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Latest result on searching for fractionally charged particles with the DAMPE

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Outline

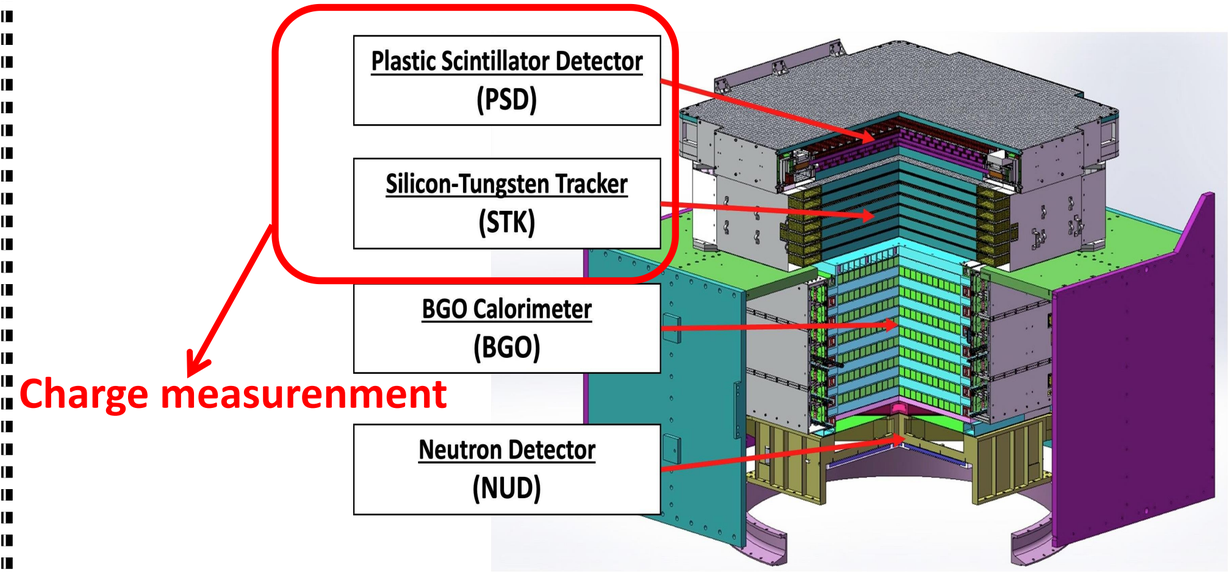
- Motivation and DAMPE
- Search for FCP with DAMPE
- Summary

Motivation and DAMPE

- All charged particles have multiples of electron charge except quarks. According to theories of quantum chromodynamics (QCD) free quarks do not exist, however Fractionally Charged Particles (FCPs) are of great interest. Our first try is based on heavy lepton assumption.
- There are three possible sources of FCP in cosmic rays:
  - early universe
  - high-energy astrophysical processes
  - extensive air shower

- DAMPE Experiment

  DAMPE is a space experiment for detecting high energy cosmic rays launched on Dec.17th 2015.



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Search for FCP with DAMPE

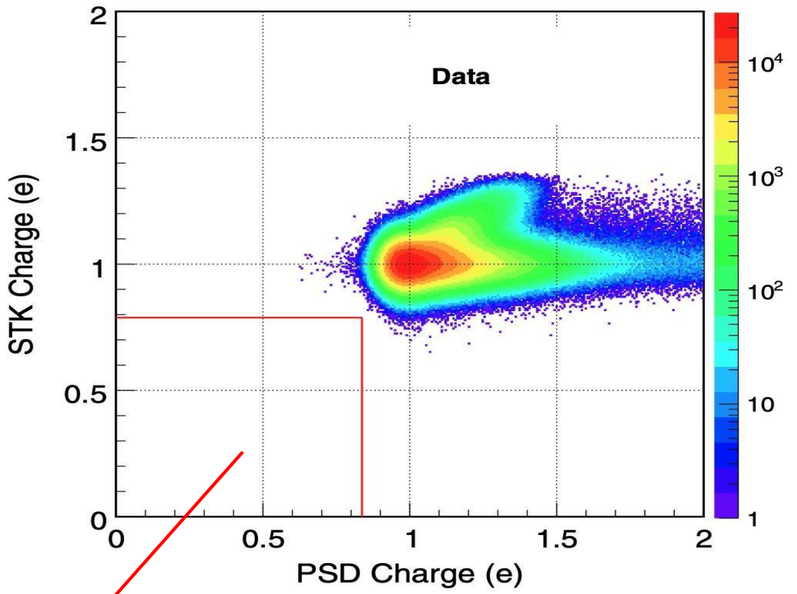
Charge reconstruction is based on Bethe-Bloch Formula. The energy deposited in the PSD and STK is proportional to the square of particle charge.

$$-\frac{dE}{dx} = Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\frac{2m_e c^2\beta^2\gamma^2 T_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2}\right]$$

	PSD Charge resolution (Charge unit, c.u.)	STK Charge resolution (Charge unit, c.u.)
Proton	0.06	0.04
Helium	0.10	0.07

Data Sample

- Simulation (Assumption):
  - like a massive lepton (e.g. muon)
  - The charge would be 2/3e
- Flight Data: 2016.01.01 ~ 2020.12.31



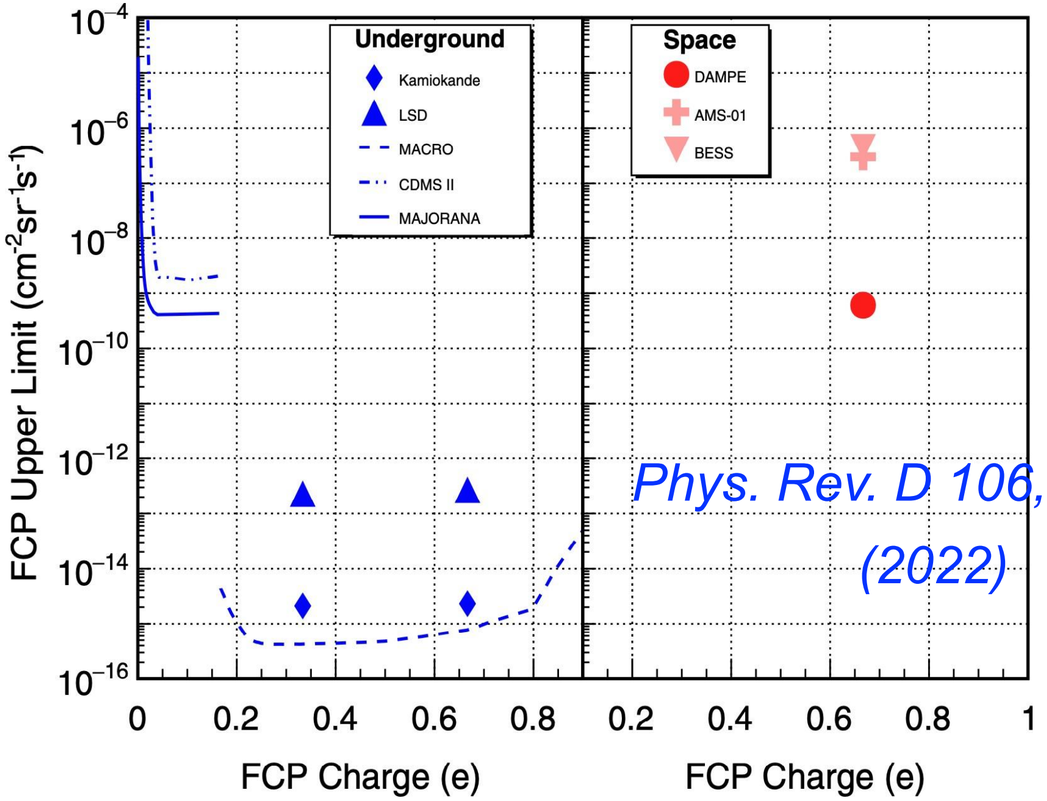
FCP Signal Region

Upper Limit of 2/3e FCP

TABLE I. The comparison between DAMPE and other similar types experiments.

Experiments	Geometric acceptance(cm^{-2} sr)	Exposure time (s)	Upper limit (cm^{-2} sr^{-1} s^{-1})
AMS-01	3000	3.6×10^4	3.0×10^{-7} (95% CL)
BESS	1500	3.2×10^5	4.5×10^{-7} (90% CL)
DAMPE	3000	2.3×10^7	6.2×10^{-10} (90% CL)

$$\Phi < 6.2 \times 10^{-10} \mathrm{cm}^{-2}\,\mathrm{sr}^{-1}\,\mathrm{s}^{-1}$$



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- Underground Experiment
  - Energy loss when particle pass through rocks about 300 GeV (1km depth)
- Space Experiment
  - Cutoff by the earth's magnetic field 6 ~ 7 GeV

Lower kinetic energy limit for space experiment !

Prospects for Searching for Light FCP

FCP should not be constrained to be heavy lepton

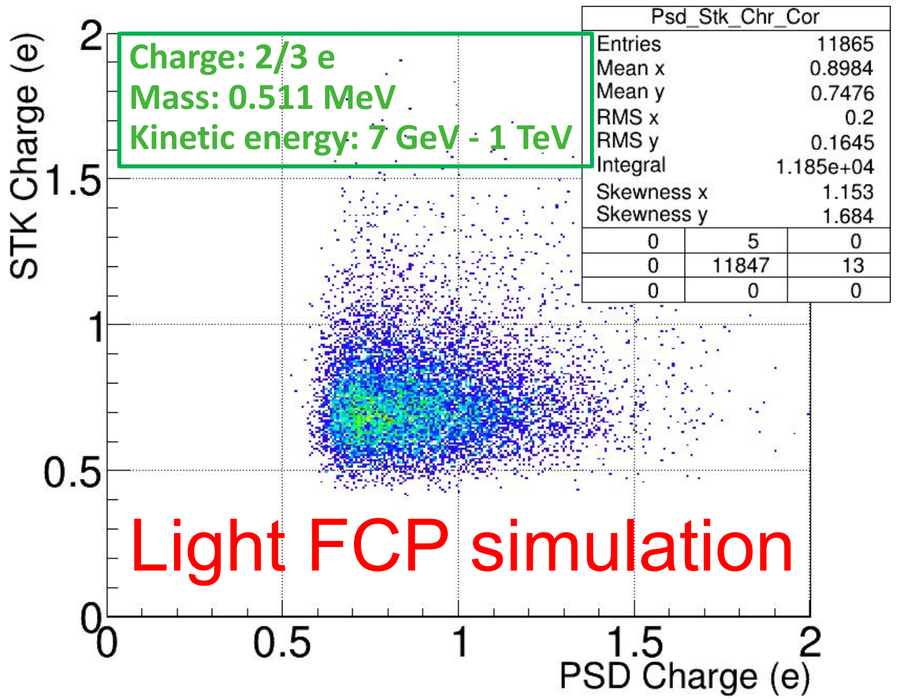
- Shower can happen
- Mass may be light
- Electron-like light-mass particle

Origin: nearby stars

Energy loss: Bremsstrahlung

$$-\frac{dE}{dx} = 4\alpha N_A \frac{Z^2}{A} z^2 \left(\frac{1}{4\pi\epsilon_0}\frac{e^2}{mc^2}\right)^2 E \ln\frac{183}{Z^{1/3}}$$

Based on the dataset accumulated by DAMPE, the mass-, energy-dependent spectrum are supposed to be observed.



Next step

- Light-mass FCP simulation.
- Evaluate the background contamination (electron, proton, gamma).
- Evaluate the selection efficiency and effective acceptance.

Summary

- We search for 2/3e FCP with DAMPE experiment
- Space experiments can detect FCPs with energy as low as a few GeV
- FCPs are assumed to be a type of heavy lepton
- No FCP signals are observed and a flux upper limit of $\Phi < 6.2 \times 10^{-10} cm^{-2} sr^{-1} s^{-1}$ is established at the 90% C.L..
- Result is published in *Phys. Rev. D 106, 063026 (2022)*
- Searching for Light FCP is on-going.

Thank you!