electron accelerator
- 2 modes of operation:
  - Energy recovery mode: 105 MeV @ 1 mA for MAGIX
  - Extracted beam mode: 150 MeV @ 0.15 mA for P2 and DarkMESA
- Currently under construction



https://magix.uni-mainz.de/mesa.php

Light Dark Matter Searches with DarkMESA

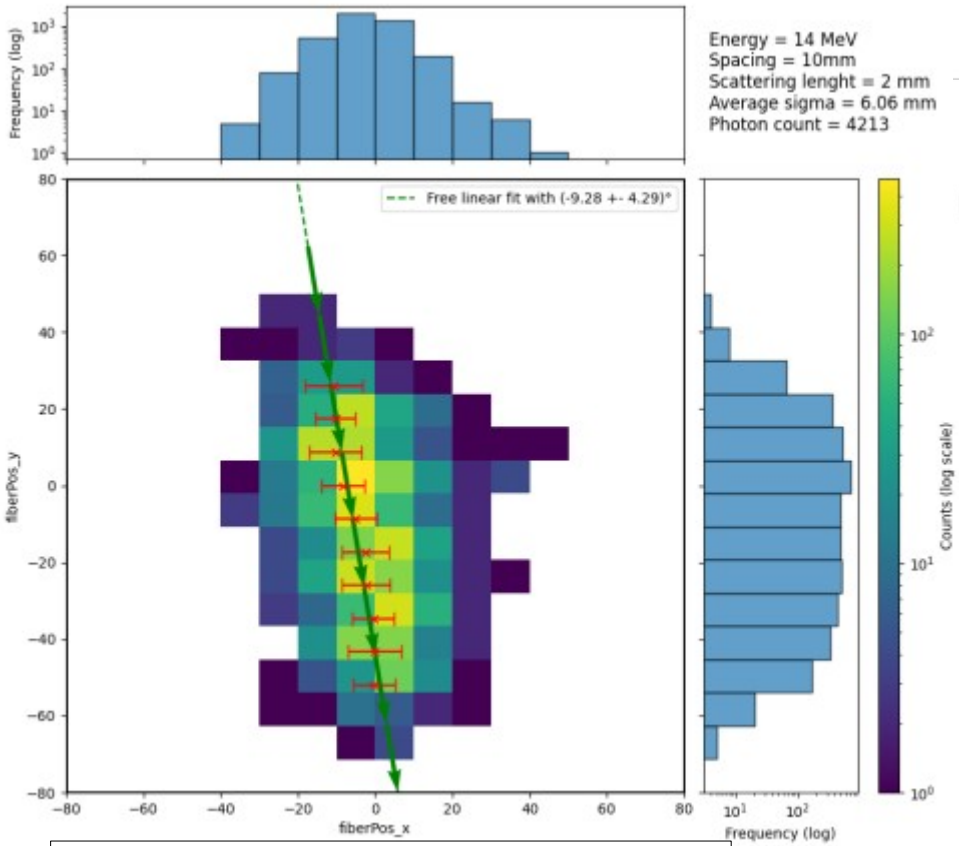
→ production of light dark matter via dark bremsstrahlung in beam dump
→ detection of dark matter via electron recoils behind shielding in detector



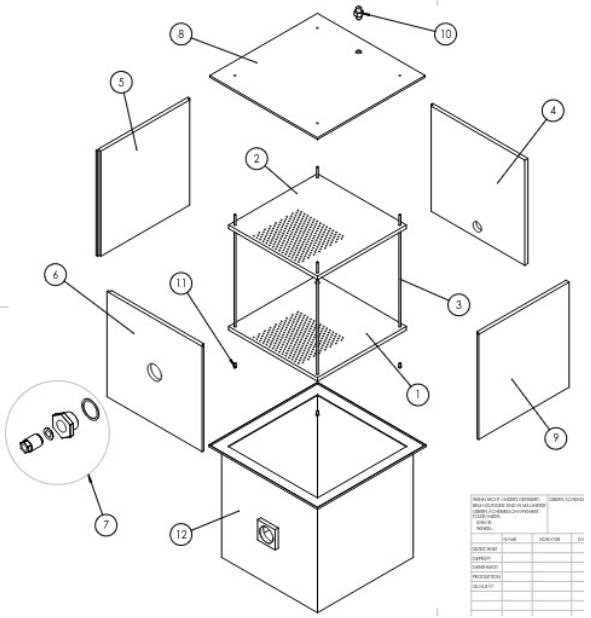
DarkMESA using Opaque Trackers in Phase B

Opaque Prototype for MAMI (Mainz) beam-time:

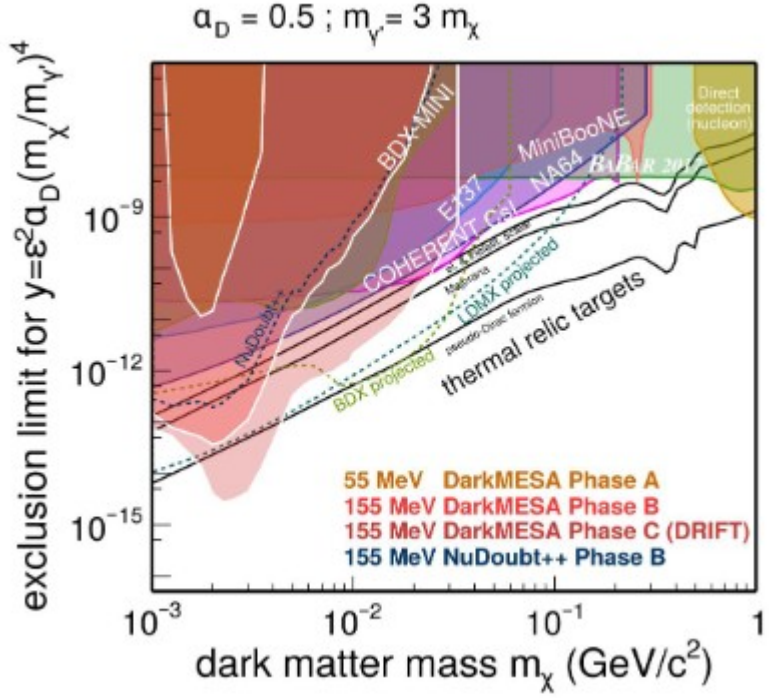
→ demonstrate electron tracking (signal events)



Simulation of 14 MeV electron



Expected Sensitivity of DarkMESA:



- Limits are calculated for $m_{\gamma'} = 3\ m_\chi$ and $\alpha_D = 0.5$
- Considered decay processes:
  - Dark Bremsstrahlung
  - Positron Annihilation

Deliverables / Conclusions

Deliverables:
→ workshop at beginning of project → get overview on community interest and define scope of possible applications
→ beam-times →MAMI/MESA → demonstration of tracking capabilities with electrons
→PS/CERN (optionally, after end of long shutdown in 2028) → proton studies
→ design report/R&D plan to be shared with community/publication → presentation of optimised tracker design

Funding request (250k€ without indirect costs) for:
→ workshop organisation
→ direct costs for beam-time prototype
→ fraction of FTE for postdoc to enable technology transfer between partners

Conclusion:
→ opaque scintillation detectors are an novel emerging technology
→ broad spectrum of applications
→ impact on hadron community (100 MeV to 1 GeV scale) → via tracking detectors
→ to be verified as objective of this LoI (feasibility study)
→ immediate application: →light dark matter searches via electron recoils in DarkMESA
→study of nuclear cross-sections at beam facilities