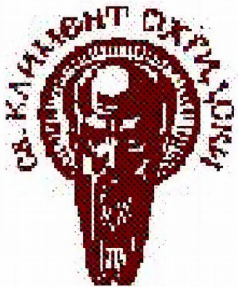


First National Forum for Modern Cosmical Researches
21-22.10.2020 Sofia Tech Park

The PADME Experiment and Dark Matter Studies

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Sofia University "St. Kliment Ohridski"*



* partially supported by LNF/INFN-SU 70-06-
497/07.10.2014 & BG-NSF DN-08-14/14.12.2016





Overlook

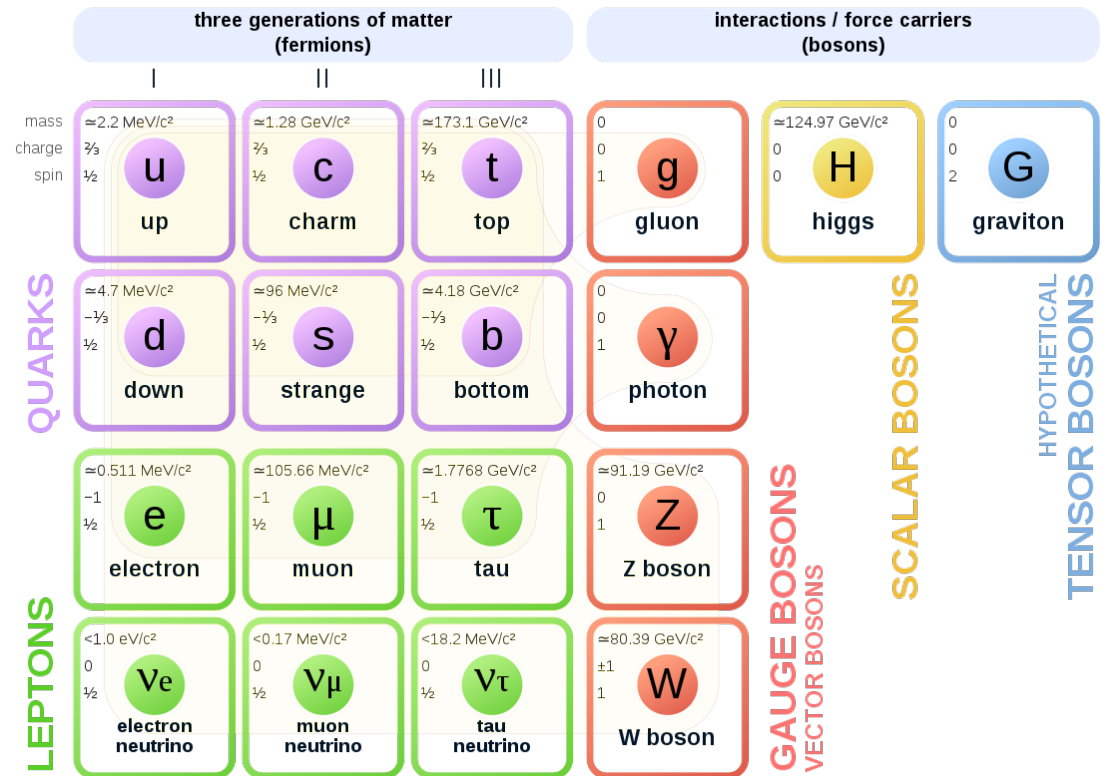
- The Standard Model (SM) and its incompleteness
- Unsolved problems in the SM
- Dark Matter
- Dark Matter Candidates
- Hidden sector
- The PADME experiment
- Detector system
- Possible researches
- Current status

The Standard Model

What do we (don't) know about modern physics?

- Particles
- Interactions
- The Higgs boson
- Still some questions
- The Standard Model is a low energy approximation of a more fundamental theory.

Standard Model of Elementary Particles and Gravity

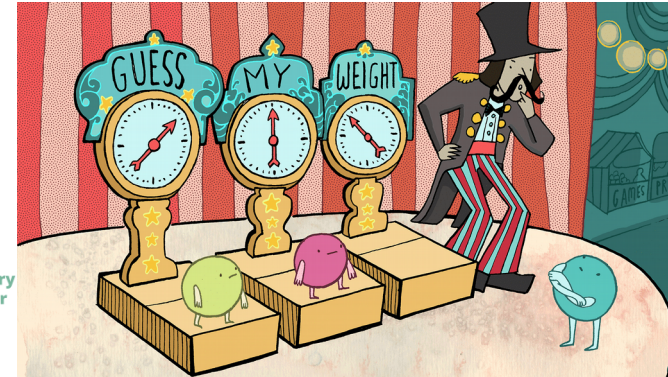
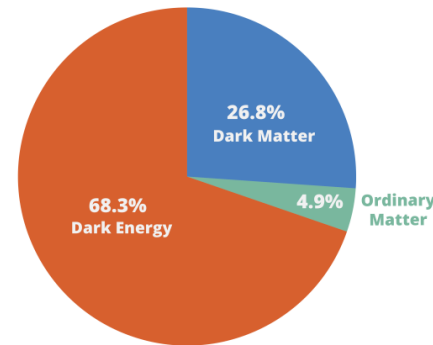


• **But which theory?**

The missing parts of the puzzle

- CP-violation
- Higgs boson mass
- Neutrino masses
- GUT
- Baryogenesis
- Dark matter
- Dark energy
- ...
- More than one answer?

Estimated matter-energy content of the Universe

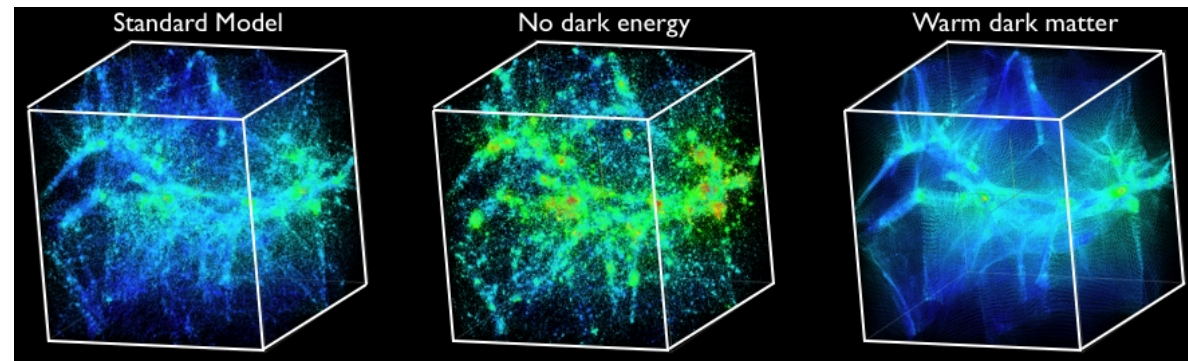


ATLAS EXPERIMENT

Artwork by Sandbox Studio, Chicago with Corinne Mucha



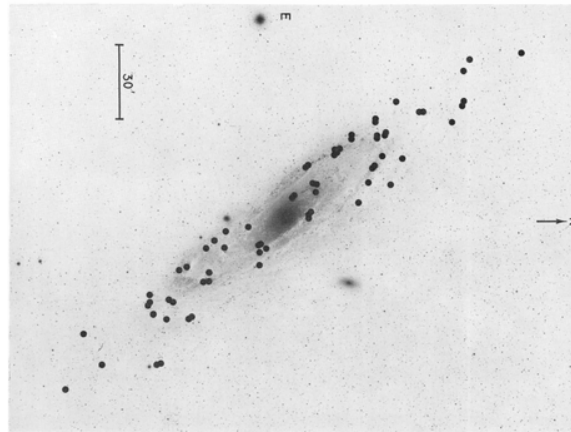
$$SU(5) \supset SU(3) \times SU(2) \times U(1)$$



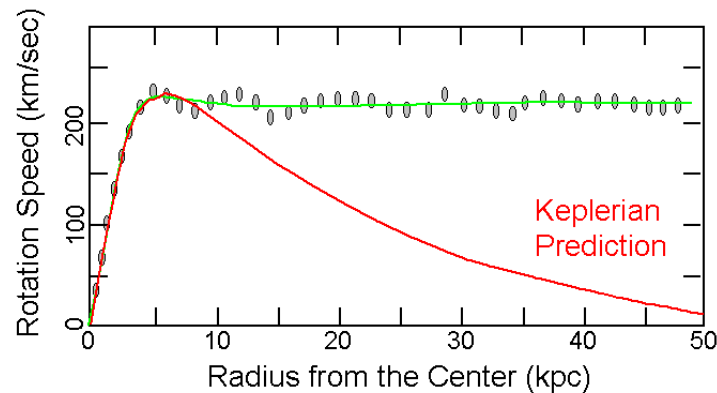
Simulated dark matter distribution for different cosmological models (colors: velocities) demonstrating the power of large-scale structure measurements to probe new physics.

Dark Matter

- Fritz Zwicky and the Coma Cluster
- Vera Rubin
- Baryonic
- Non-baryonic

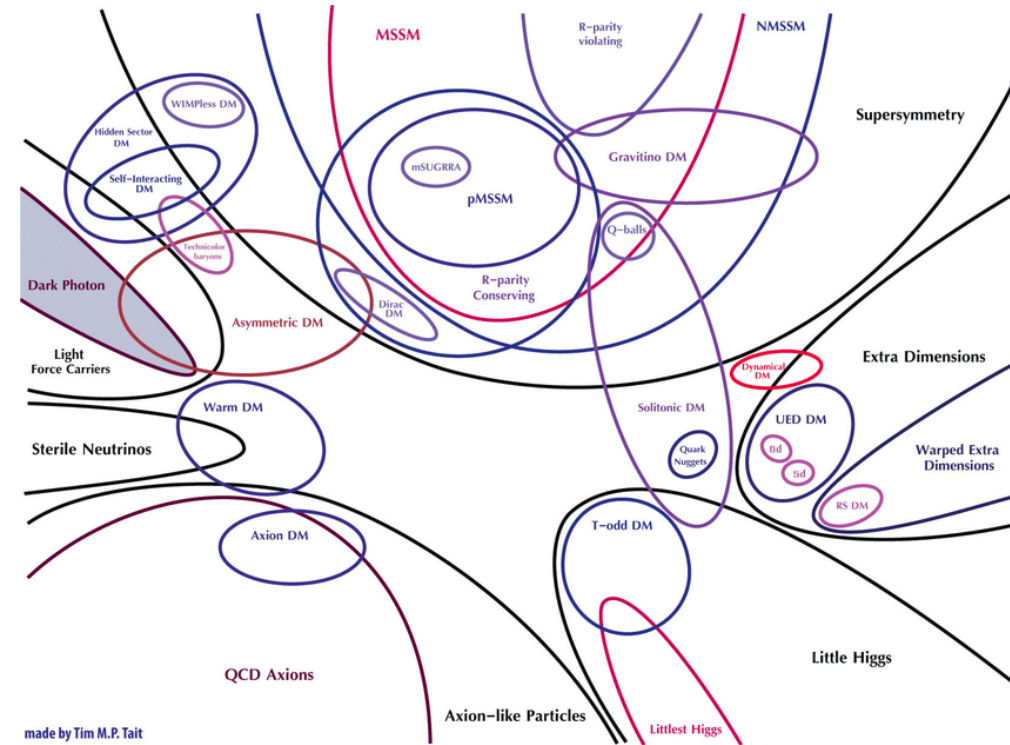
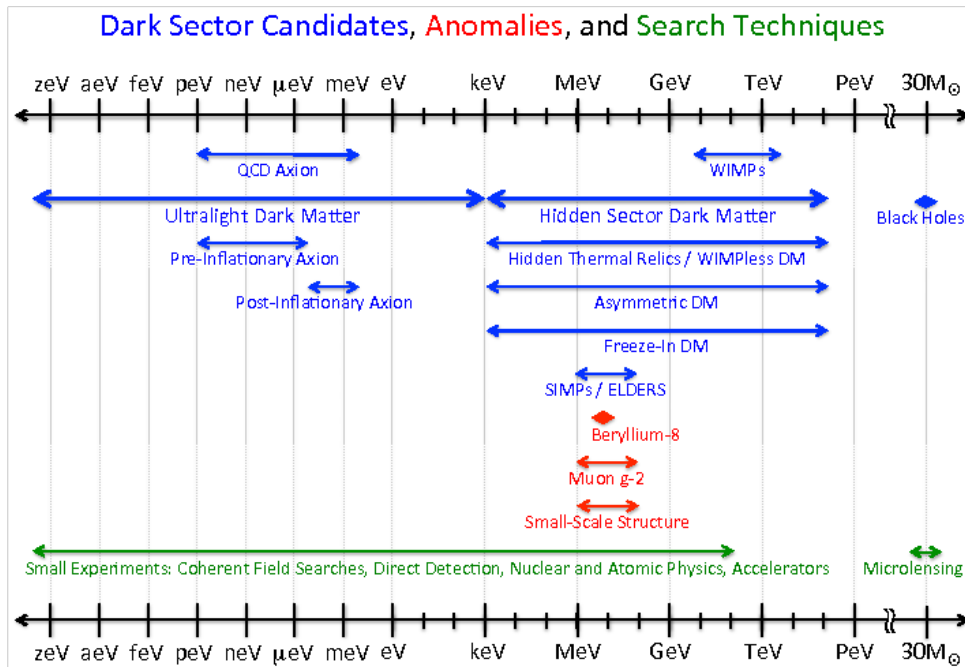


Observed vs. Predicted Keplerian

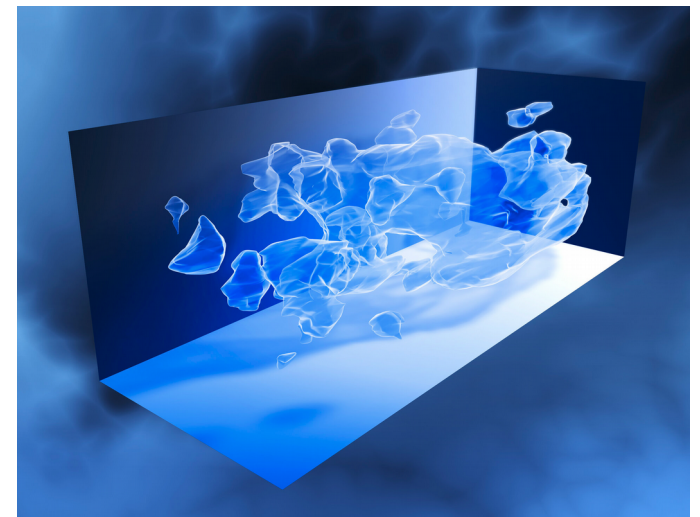


$$\frac{mv^2}{r} = \frac{mMG_N}{r^2}$$

Possible Candidates



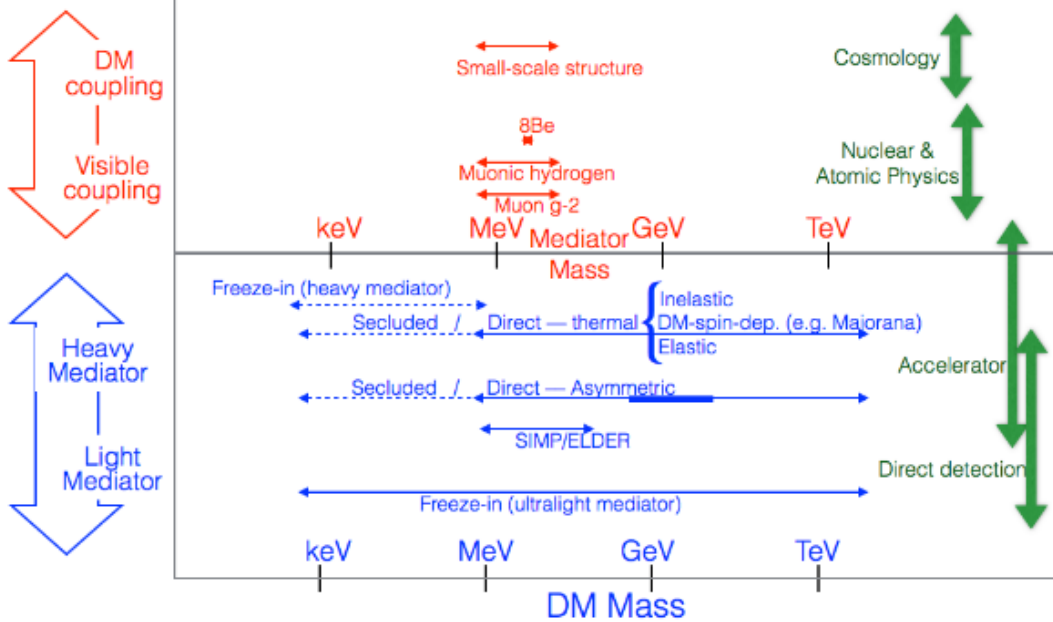
- Many candidates
- Many fields for research
- One may solve more than one problem
- Throw a needle in the Universe or...



Credit: Hubble Space Telescope Project

Come to the dA'rk sector

Hidden-sector Dark Matter: Anomalies, Production Mechanisms, and Detection Strategies

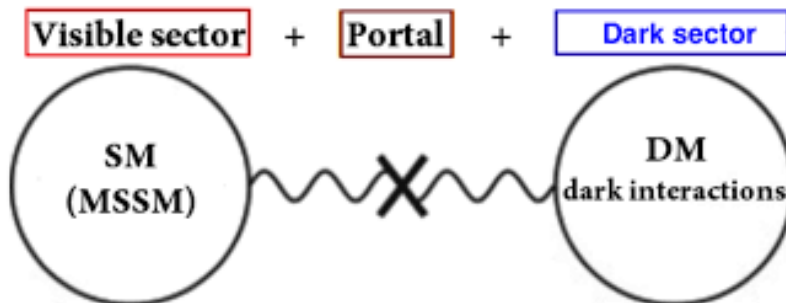


Particle	mass	charge	spin
u (up quark)	~2.3 MeV/c ²	2/3	1/2
c (charm quark)	~1.275 GeV/c ²	2/3	1/2
t (top quark)	~173.07 GeV/c ²	2/3	1/2
g (gluon)	0	0	1
H (Higgs boson)	~126 GeV/c ²	0	0
d (down quark)	~4.8 MeV/c ²	-1/3	1/2
s (strange quark)	~95 MeV/c ²	-1/3	1/2
b (bottom quark)	~4.18 GeV/c ²	-1/3	1/2
γ (photon)	0	0	1
e (electron)	0.511 MeV/c ²	-1	1/2
μ (muon)	105.7 MeV/c ²	-1	1/2
τ (tau)	1.777 GeV/c ²	-1	1/2
Z (Z boson)	91.2 GeV/c ²	0	1
ν _e (electron neutrino)	<2.2 eV/c ²	0	1/2
ν _μ (muon neutrino)	<0.17 MeV/c ²	0	1/2
ν _τ (tau neutrino)	<15.5 MeV/c ²	0	1/2
W (W boson)	80.4 GeV/c ²	±1	1

Standard Model

Portal

Hidden Sector



Credit: Institute for Basic Science

Positron Annihilation into Dark Matter Experiment

M. Raggi and V. Kozhuharov, Adv. High Energy Phys.2014, 959802 (2014), 1403.3041.
 M. Raggi, V. Kozhuharov, and P. Valente, EPJ Web Conf.96, 01025 (2015), 1501.01867.



Cornell Laboratory for
Accelerator-based Sciences
and Education (CLASSE)



P. Albicocco,^a J. Alexander,^b F. Bossi,^a P. Branchini,^c B. Buonomo,^a C. Capocchia,^a E. Capitulo,^a G. Chiodini,^d A.P. Caricato,^{d,e} R. de Sangro,^a C. Di Giulio,^a D. Domenici,^a F. Ferrarotto,^f G. Finocchiaro,^a S. Flore,^{f,g} L.G. Foggetta,^a A. Frankenthal,^b G. Georgiev,^{h,a} A. Ghigo,^a F. Giacchino,^a P. Gianotti,^a S. Ivanov,^h V. Kozhuharov,^{h,a} E. Leonardi,^f B. Liberti,ⁱ E. Long,^{j,f} M. Martino,^{d,e} I. Oceano,^{d,e} F. Oliva,^{d,e} G.C. Organtini,^{j,f} G. Piperno,^{f,j,1} M. Raggi,^{j,f} F. Safal Tehrani,^f I. Sarra,^a B. Sciascia,^a R. Simeonov,^h A. Saputi,^a T. Spadaro,^a S. Spagnolo,^{d,e} E. Spiriti,^a D. Tagnani,^c C. Taruggi,^{a,k} L. Tsankov,^h P. Valente,^f and E. Vilucchi^a



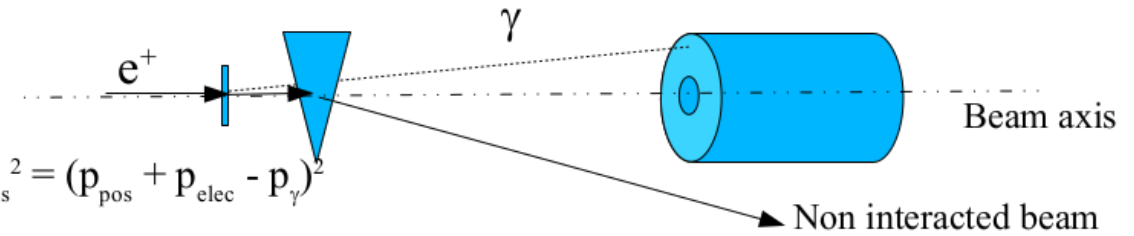
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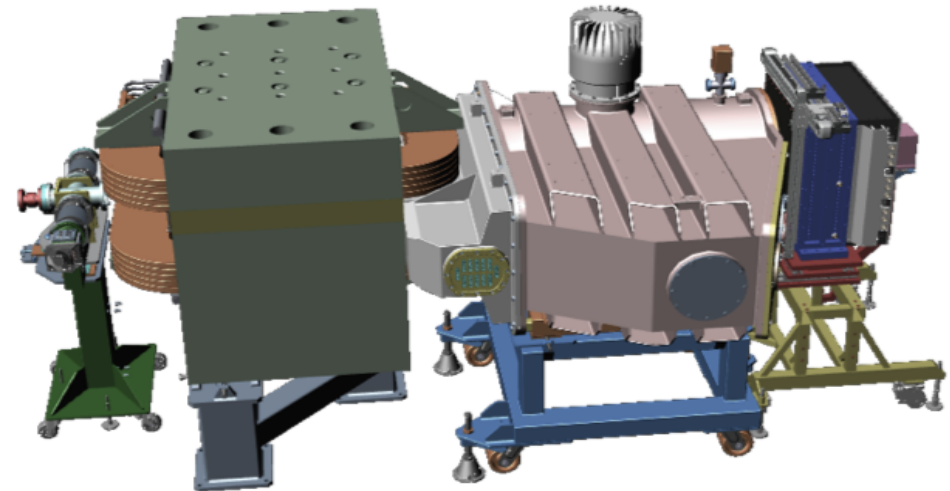
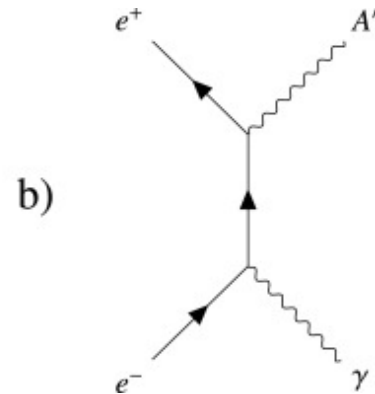
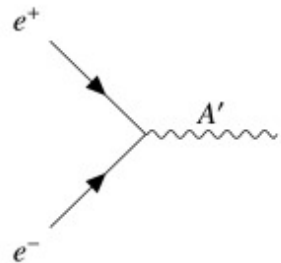
PADME



$$e^+ + e^- \rightarrow \gamma + A'$$

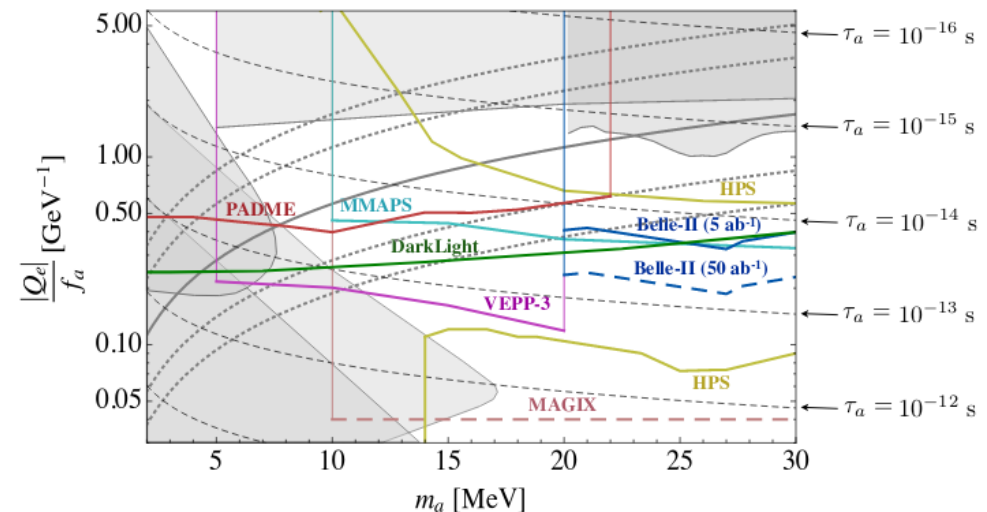
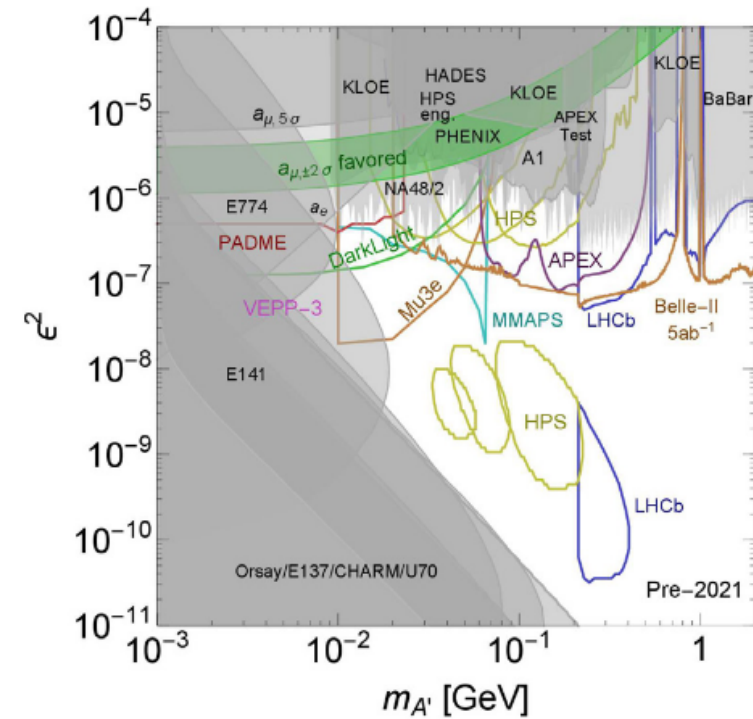


- Small scale fixed target experiment $M_{\text{miss}}^2 = (p_{\text{pos}} + p_{\text{elec}} - p_{\gamma})^2$
- E+ @ Frascati beam test facility from DAΦNE Linac
- Positron beam ($E \sim 550$ MeV) on a thin target
- Positron momentum is determined by the accelerator characteristics
- Missing mass technique
- $M_{A'} \sim 2 - 23.7$ MeV



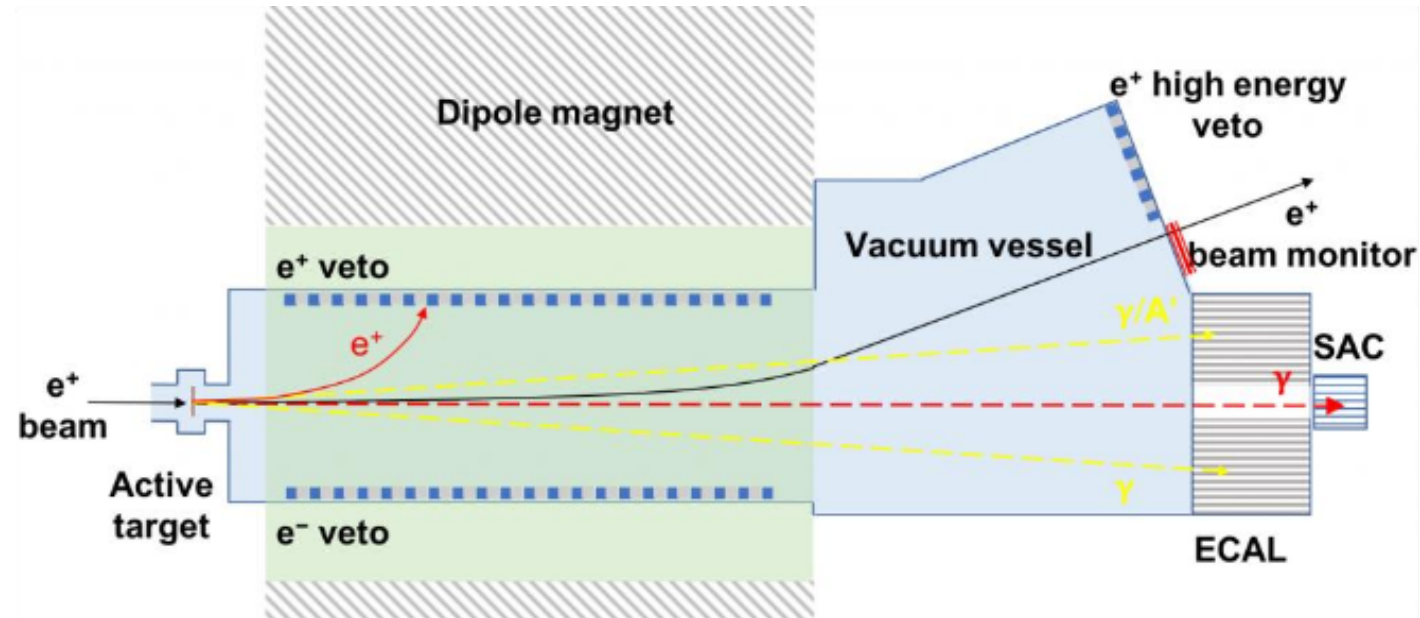
Fields of research

- Experimental searches for the dark photon
- The first experiment to look for the dark photon in the invisible decay using e^+ beam on fixed target
- Dark photon escapes detection
- Possibilities for different portals – ALPs
- Final states for ALP production
 - visible – $\gamma + x$ (missing mass)
 - invisible – $\gamma\gamma\gamma$ or $\gamma e^+ e^-$
- Dark Higgs
- ^8Be anomaly



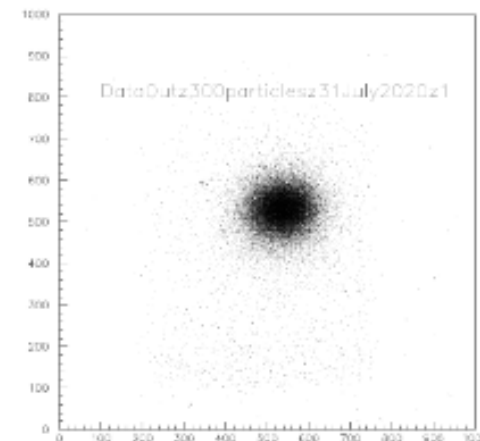
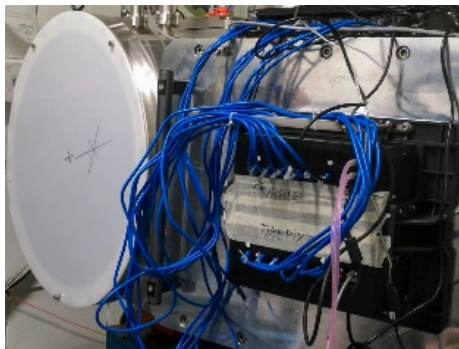
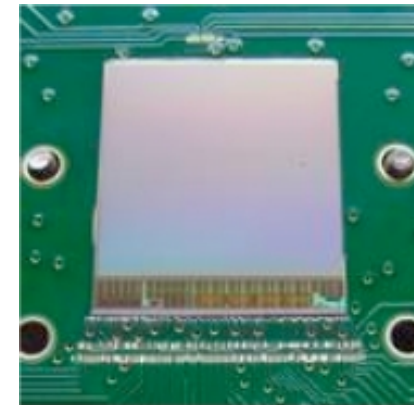
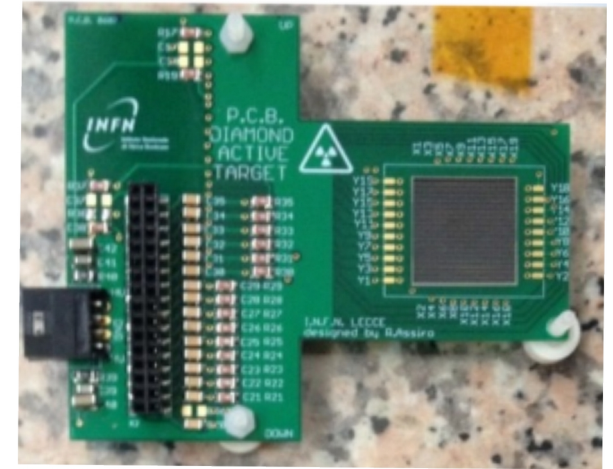
Detector System

- Target
- Mimosa
- TimePix
- Veto detectors
- Calorimeter
- SAC



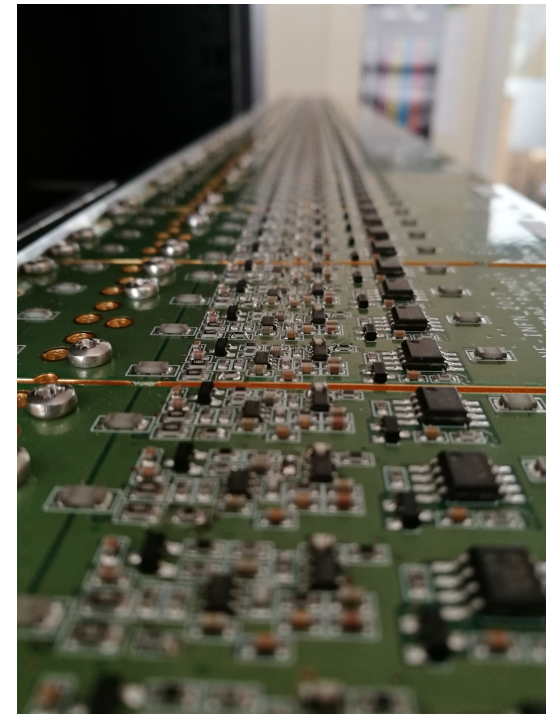
Detector system

- Target
 - 100 μm thick polycrystalline diamond target
 - information about incoming beam (position, size and intensity)
 - designed and assembled at the University of Salento (Lecce)
- Mimosa
 - monolithic pixel tracker
 - information about beam position and divergence
- TimePix3
 - not interacting e+beam
 - position, time and energy of each particle.



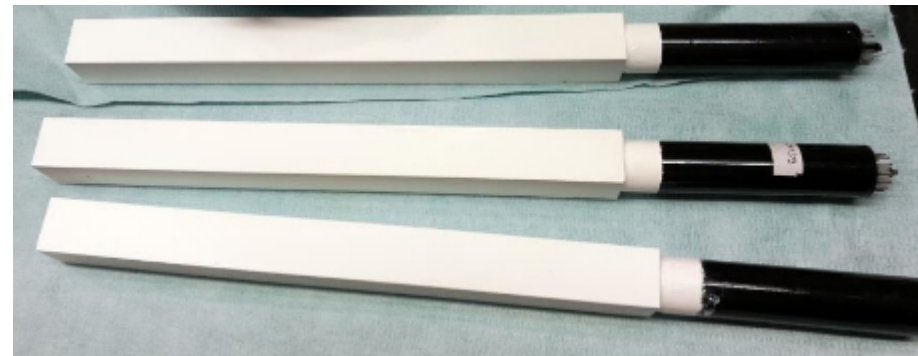
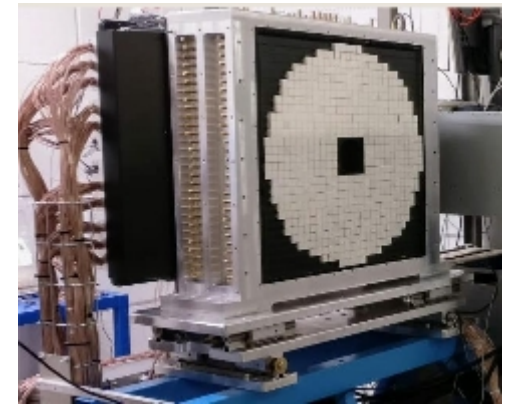
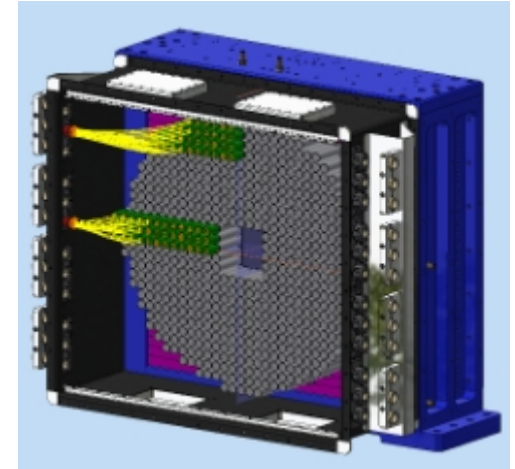
Detector system

- Pveto
 - 96 scintillating bars
- Eveto
 - 90 scintillating bars
- Both in vacuum (10⁻⁵ mbar) and magnetic field (~ 0.45 T)
- HEPVeto
 - 16 scintillating bars
- SiPMHamamatsu S13360 3 × 3 mm² × 25 μ m cell
- Veto Bremsstrahlung events
- Sofia University



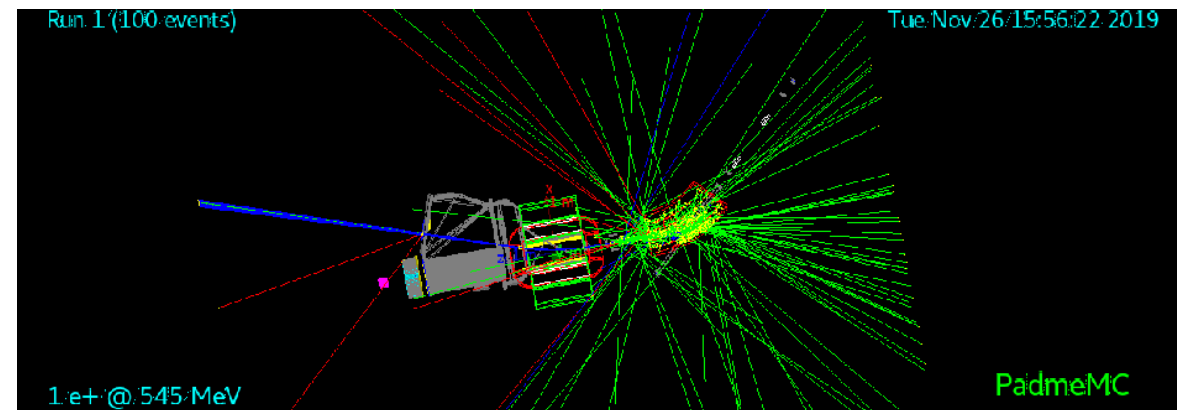
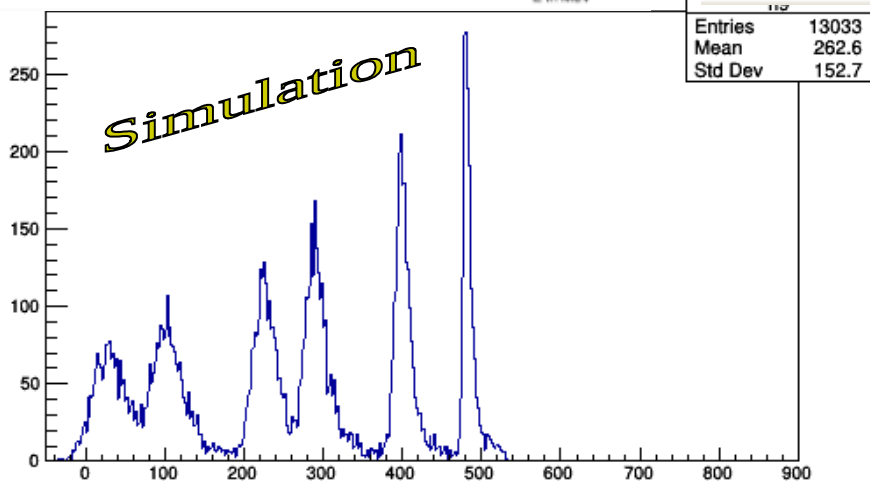
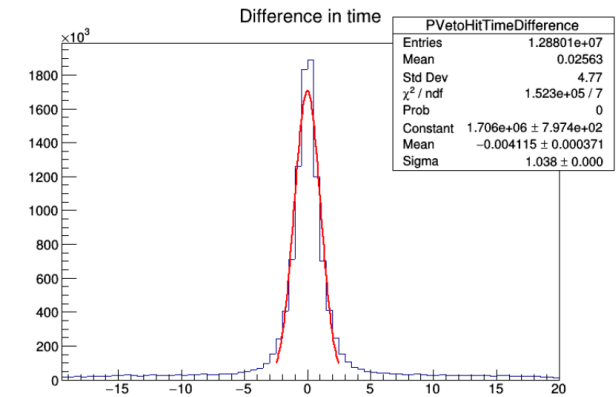
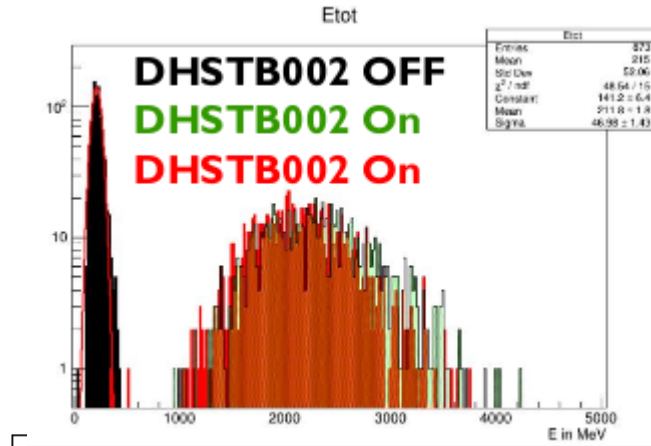
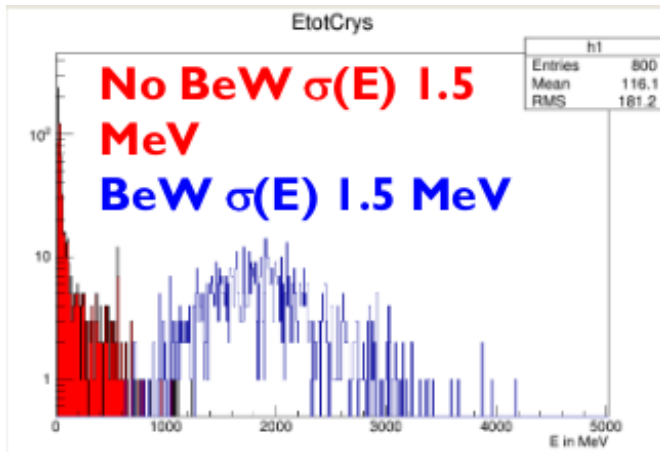
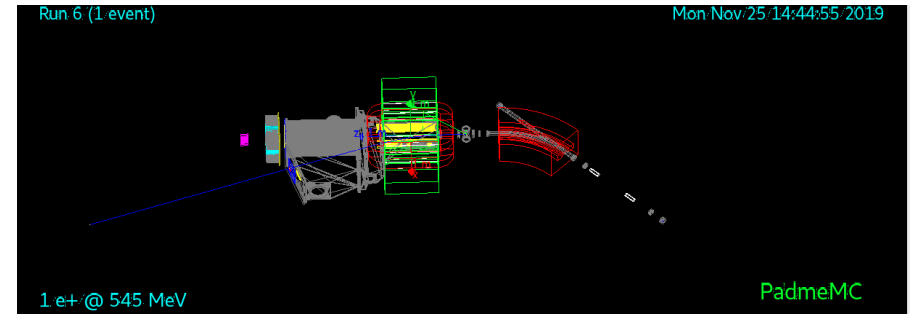
Detector system

- ECAL
 - Detect the γ in the final state
 - BGO crystals
 - 616 crystals $21 \times 21 \times 230 \text{ mm}^3$
- SAC (Small Angle Calorimeter)
 - 25 $3 \times 3 \times 14 \text{ cm}^3 \text{ PbF}_2$ crystals (Cherenkov)
 - Angular coverage: $[0, 18.9] \text{ mrad}$
 - Two independent calibrations
 - beam
 - cosmic rays

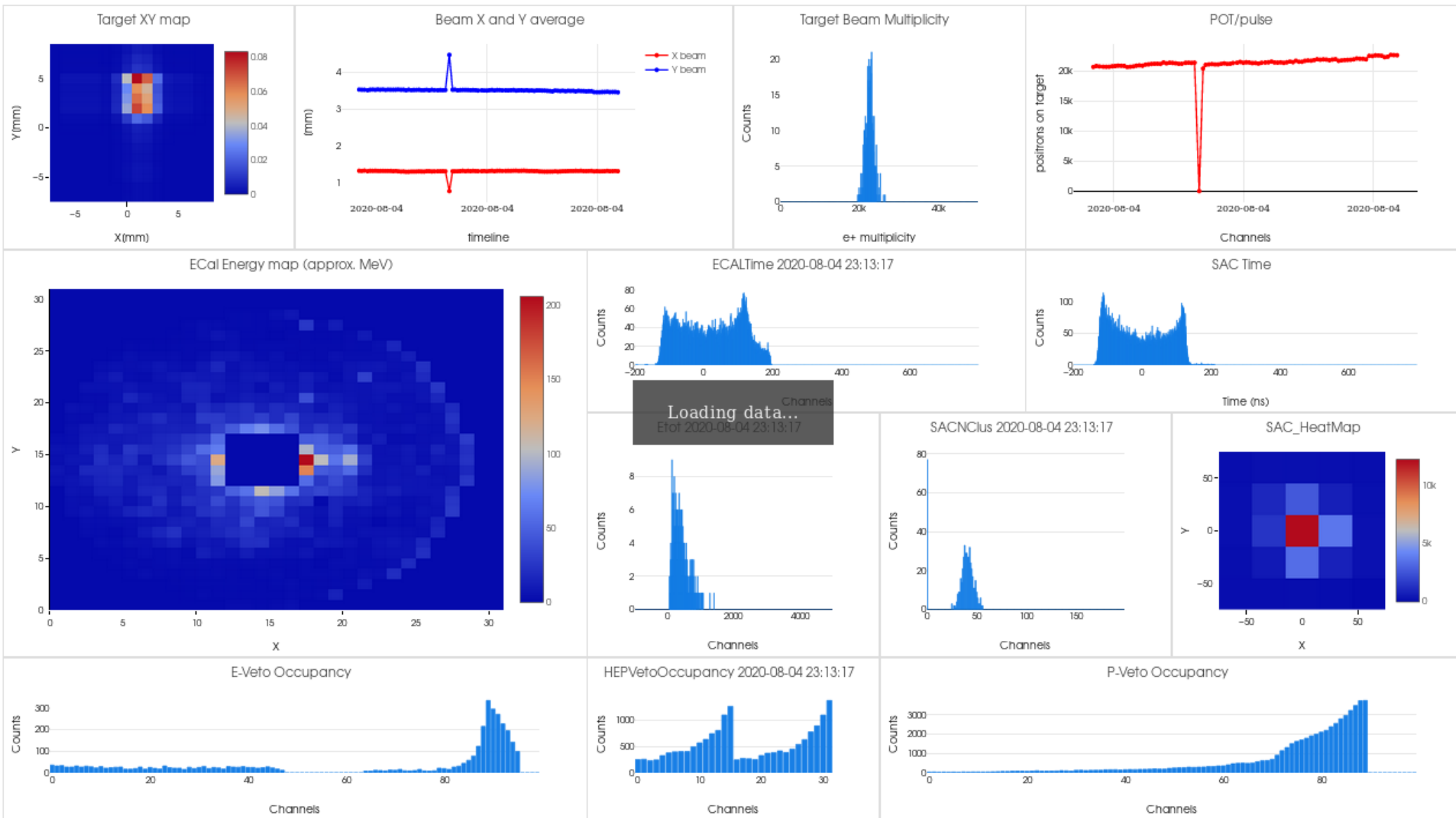


PADME Monte Carlo and Padme Reconstruction

- Detectors calibration
- Background studies



The data taking in real time





Conclusion

- The Dark matter may hide the missing parts of the SM
- PADME searches for portals that can throw some light on the dark sector
- On 4/10/18 PADME started the commissioning data taking
- The collected data helped us to observe our detector's behavior
- A lot about the experiment's background was learned
- At the moment new physics run is ongoing