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The charged particle veto system of the PADME experiment

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The role of the veto system

The PADME experiment will search for the production of the dark photon A'* with the **missing mass method**[1]

The experiment will be allocated at the Beam Test Facility of the Laboratori Nazionali di Frascati(LNF)

$$m^2_{A'} = (P_{beam} + P_{e^-} - P_\gamma)^2$$

Beam delivered by the DAΦNE Linac
5000 e⁺ per bunch

For E_{beam}=550 MeV $M_{A'} \leq 23.7$ MeV/c²

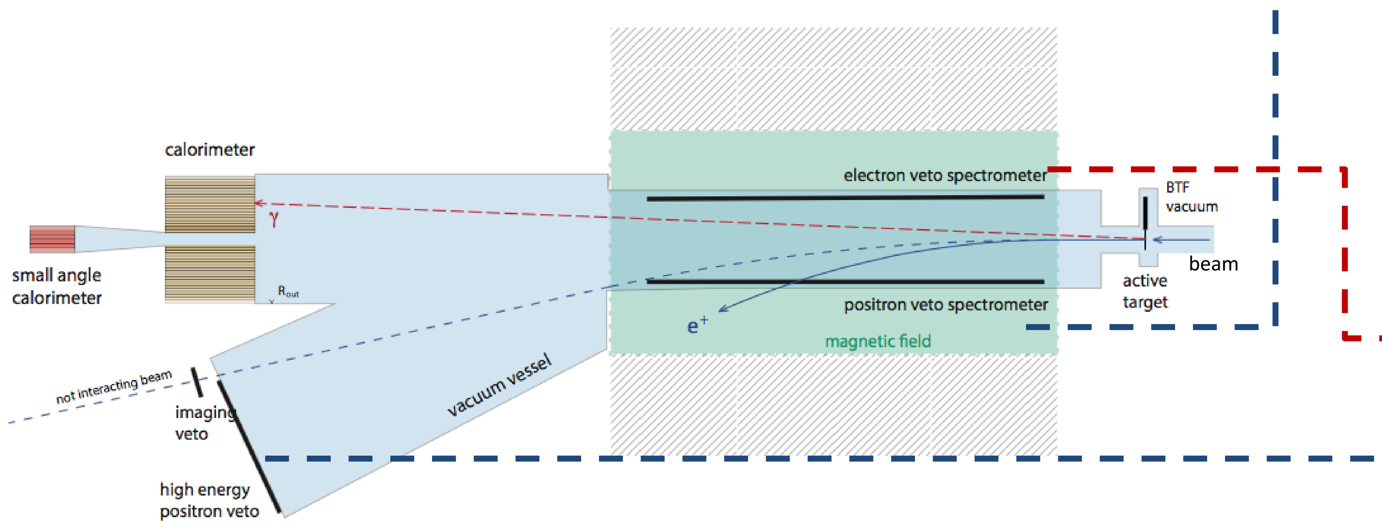
*Physics motivation and experiment layout more deeper illustrated in the poster: **"The investigation on the dark sector at the PADME experiment".**

SIGNAL $e^+e^- \to \gamma A'$

BACKGROUND

Bremsstrahlung on the active diamond target $e^+N \to e^+N\gamma$

Annihilation into 2(or 3) SM photons $e^+e^- \to \gamma\gamma(\gamma)$



Positrons that emit bremsstrahlung photons will have lower energy

$E_{e+} < E_{beam}$

2 different veto systems for positrons which differ from the energy of the photon emitted

1. Positron Veto in the magnetic field, covering the internal left vertical wall (1 m long) of the dipole magnet

2. HEP High Energy Positrons — Covering the angular region between the beam dump and the magnet (450<E_{e+}<550 MeV)

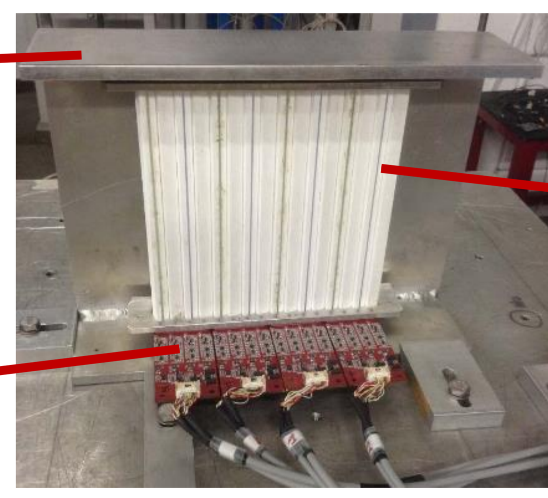
A Bremsstrahlung event is identified by an ECAL cluster and a hit in PV in time coincidence **Time reso<1ns needed!**
Energy balance with the beam may be requested to improve the Bremsstrahlung event identification

Electron veto
in the magnetic field, covering the internal right vertical wall (1 m long) of the dipole magnet to search for visible decays of the dark photon!

Veto system parameters

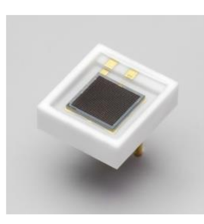
SUPPORT FRAME

Alluminum support structure to hold an array of 96(16) scintillating bars for PV and EV (HEP) together with the FEE boards
Scintillating bars are parallel to the magnetic field direction and rotated around their longitudinal axis by 0.1 rad to minimize geometrical inefficiencies



FRONT-END ELECTRONICS (FEE)

Silicon photo-multiplier SiPM
- ✓ Able to work inside vacuum
- ✓ Sustain stationary magnetic field of 0.6 T
- ✓ Low Operating Voltage
- ✓ Cheap



Hamamatsu 13360

FEE channel includes a transimpedance amplifier (gain=4)

HV regulation module+voltage end current monitor
One FEE board serves 4 channels

GAIN≈10⁵ -10⁶

Signals will be digitized by **CAEN V1742**

SCINTILLATING BARS

SCINTILLATORS
Polystyrene-based scintillating plastic bars with 1,5% POPOP produced by **UNIPLAST**

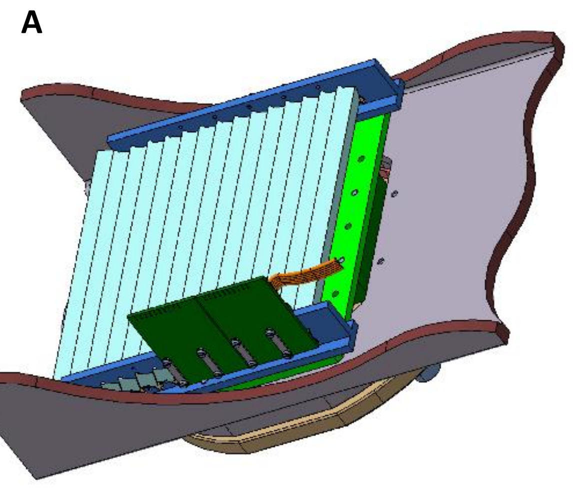
DIMENSION **Long side perpendicular to the beam!**
Cross section :10x10 mm² **Length**: 200 mm(to be cut and polished)

OPTICAL FIBERS
BCF-92 optical fibers housed in a longitudinal groove of cross section 1.3x1.3 mm²

BCF-92
- light attenuation length is >3.5 m
- maximal absorbition at 400nm, matching POPOP emission
- maximal emission at 492 nm(Wave Length Shifter)

The construction of a prototype

A



- **16 bars** cut at the desidered length (of approximately **180 mm** to fit into the dipole magnet clearance) and covered with a chemical reflector; 4 counters served by each board (in green in fig.A). Several types used to compare performance (B).
- Support holding scintillators and FE boards assuring thermal coupling to the vacuum vessel
- WLS fibers of type BCF-192; some of them glued with Eljen EJ500 optical epoxy cement
- Optical contacts improved with Saint-Gobain BC-630 silicone optical grease
- SiPMs Hamamatsu S12572 used for the first prototype (> noise than 13360 SiPMs, chosen for the final experiment)

B

Channels	Scintillator species	Readout/Light collection
4 and 8	Fiber glued in the groove	Scintillator only
5 and 9	Fiber glued and aluminised*	Fiber and scintillator
6 and 10	No fiber used	Scintillator only
7 and 11	Fiber in the groove	Fibre and scintillators

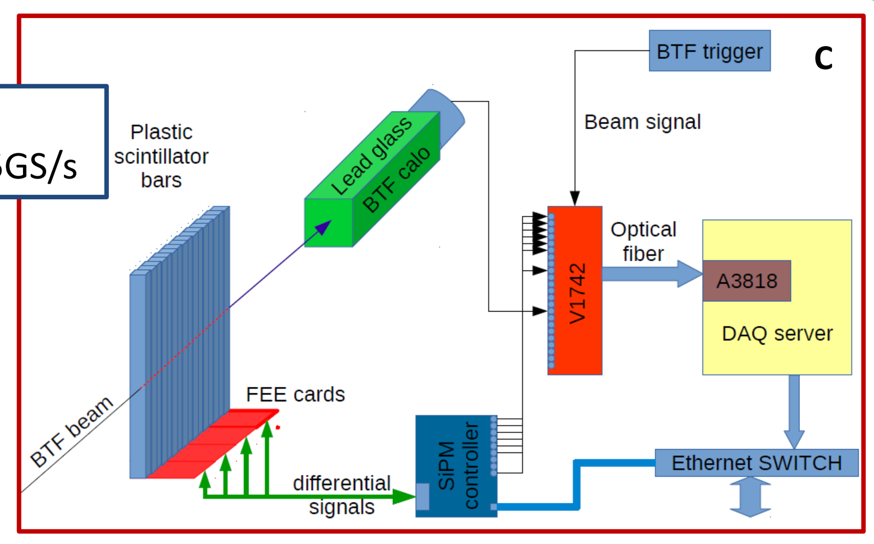
*8mm Al emulating the wall of the vacuum vessel

Tested on beam in April 2017 and candidate to be the first version of the HEP detector in PADME

Test beam of the prototype

At the Beam Test Facility of LNF, Frascati E_{beam} = 500 MeV

DAQ
CAEN V1742 rate: 5GS/s

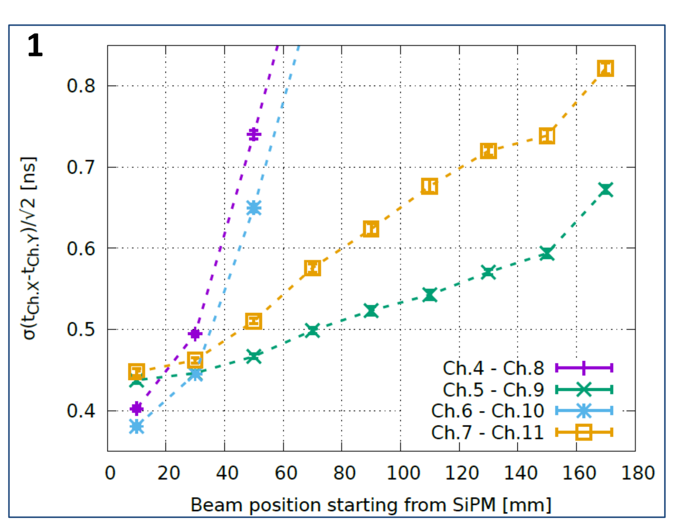


Lead glass calo(BTF Calo) downstream to measure beam multiplicity (particles per bunch) and energy.
Beam crossing all scintillators in the array as shown in fig. C.
A remote controlled table hosting the prototype allows varying the distance of the hit from the SiPM (9 steps from 10 mm to 170 mm).

Channels 0-3 and 12-15 used as offline trigger

RESULTS[2]

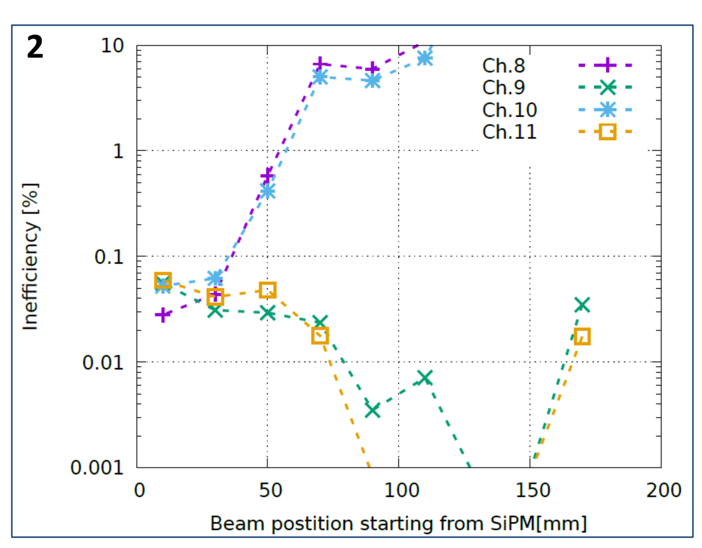
Time resolution measured using Δt for pairs of scintillating bars of the same kind (see scheme B) as a function of the distance of the beam impact point from the SiPM.
The different species of scintillators (and also the beam position) affect a lot the trend (fig.1).
Best performance (<1 ns at all distances) for scintillators with glued fibers .



Efficiency:
N_{events} with N_{phe-} >10 / $N_{triggers}$

Inefficiency (fig.2):
- below 0.1% at all distances for with optical fibers readout
- increasing quickly with the distance from SiPM for scintillators without fibers

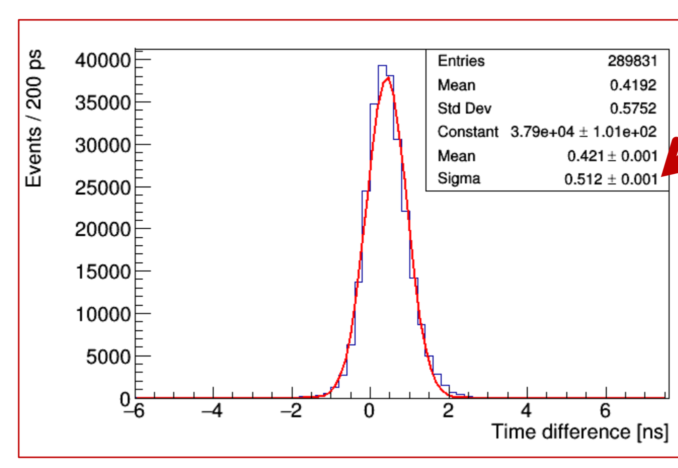
Noise below 1% for all scintillators



Updates

- ✓ Successful operation of FEE in vacuum demonstrated
- ✓ SiPM tested with a led driver, giving a good time resolution

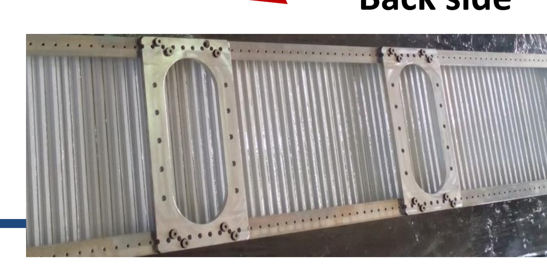
$\sigma_{\Delta t} \approx 500$ ps



- ✓ Veto experimental setup almost ready to be integrated in the final layout of the experiment

Front side

Back side



References

[1]M. Raggi and V. Kozhuharov, "*Proposal to Search for a Dark Photon in Positron on Target Collisions at DAΦNE Linac*", Adv. High Energy Phys., 2014;

[2]F.Ferrarotto et al., "*Performance of the prototype of the charged particle veto system of the PADME experiment*", DOI 10.1109/TNS.2018.2822724, IEEE Transactions on Nuclear Science.