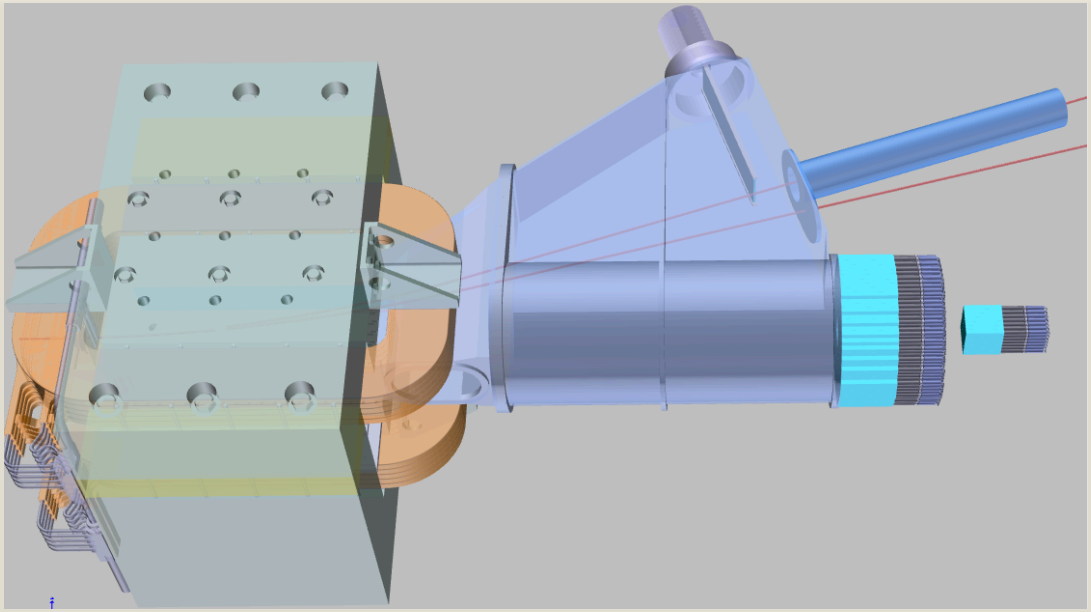
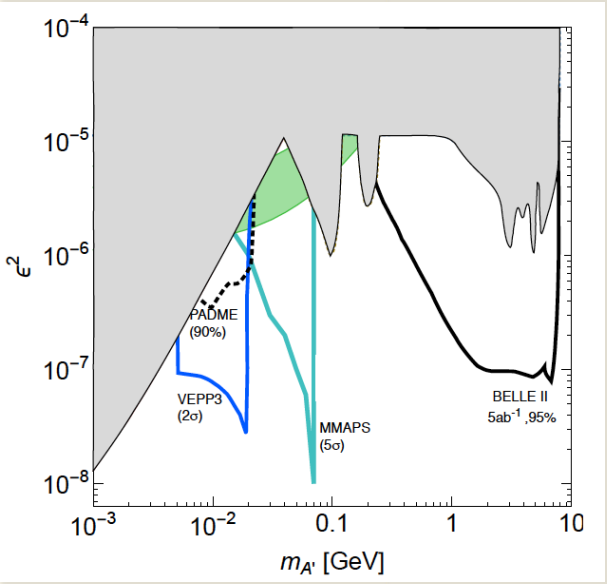
PADME status report



Dr. Mauro Raggi,
Sapienza Università di Roma e INFN Roma
52nd LNF Scientific Committee Meeting

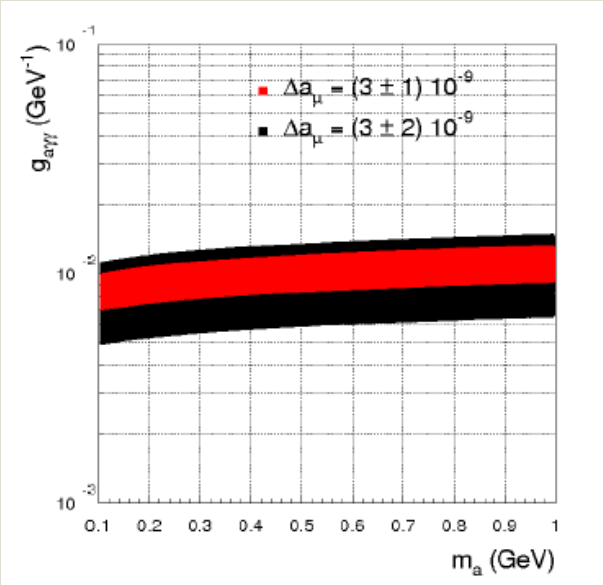
The PADME physics cases

Dark Photon arXiv:1608.08632v1



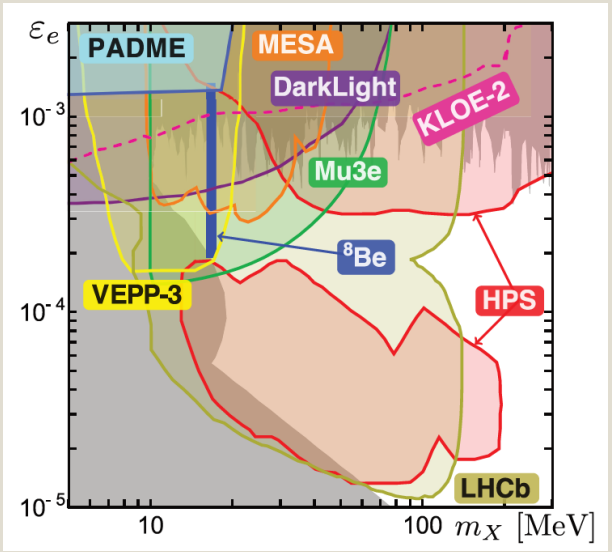
Invisible final state $e^+e^- \rightarrow \chi\chi$

ALPs and g-2 arXiv 1607.01022v2



ALPs final state $a \rightarrow \gamma\gamma$

Fifth force arXiv:1608.03591v1

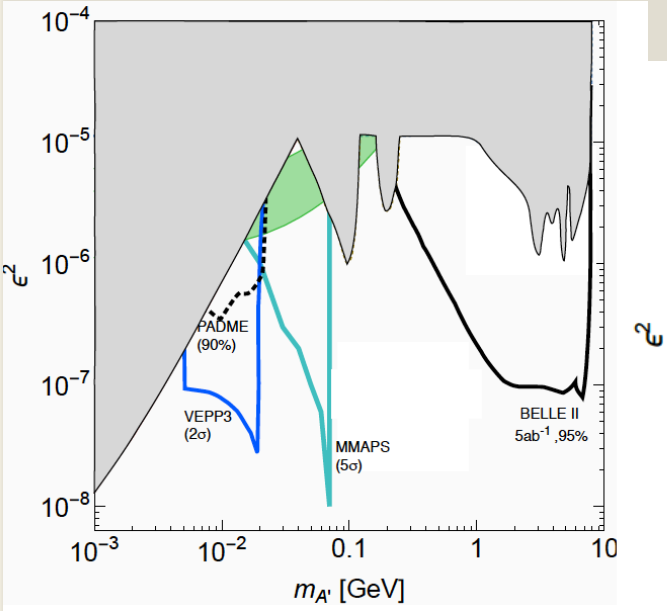


Final state $X \rightarrow ee$

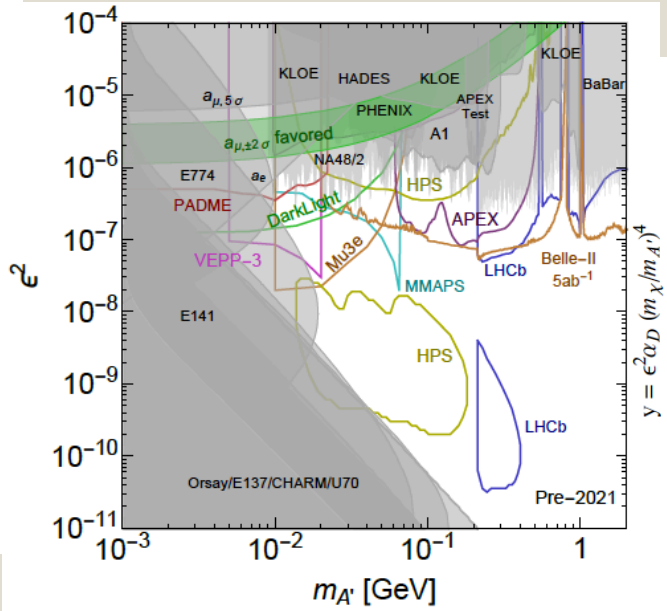
In all of this 3 important papers PADME is cited as among the experiments able to improve on current limits

PADME and Dark sector report

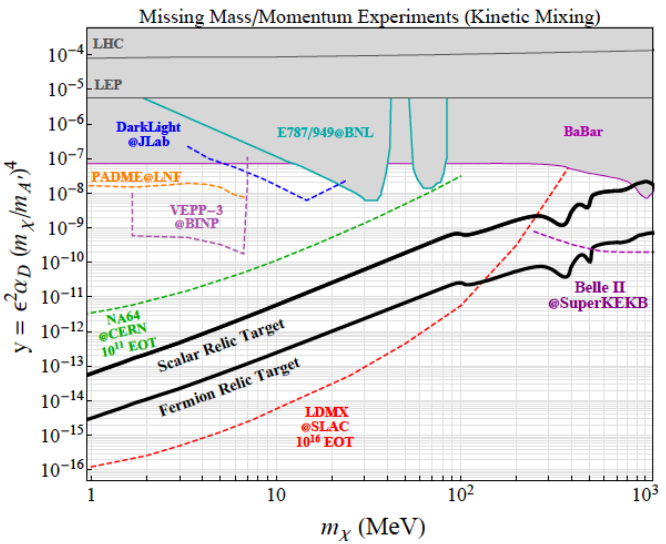
Invisible final state $e^+e^- \to \chi\chi$



Visible final state $A' \to ee$



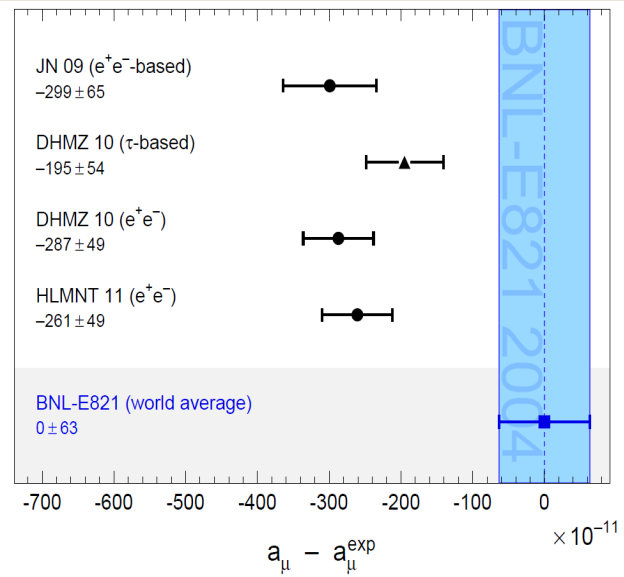
DM searches



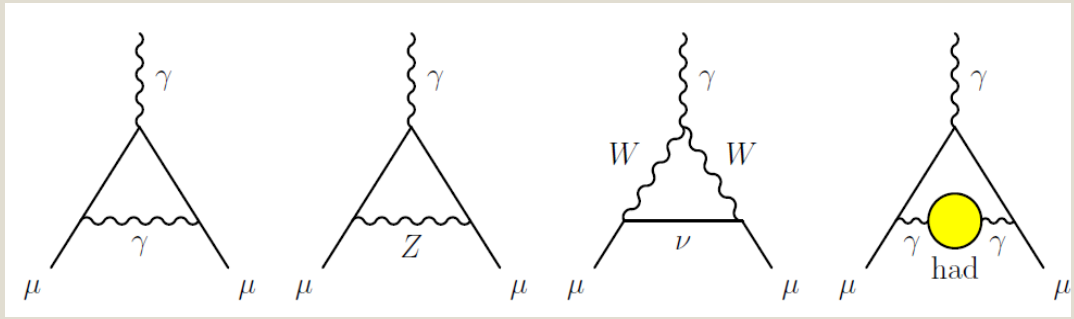
PADME has been added to plots in all of the possible searches categories: Invisible, Visible and light dark matter searches.

arXiv:1608.08632

Dark sector and g-2μ

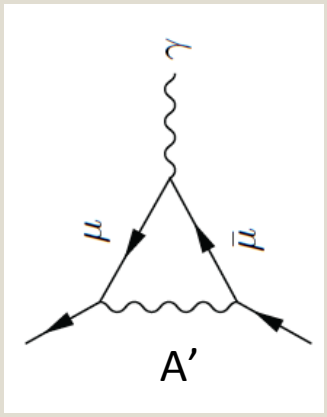


g-2 in the standard model



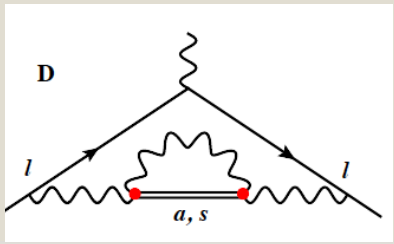
About 3σ discrepancy between theory and experiment. Could be due to hadronic uncertainties on the Light by Light scattering?

g-2 and A'



Additional diagram with dark photon exchange can fix the discrepancy!
(with sub GeV A' masses ☺)

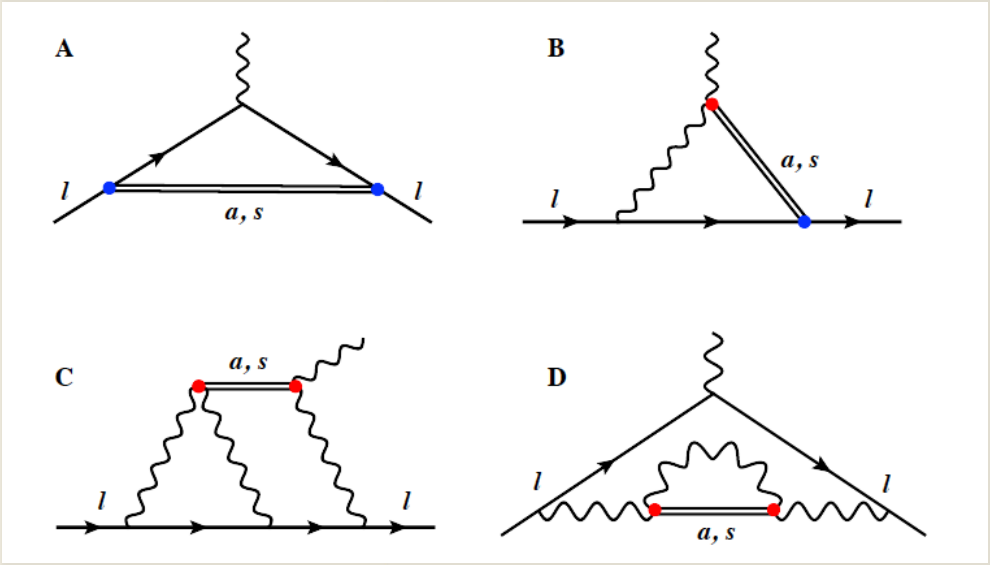
g-2 and ALPs

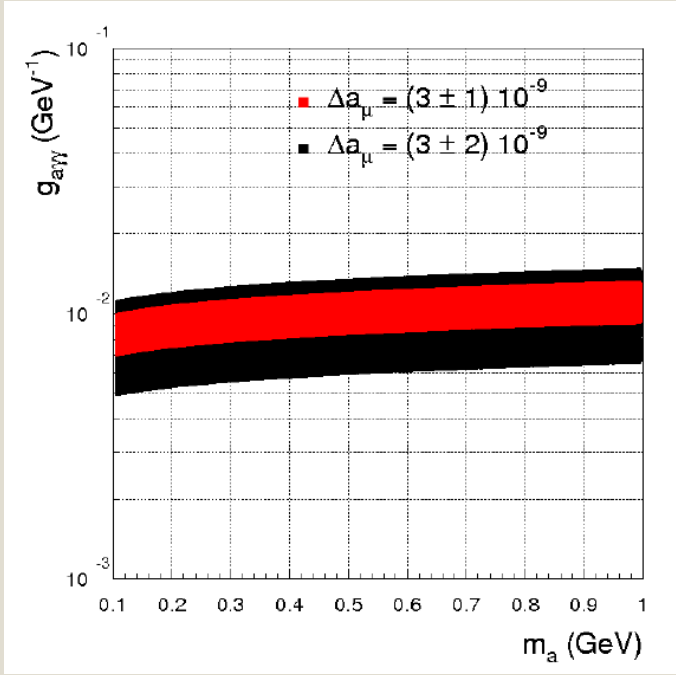


Additional diagram Axion like Particle exchange can fix the discrepancy!
(with sub GeV ALPs masses ☺)

ALPs and g-2

W.J. Marciano, A. Masiero, P. Paradisi, and M. Passera arXiv:1607.01022v1



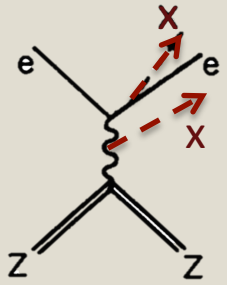


Production mechanisms at PADME

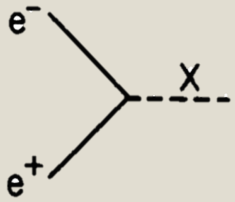
$$e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^-a\,,$$
$$e^+e^- \rightarrow \gamma^* \rightarrow \gamma a\,,$$

ALP physics at PADME

Bremsstrahlung



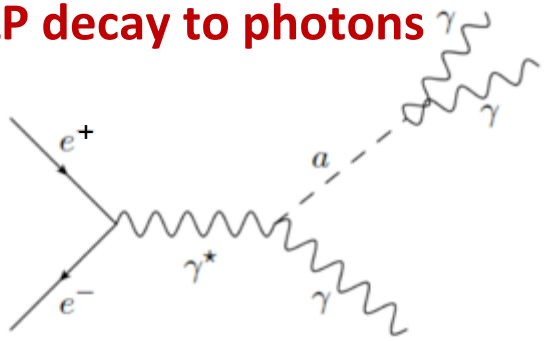
Annihilation



Phys rev D 38 11 1998

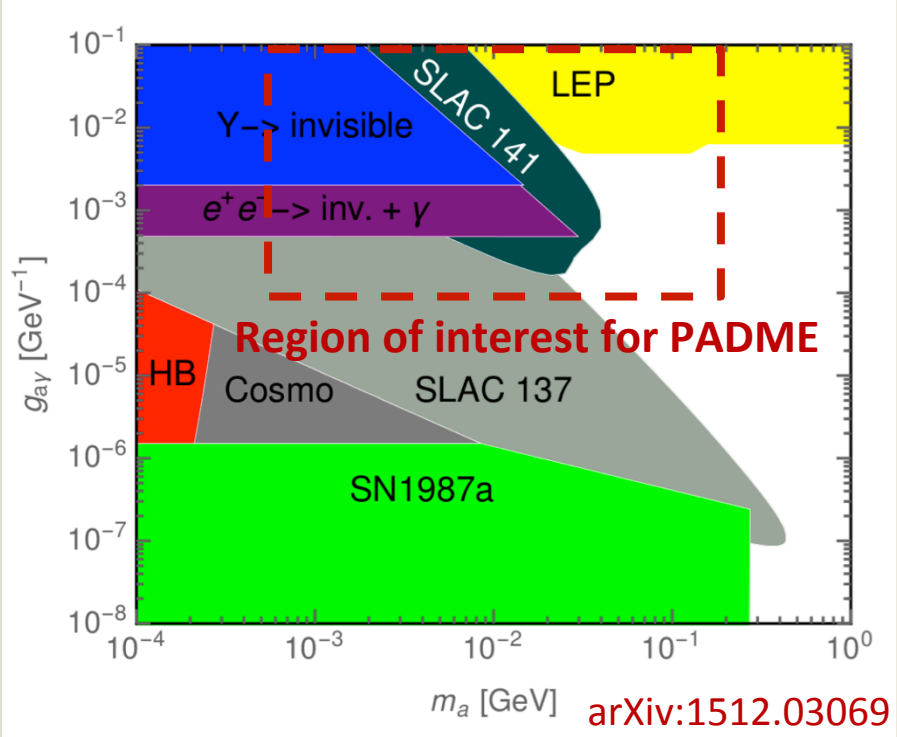
PADME ALPs produced in annihilation by looking for:
$1\gamma + M^2_{miss}$ or $\gamma\gamma\gamma$ final states

ALP decay to photons



Using the Bremsstrahlung production masses in the region of ~100MeV can be explored.

Limits on ALPs coupling to photons

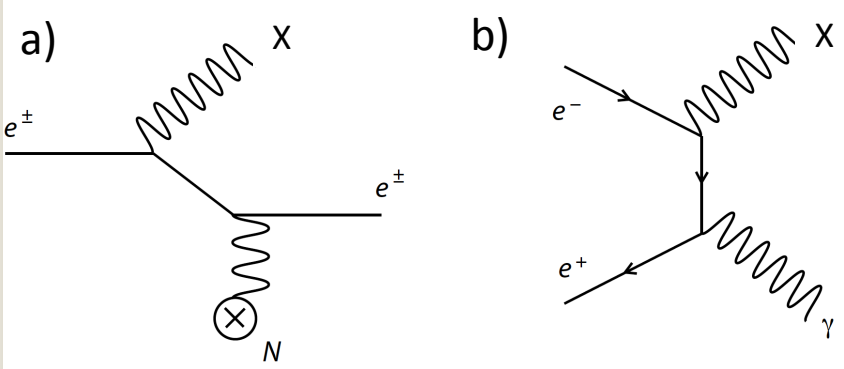


arXiv:1512.03069

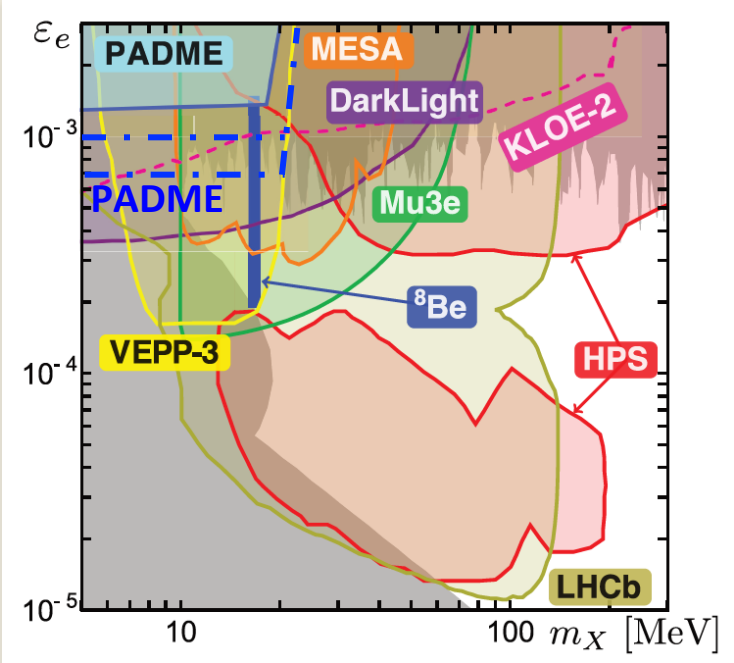
Production by radiation coming from intermediate virtual photon under study at LNF theory group(E. Nardi, F. Pelusi)

PADME and the Fifth force

Production mechanisms

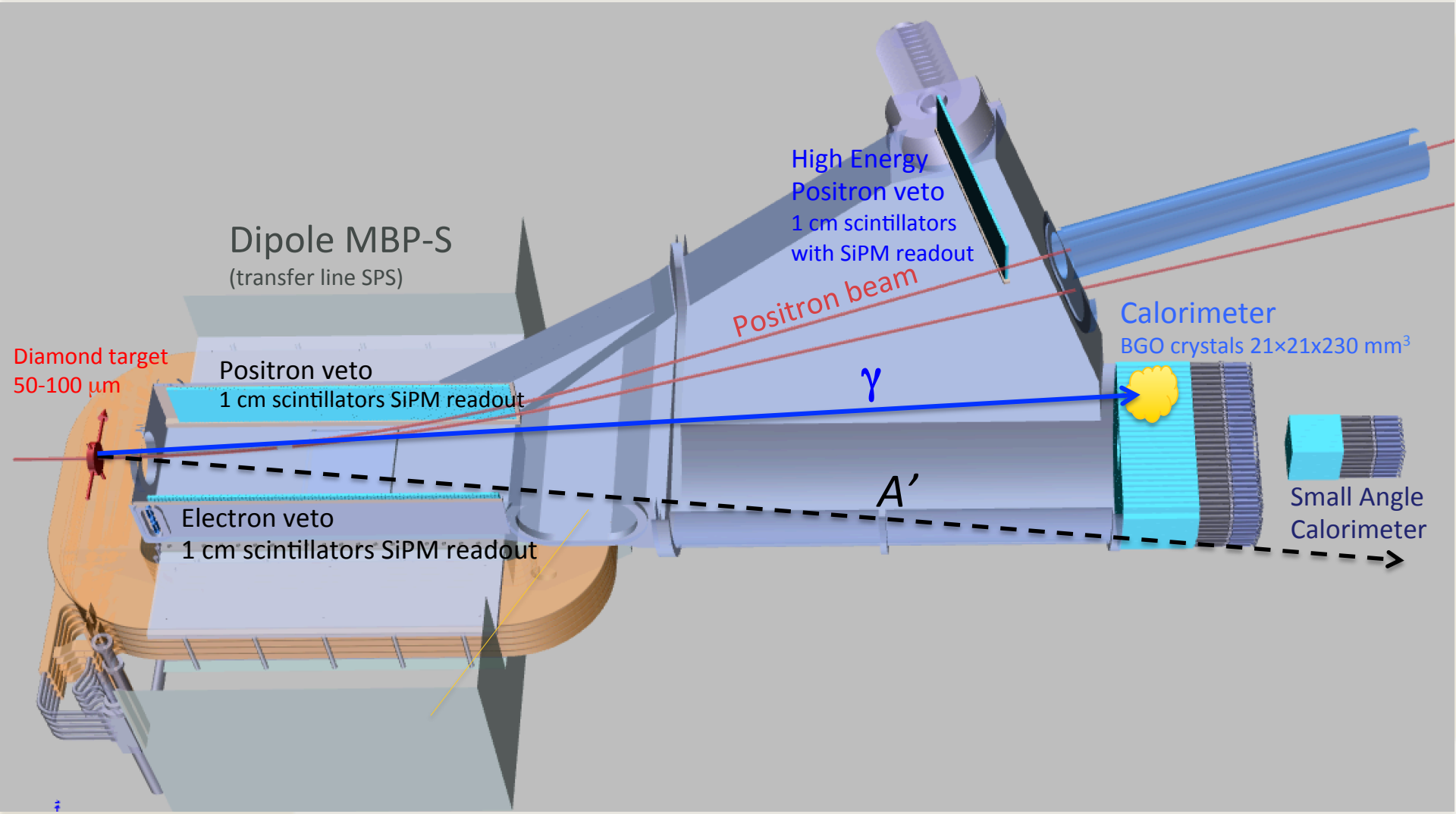


- Present sensitivity estimate including **only** production mechanism b): it would be much improved using also mechanism a)
  - Requires detecting the out-coming positron, which already we do for vetoing ordinary Bremsstrahlung
- PADME sensitivity in the paper just uses our first published simulation: it's much better with new estimate and with >160ns beam length
- More space for improvement with a better detection of e^+e^- pairs and in the production.

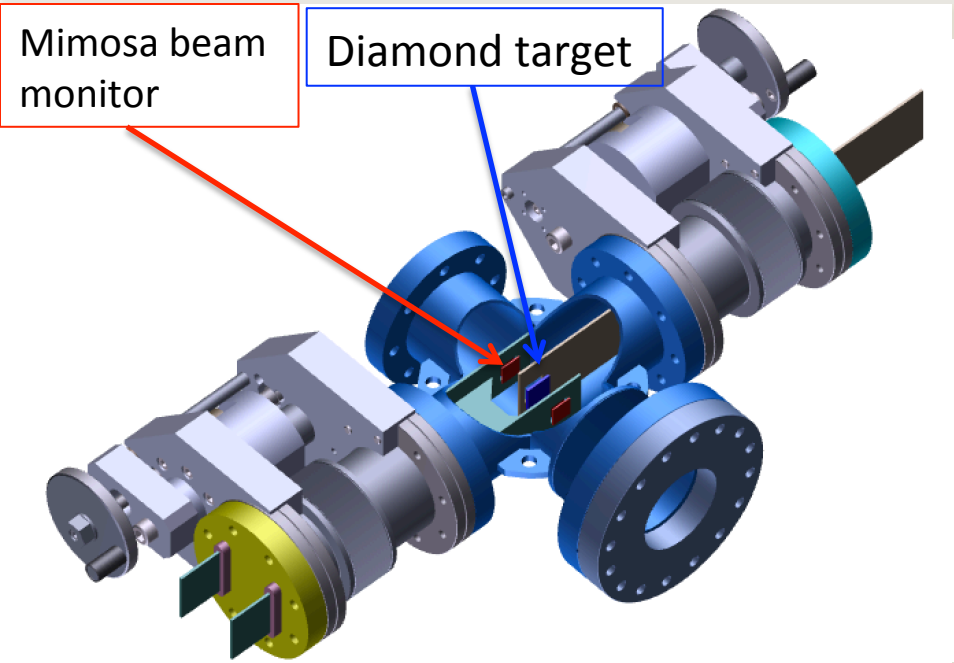


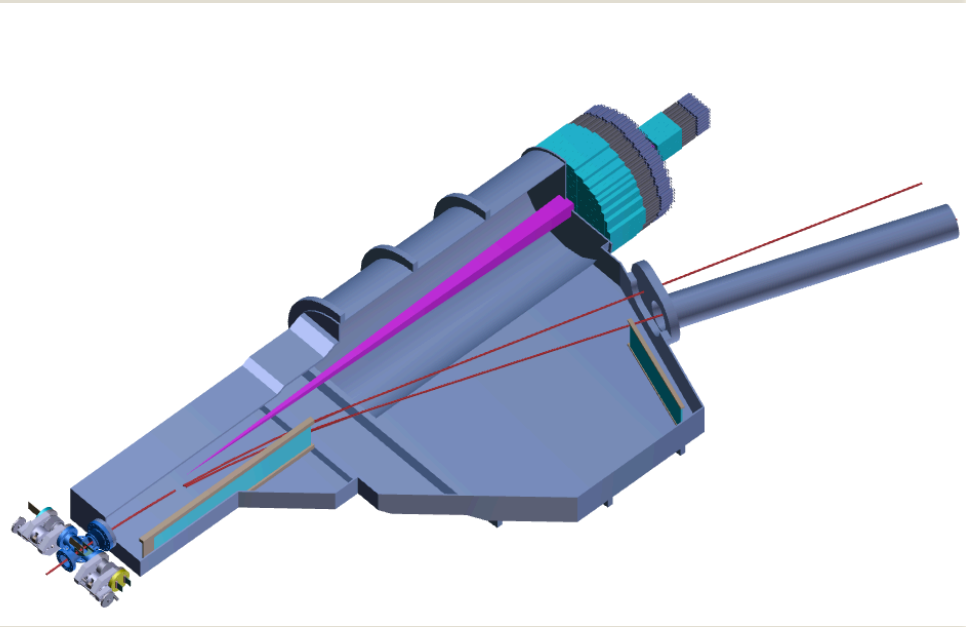
PADME. The PADME experiment will look for new light gauge bosons resonantly produced in collisions of a positron beam with a diamond target, mainly through the process $e^+e^- \to X\gamma$ [133]. The collaboration aims to complete the detector assembly by the end of 2017 and accumulate 10^{13} positrons on target by the end of 2018. The expected sensitivity after one year of running is $\varepsilon_e \sim 10^{-3}$, with plans to get as low as 10^{-4} [134, 135].

The PADME Setup



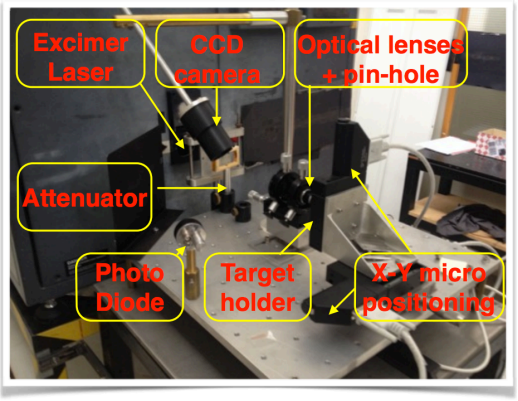
Beam region and vacuum chamber





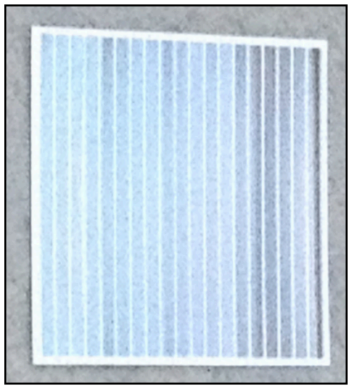
First baseline layout available for both vacuum chamber and target region
Details to be fixed to reach a final layout

Progress on the diamond target



New setup in Lecce for graphitic electrodes fabrication: compact setup to avoid ozone hazard

100 um thick,
19X+19Y GRAPHITIC STRIPS!!!



Realised in 4 working days

New procedure for graphitization much faster!
Final sensor for PADME 100μm thickness.
Best bonding procedure under study

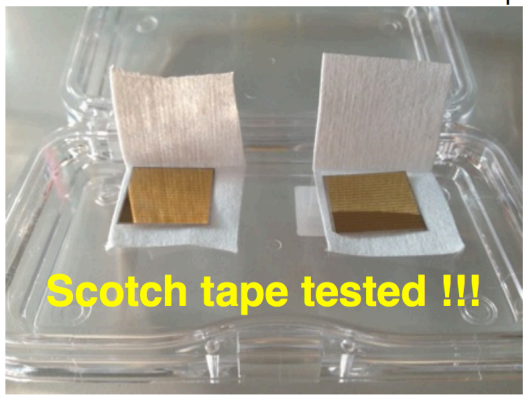
4 active target already built:

2x100μm metallized target

1x100μm graphitized target

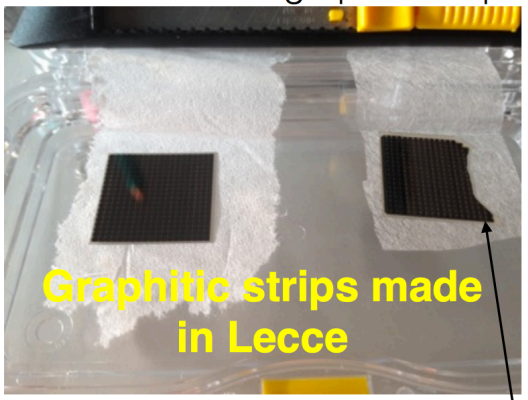
1x50μm graphitized target

Two 100 um thick and CrAu strips



1. Used in tb July `16.
   -Send it back to vendor
   -cleaned
   -remetalized
2. New purchased sensor

Two sensors with graphitic strips



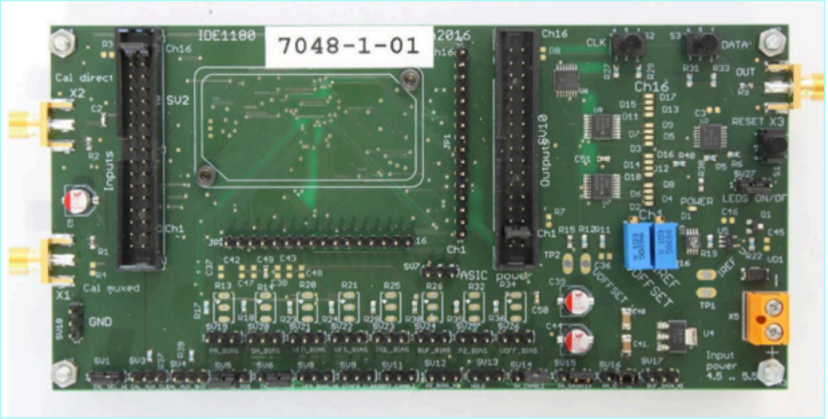
1. 100 um thick.
   -Realized in Lecce in July `16
2. 50 um thick tb nov `15
   -Useful for all prototyping steps

4 ACTIVE TARGET for PADME (one 50 um thick)

SAPIENZA UNIVERSITÀ DI ROMA

INFN Istituto Nazionale di Fisica Nucleare

Front end electronics

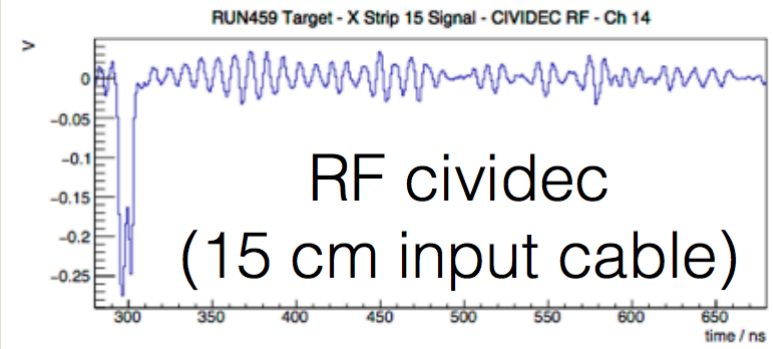


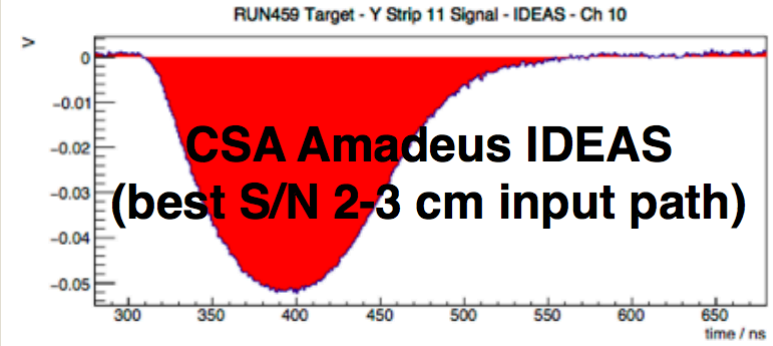
16 CSA Amadeus chip Eval board from IDEAS

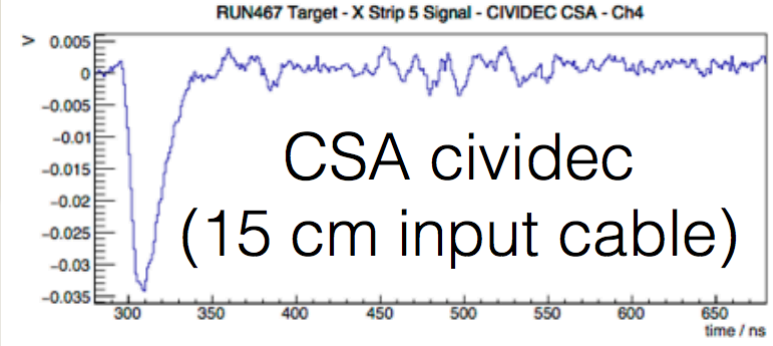
Electronics CSA amadeus chip chosen

Timing performance degraded but good signal to noise ratio.

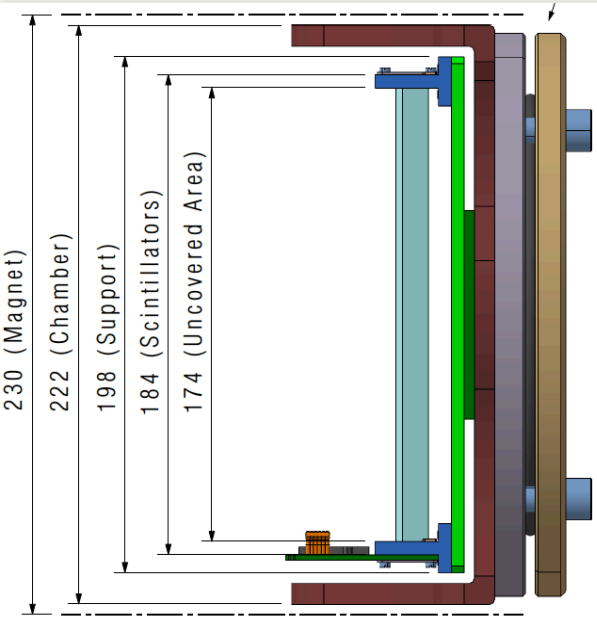
Only need to measure the charge OK!

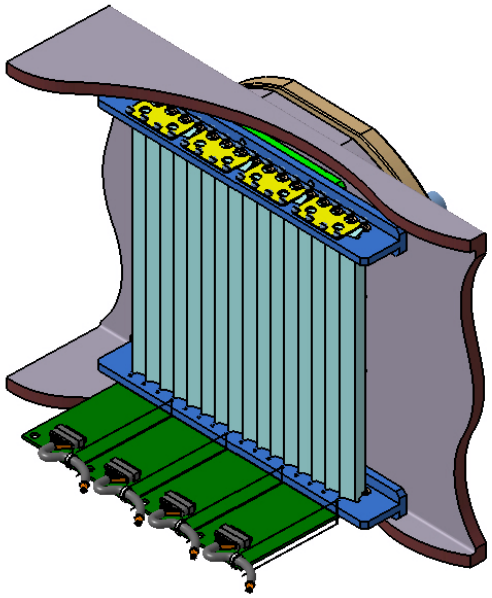


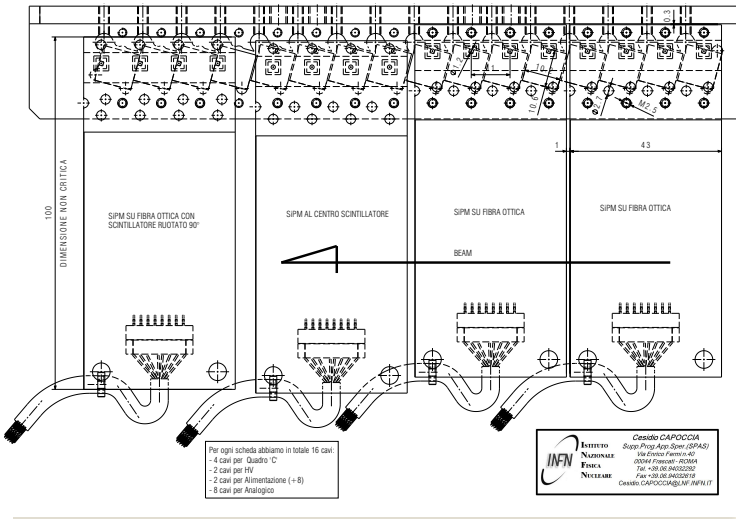




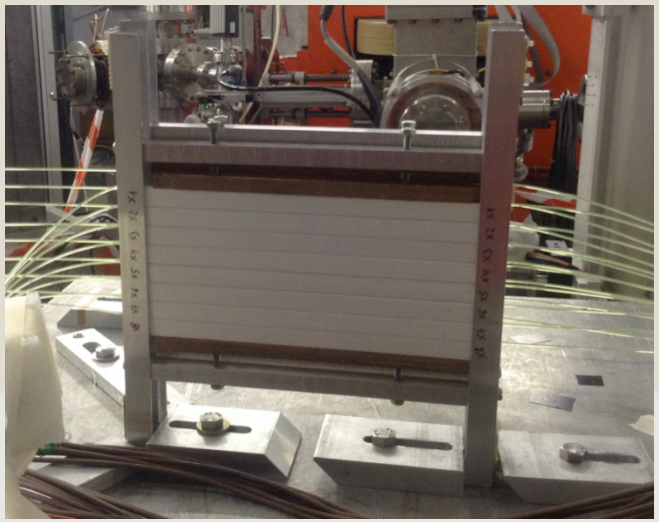
Optimized positron veto geometry



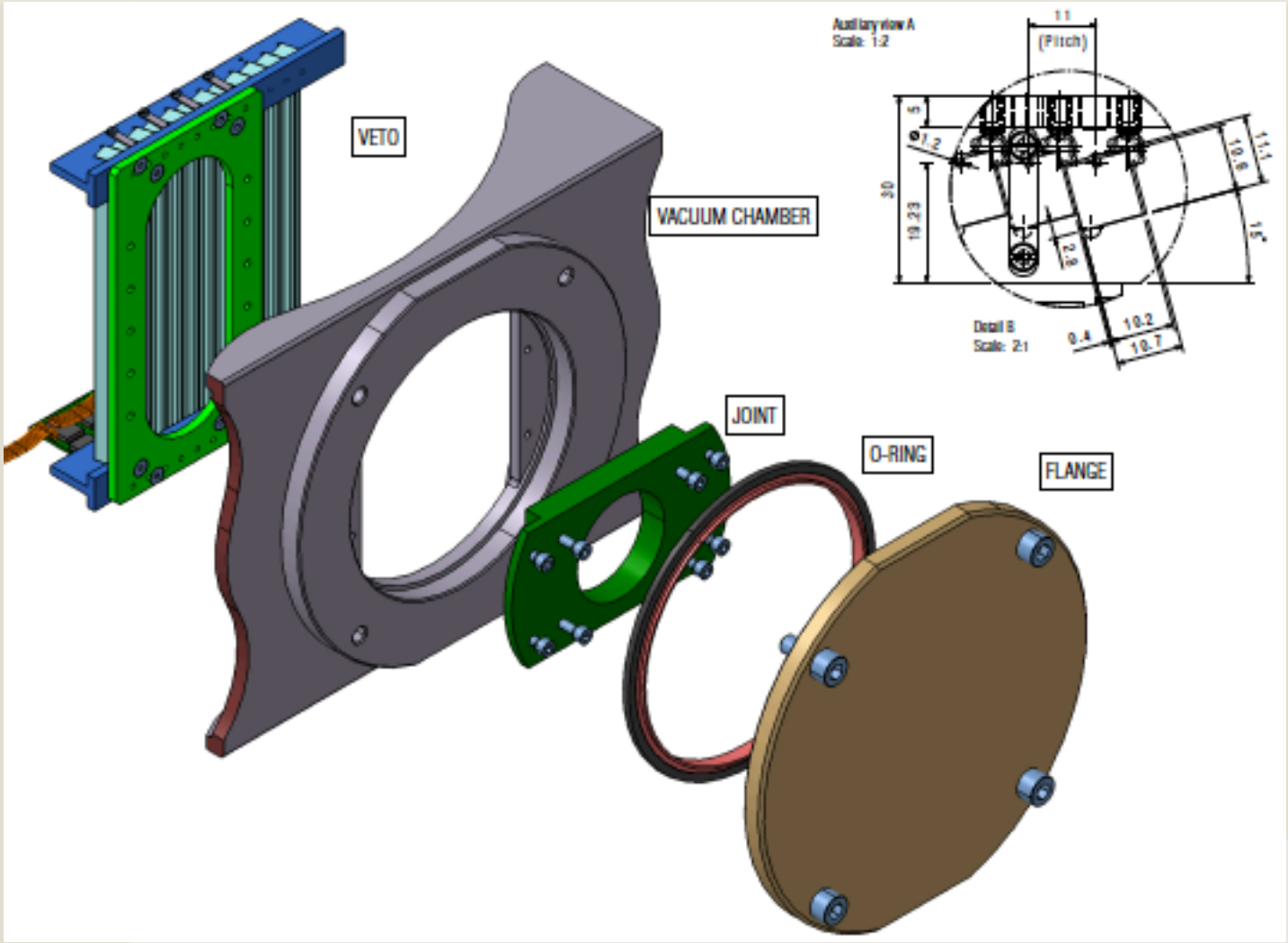




Improved scintillator dimension from 16 cm to 18.4 cm
New clean area 17.4 vs 16 cm
Better veto efficiency and less passive material



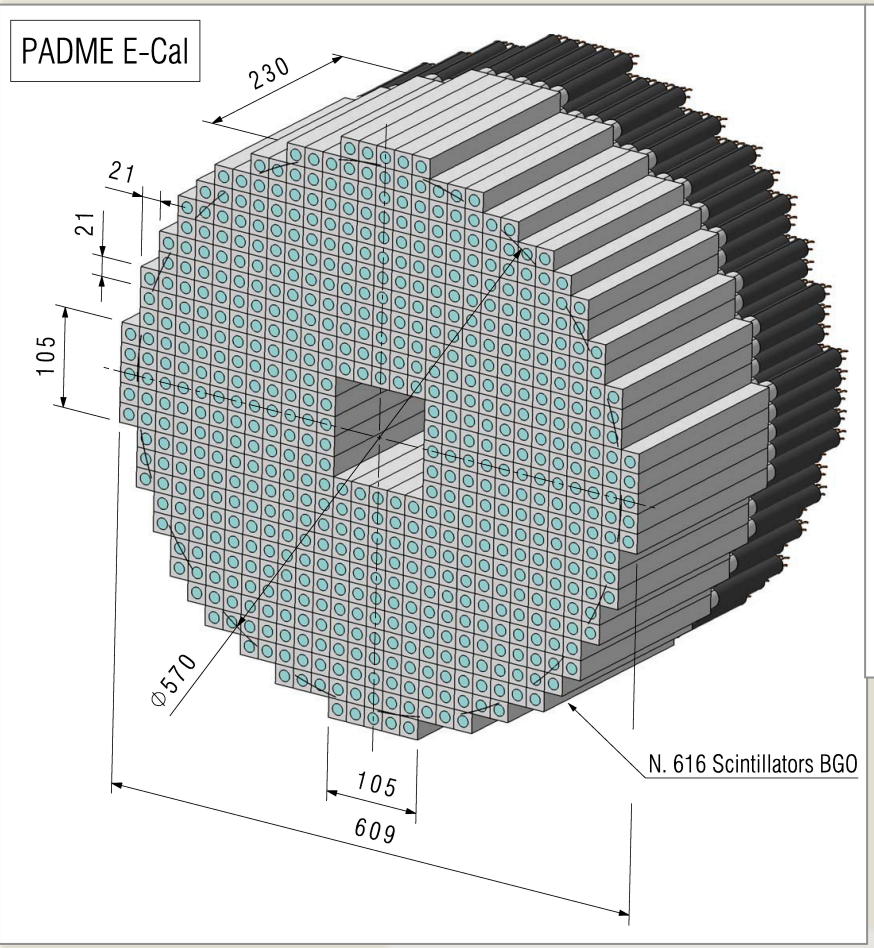
Study of the supports

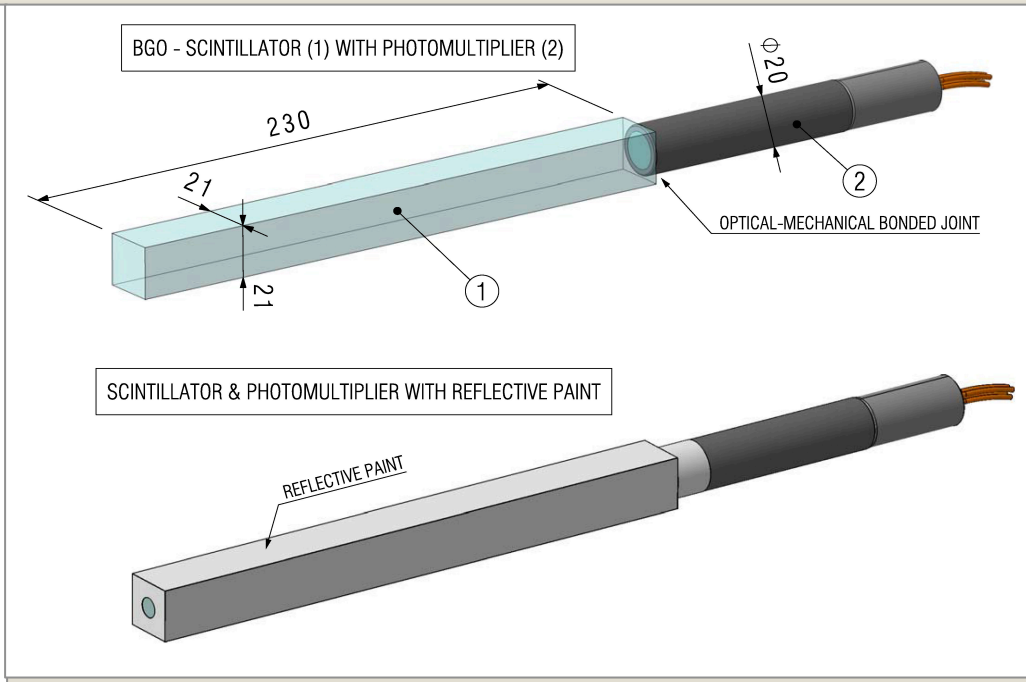


Calorimeter status

Details in: “PADME Calorimeter meeting September 8th”
https://agenda.infn.it/conferenceDisplay.py?confId=11912
Calorimeter July test-beam ArXiV
https://arxiv.org/abs/1611.05649

Calorimeter final design

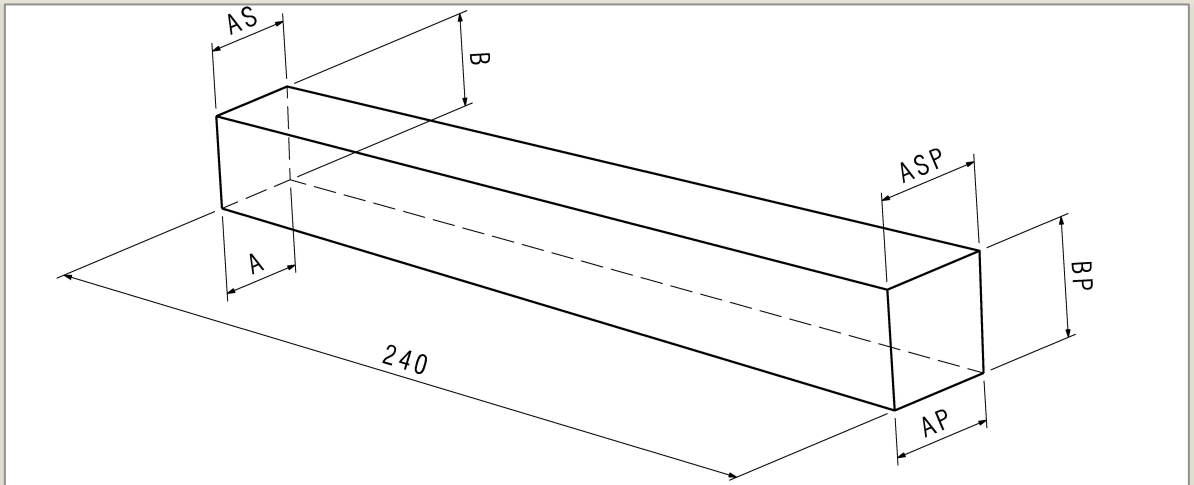




Geometry of Ecal and single crystal geometry finalised.

Materials and assembly procedure for single crystals defined

Status of crystal recovery

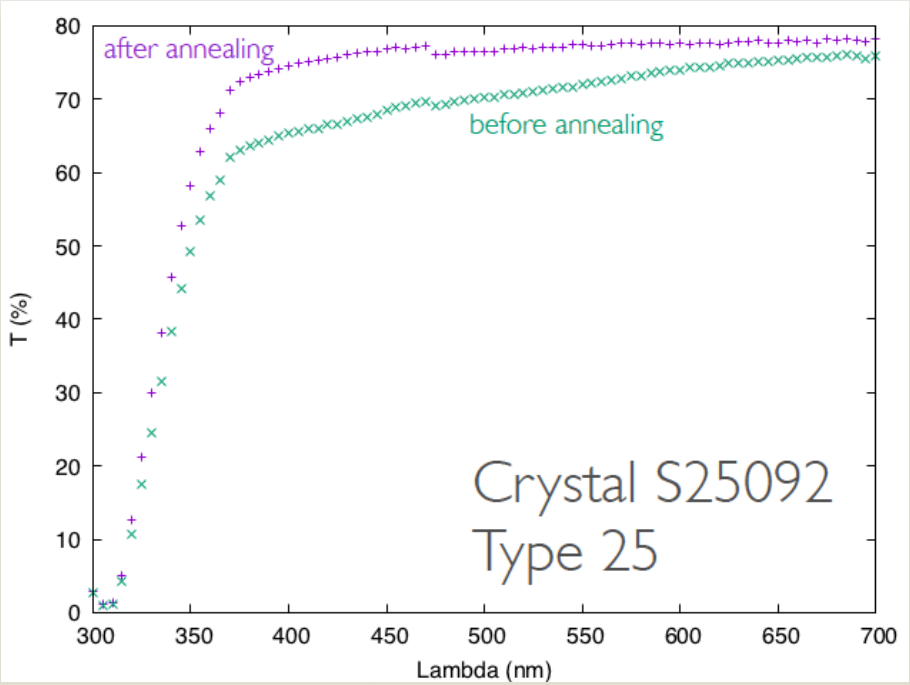


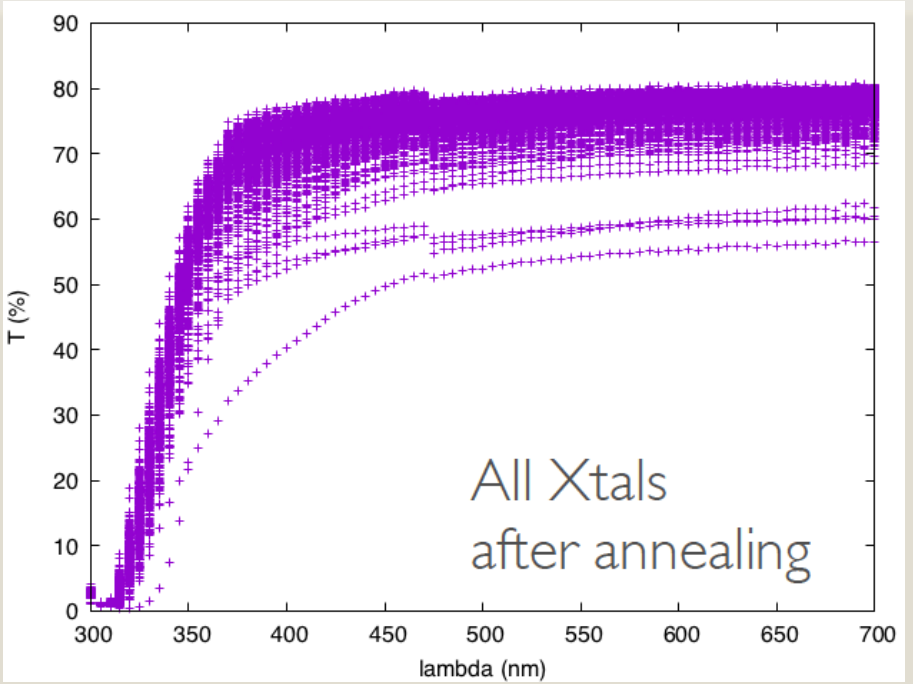
Type	A	AS	B	AP	ASP	BP	min size	Qu	Integral			
30	21,26	22,29	21,78	28,31	29,68	29,00	21,26	78	**78**			
32	21,29	22,55	21,92	28,62	30,32	29,47	21,29	75	**153**	75		
34	21,73	23,33	22,53	29,46	31,63	30,54	21,73	74	**227**	149	74	
29	22,81	23,89	23,35	30,20	31,64	30,92	22,81	57	**284**	206	131	57
27	22,95	23,86	23,40	30,04	31,23	30,63	22,95	127	**411**	333	258	184
31	23,03	24,37	23,70	30,80	32,59	31,70	23,03	69	**480**	402	327	253
26	23,88	24,80	24,33	31,25	32,45	31,85	23,88	125	**605**	527	452	378
28	24,51	25,65	25,08	32,25	33,75	33,00	24,51	96	**701**	623	548	474
25	24,78	25,71	25,24	32,43	33,65	33,04	24,78	125	**826**	748	673	599
								to 616 >	**210**	**132**	**57**	**-17**

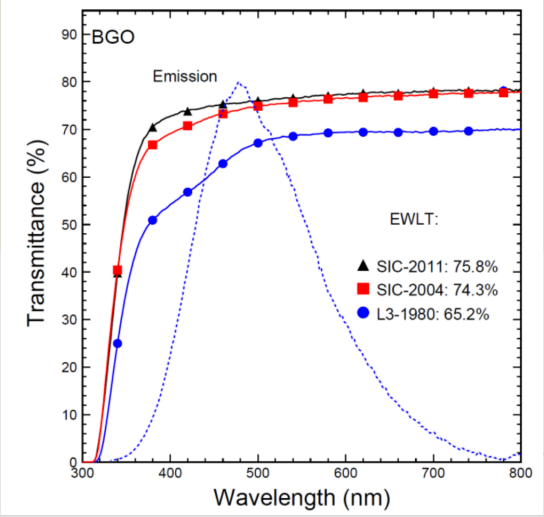
826-153=673 crystals PADME 21x21x230mm^3 (616 needed) **OK**

~100% already recovered and measured. Waiting to be shipped for the machining

Effect of the annealing procedure

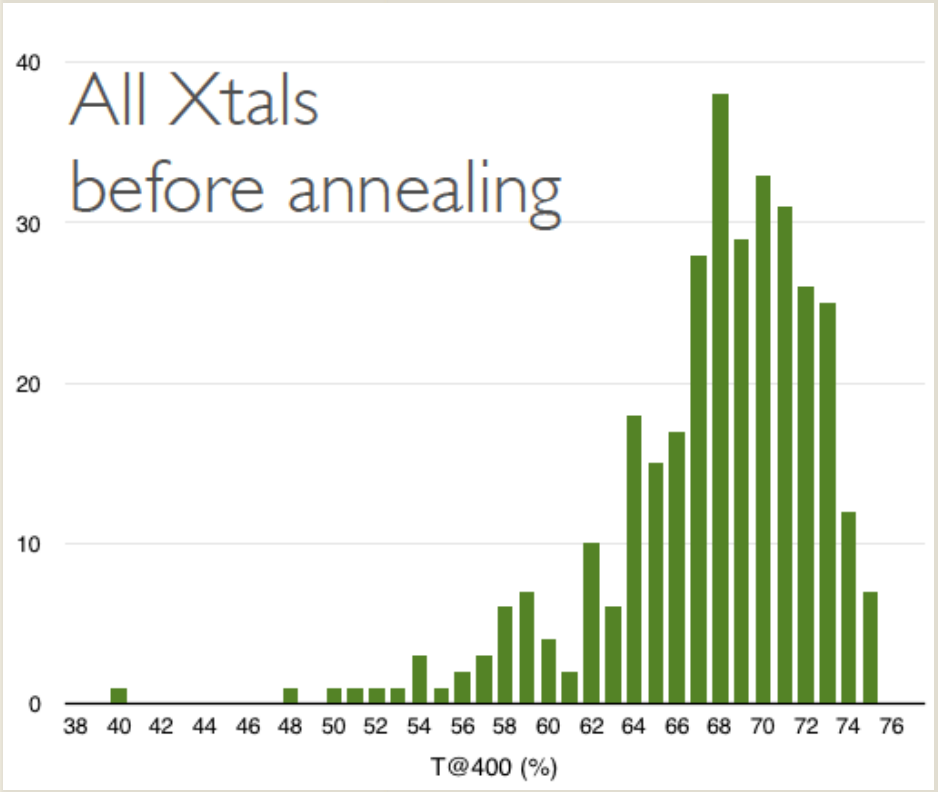


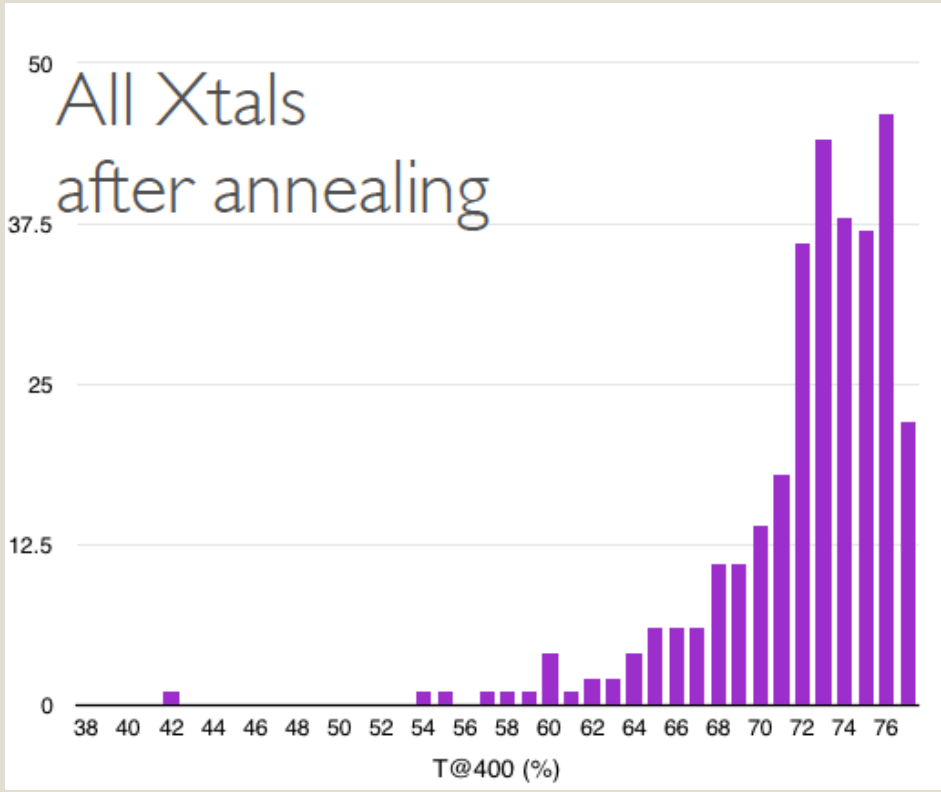




Transmission after annealing very similar to the one of brand new crystals!

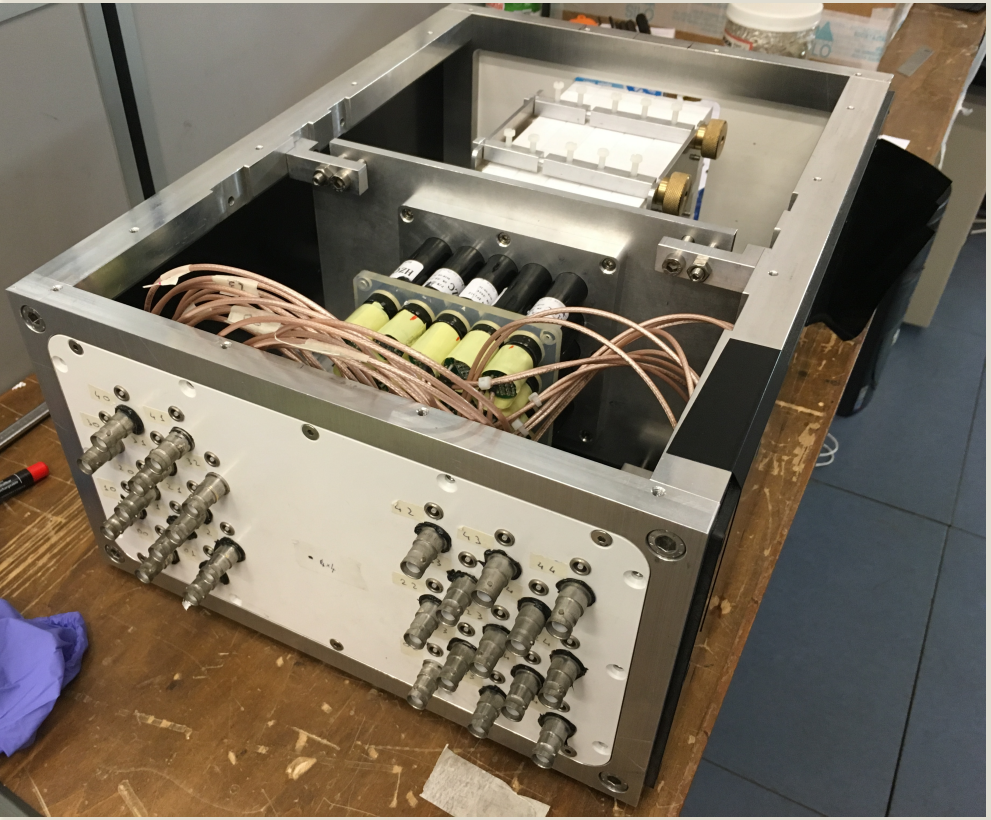
Effect of annealing

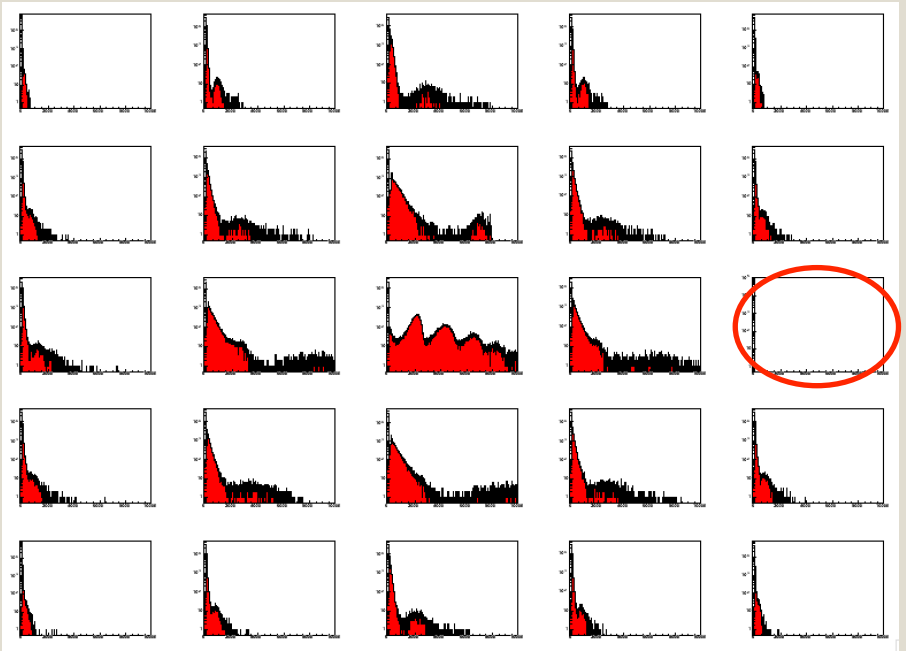




Few crystals out of the core distribution. Very good transparency ~70% at 400nm after the annealing.

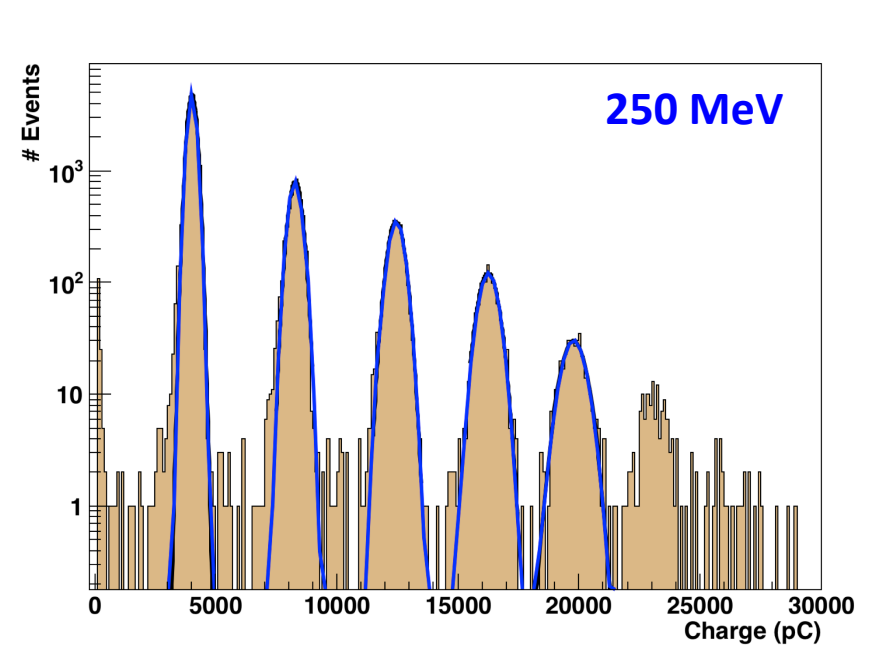
5x5 calorimeter prototype

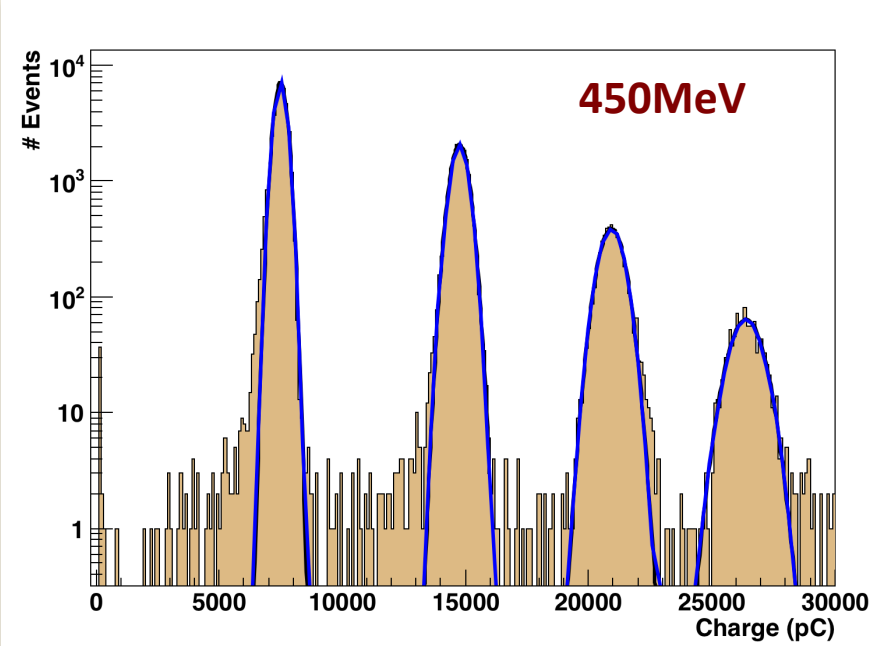




Uses 25 20x20x220 mm^3 BGO crystals wrapped with Teflon.
Coupled to **XP1912 HZC Photonics PMTs** by using optical grease.
PMT high voltage set to the equalization values provided by firm.
24 over 25 PMT working

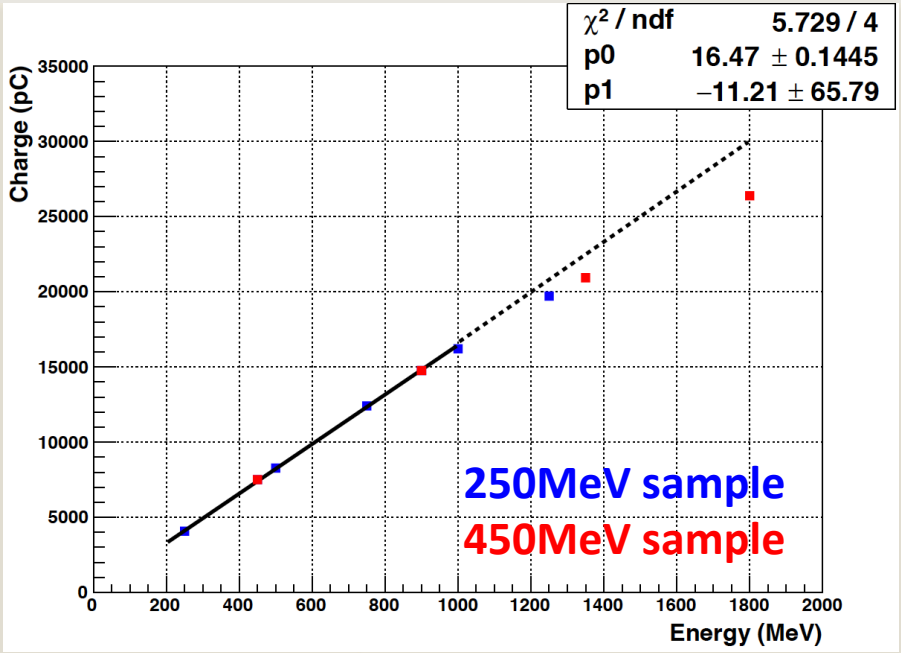
250MeV and 450MeV samples

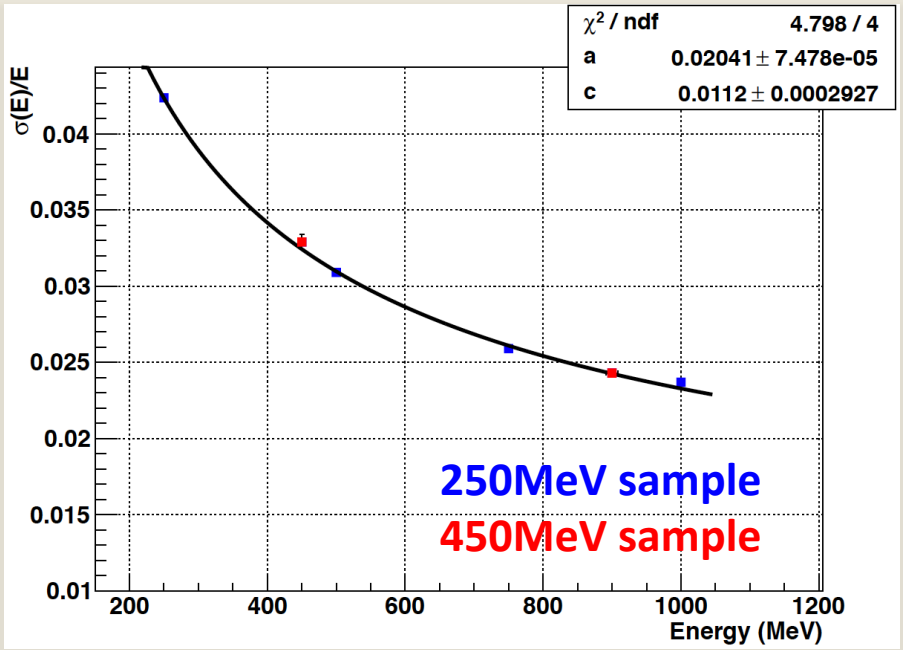




Up to 4 electrons in both 250 MeV and 450 MeV runs
Linear up to 1GeV due to saturation in the FADC.
Linearity can be improved by fitting the signal shape

Linearity and energy resolution





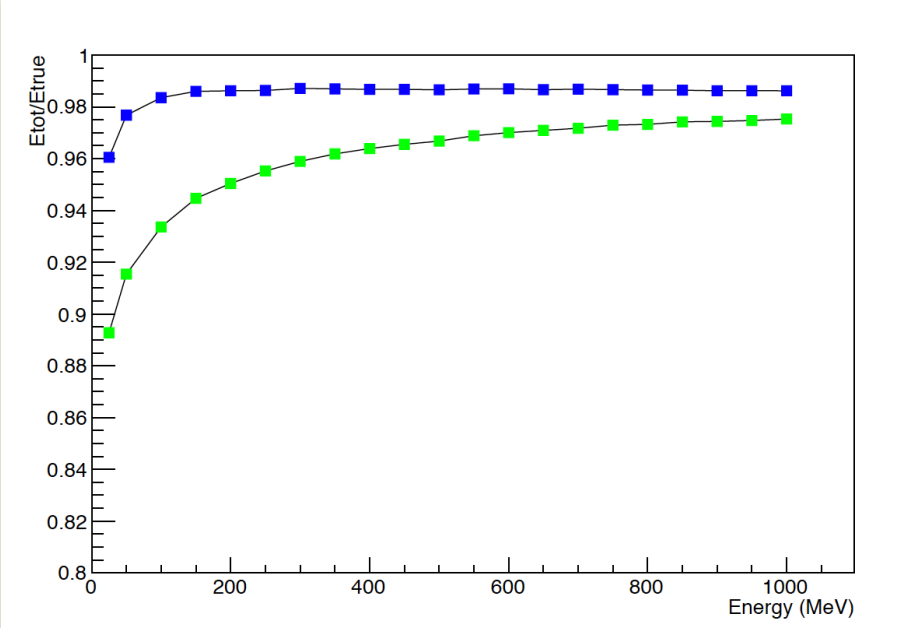
Fit with blue points (250MeV) red points superimposed.

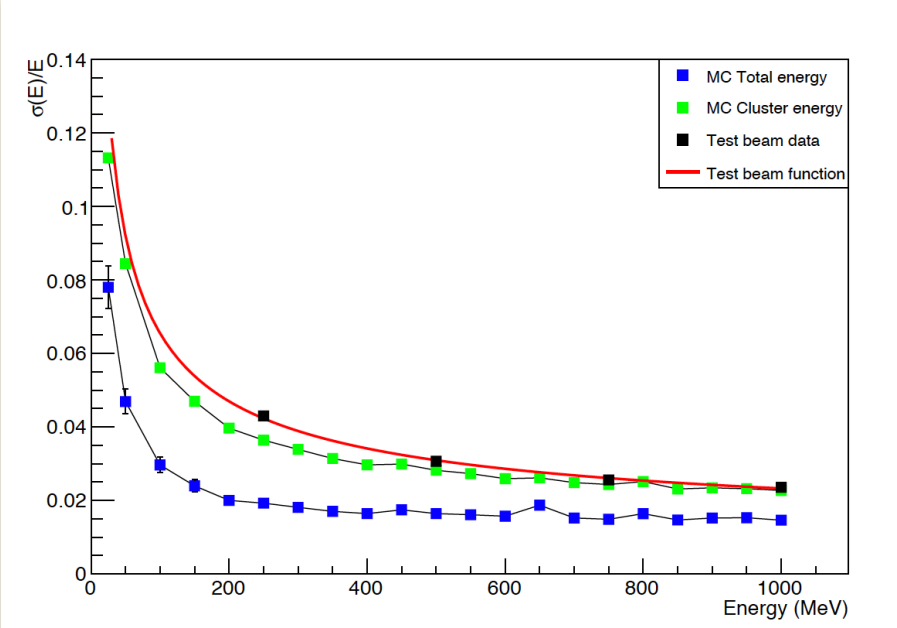
$\sigma(E)/E=2.04\%/\sqrt{E}\oplus 1.1\%$ Good linearity up to 1GeV

(region of interest for PADME 30-400 MeV)

New data at 100MeV collected during October test beam.

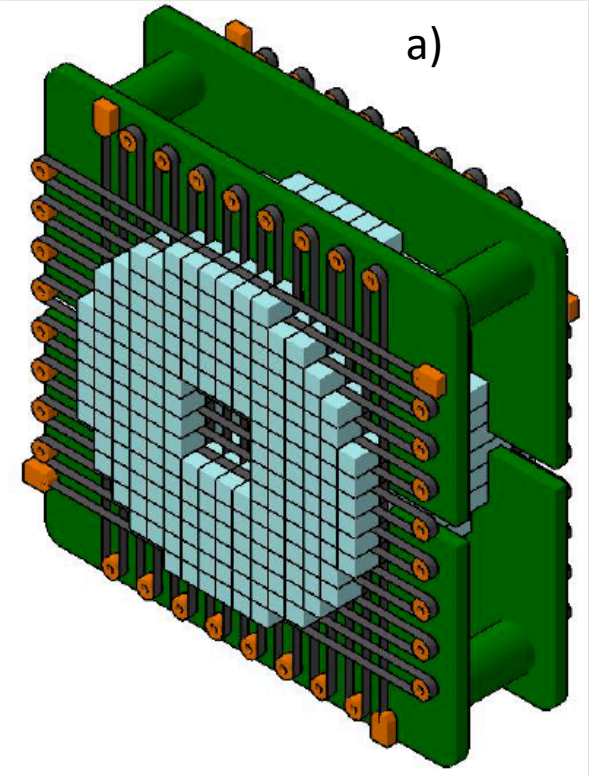
Data/MC comparison



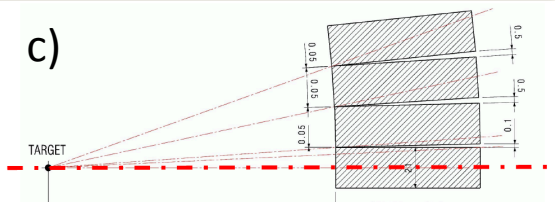


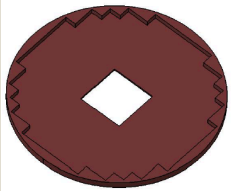
- Tuning of the MC reconstruction based on test beam data:
  - Number of measured photo electrons: ~ 200.
  - Minimum energy in the MC zero suppression: 1.5 MeV
  - Cell to Cell inter-calibration errors: 10%
  - Energy spread of 1% introduced in the simulation
    - Need to introduce energy dependent energy spread

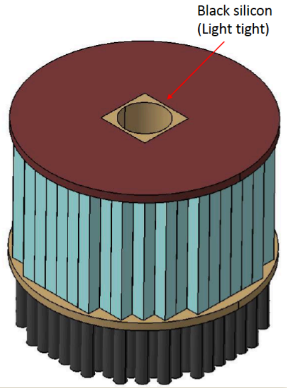
Possible assembly procedure

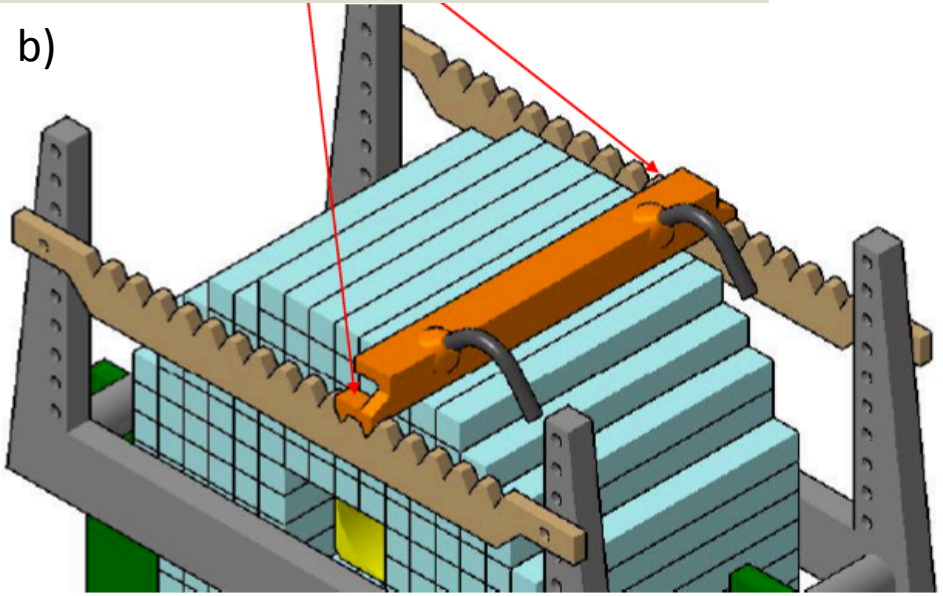


a) "Tennista" or "string solution"
b) "Muratore" or "**bricklayer**"
c) "Puntante" or "pointing"







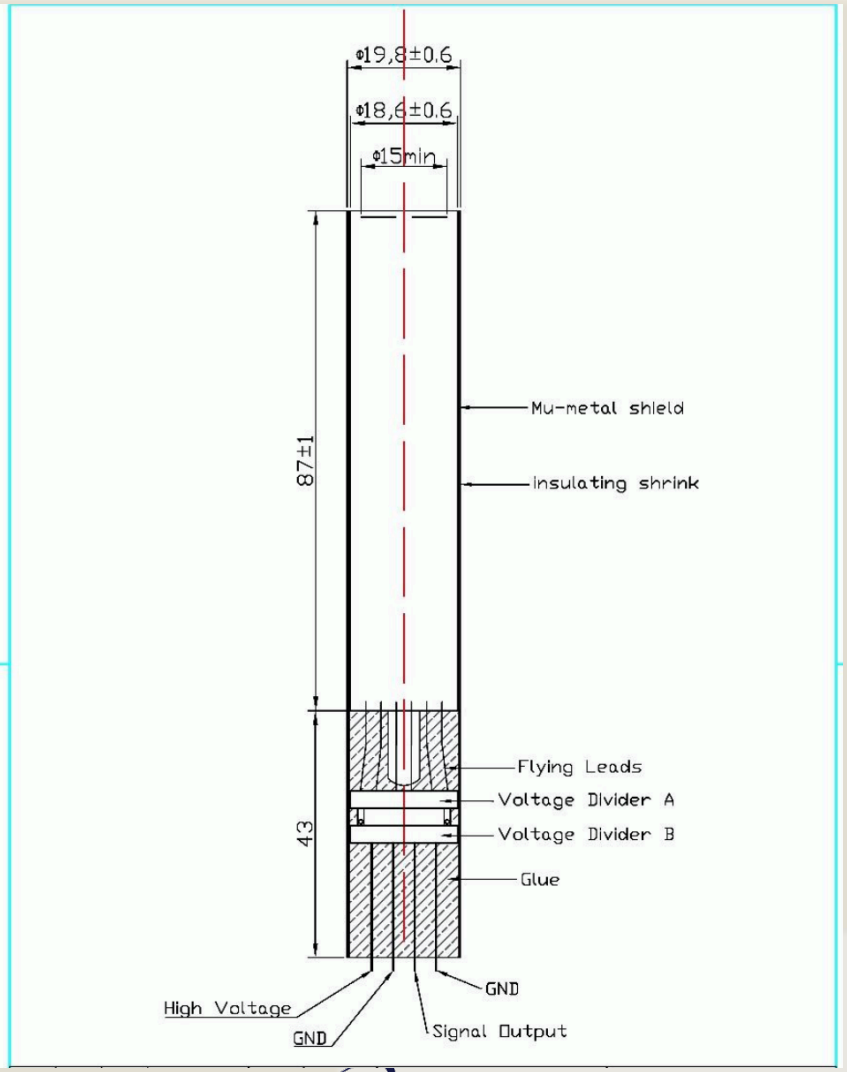


SAPIENZA UNIVERSITÀ DI ROMA

INFN Istituto Nazionale di Fisica Nucleare

PADME

XP1911 + Custom PMT base HZC

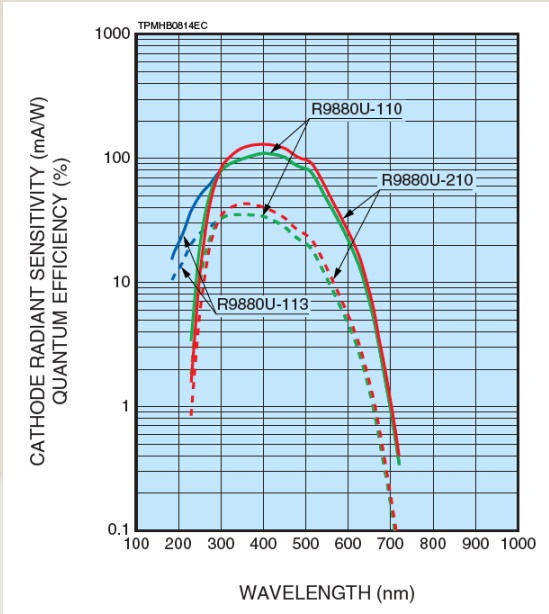


- We identified a possible solution for the photo-detector in the HZC XP1911 PMT.
- Customized based required under development based on PADME specifications.
- Order placed for 25 pieces expected to be delivered by the end of 2016;

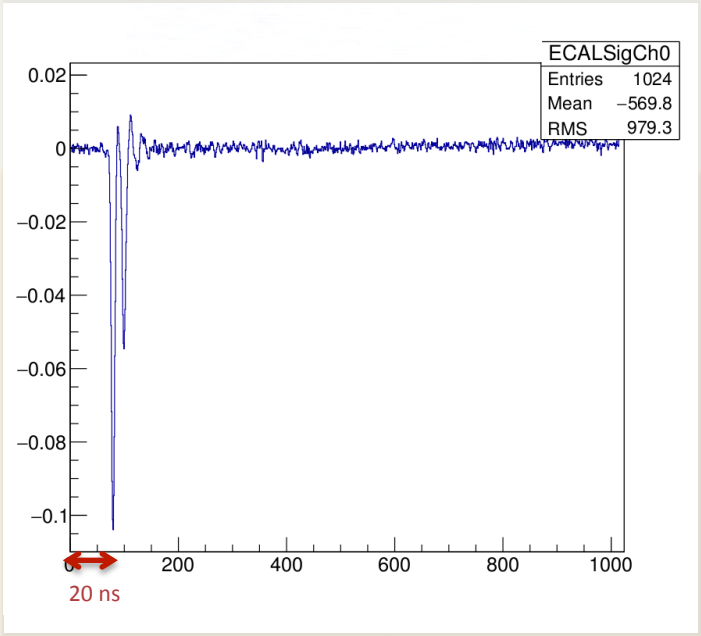
First Small Angle Calorimeter test

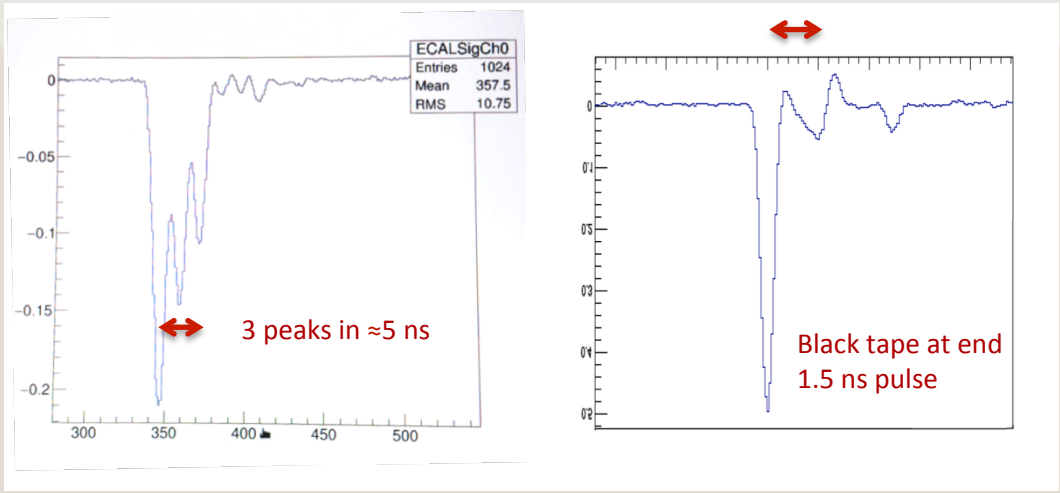
- Intended to veto photons in the range of 50-400 MeV
  - Efficiency of >95% enough to reduce 3γ background
- Need 200-400 ps time resolution and very short dead time to keep random veto under control

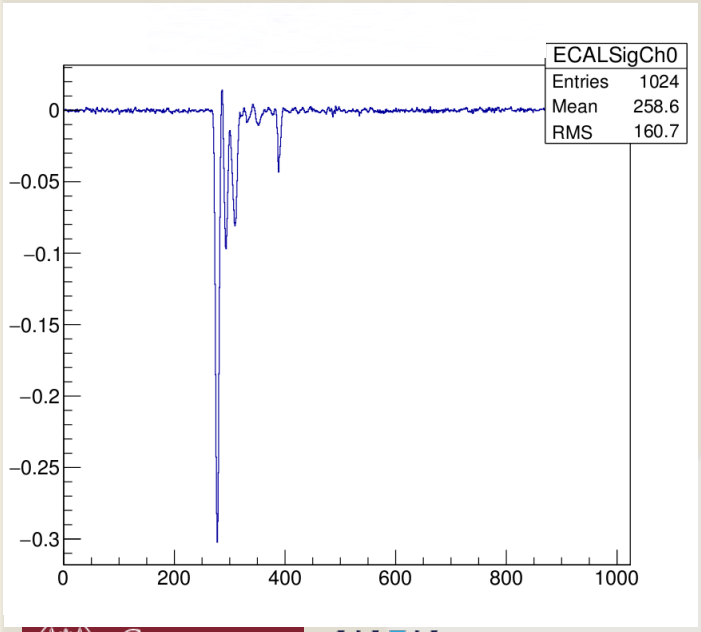
- First tests during November calorimeter beam-time
- Just one lead-glass bar, 20×20×200 mm^3, wrapped in Teflon
- Hamamatsu R9880U-110, 16mm, fast PMT (0.6ns rise time)
- CAEN V1742 digitizer set to 5 GS/s

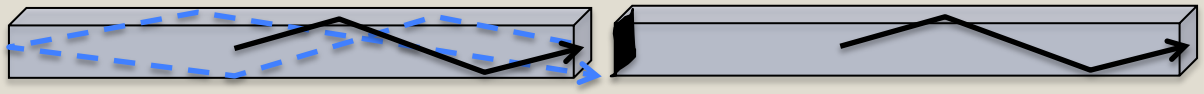


Very short signals!







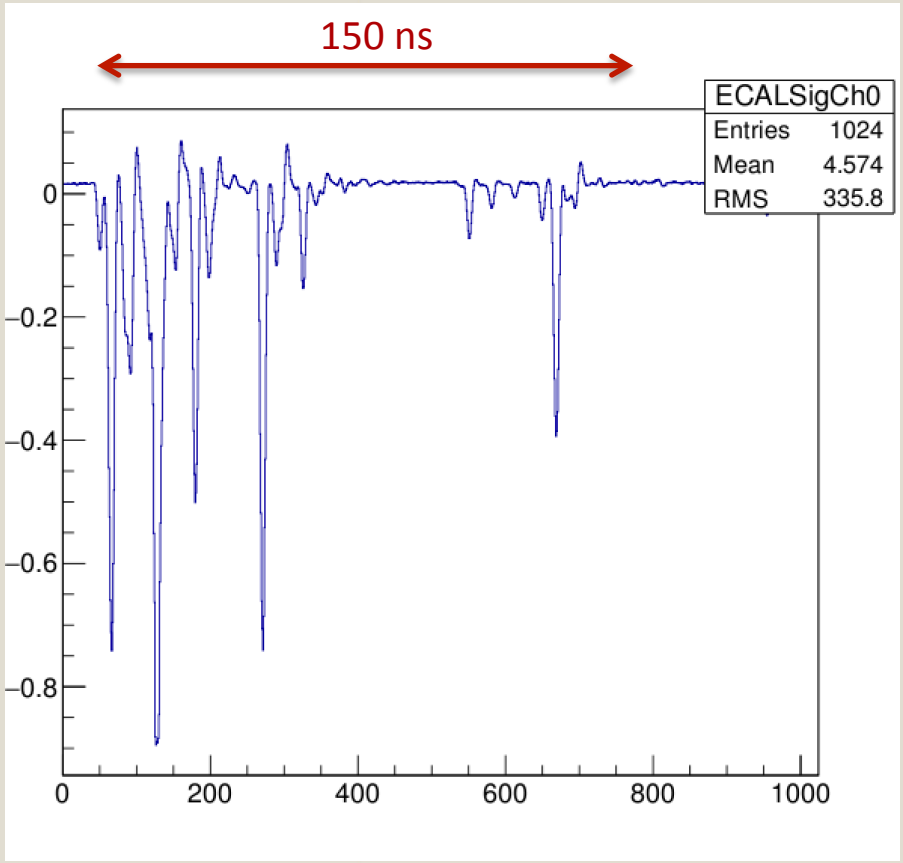


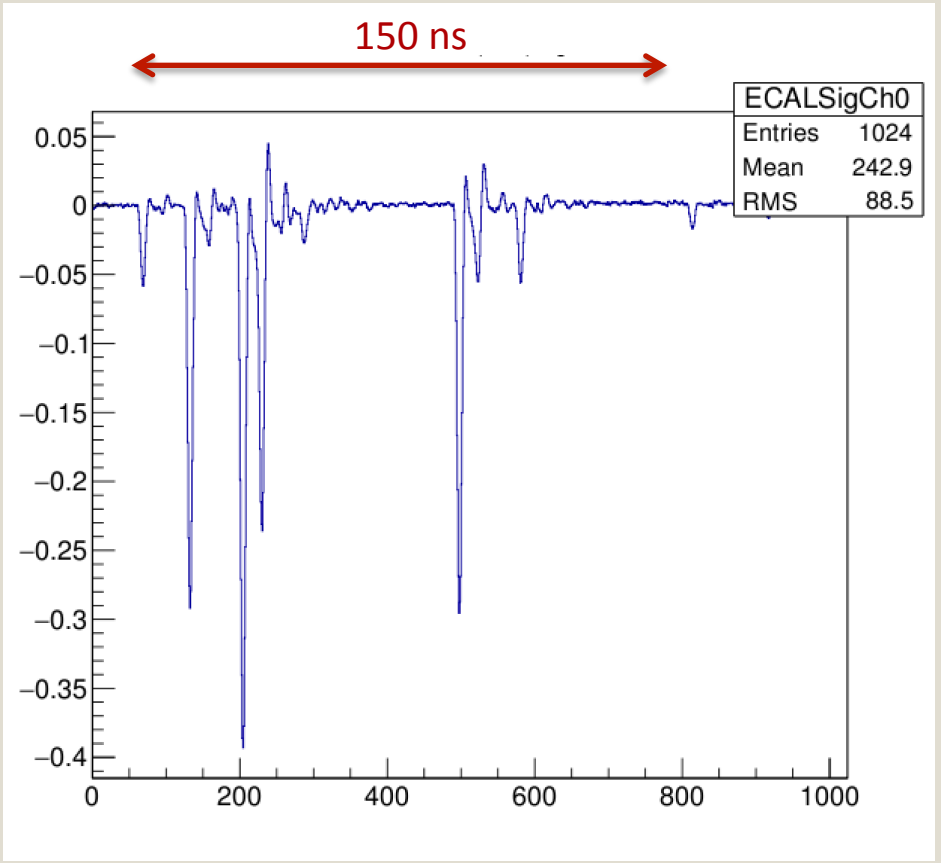
Light reflections?

- n = 1.8467, speed of light≈16 cm/ns, 40 cm=2.5 ns
- Number of events with multiple peaks reduced by rotating the crystal by ≈60° wrt the beam direction
- Much better results by placing black tape absorber on the crystal front face.

Technology choice SF57+R9880U-110 seem ok!

Long beam pulses





Tenders in 2016

- **During 2016 we prepared tenders for calorimeter components**
  - 630 Crystal preparation: Cutting, polishing, painting and PMT gluing of the crystals
  - Calorimeter HV system: Main frame with ~630 single power supply channels
  - 630 PMT bid: 630 PMT 19mm with divider
  - Readout: 28 readout digitizer board for the readout
- **We expect to have all the material for the calorimeter assembly by March-April 2017**

Anagrafica PADME 2017

Researchers

INFN Lecce **2. FTE**

G. Chiodini 30%
S. Spagnolo 20%
Pietro Creti (I tec) 20%
Viviana Scherini ass INFN 30%

INFN Lecce and Università Salento

A. Caricato (ric) 30%
G. Maruccio (Professore) 20%
M. Martino (Professore) 30%
A. Monteduro (AdR) 20%

INFN LNF **4.9 FTE**

(Divisione Ricerca)
P. Albicocco 30%
R. Bedogni 20%
F. Bossi 30%
R. De Sangro 20%
G. Finocchiaro 20%
P. Gianotti 30%
M. Palutan 20%
G. Piperno (A.d.R.) 100%
I. Sarra (A.d.r) 20%
B. Sciascia 20%
T. Spadaro 20%
E. Spiriti 10%
V. Kozhuharov (Università Sofia) 50%
G. Georgiev (Università Sofia) 50%
(Divisione Acceleratori)
B. Buonomo (20%)
L. Foggetta (20%)
A. Ghigo (10%)

INFN Roma **2.7 FTE**

P. Valente 50%
F. Ferrarotto 50%
E. Leonardi 50% (Tecnologo)
S. Fiore (ENEA) 20%
F. Ameli 20% (Tecnologo)

INFN Roma and Università Sapienza

G. Organtini (Professore) 30%
M. Raggi (RTDb) 50%

INFN Roma

Supporto per montaggi e cablaggi 20%
Supporto per elettronica di readout 20%

INFN Lecce

G. Fiore (Tecnico e progettista) 30%

INFN Lecce and Università Salento

M. Corrado (Tecnico) 20%
C. Pinto (Tecnico elettronico) 20%

Supporto tecnico

INFN LNF

(SPAS)
C. Capoccia (Progettista meccanico) 50%
E. Capitolo (Progettista meccanico) 50%
(SELF)
G. Corradi (Progettista Elettronico) 30%
Frascati Officina meccanica
2 mesi uomo II sem (2016)

Total 9.6 FTE
(32 researchers +5 wrt 2016)
Just 1 post doc
Lost PD_DTZ

Conference talks 2016

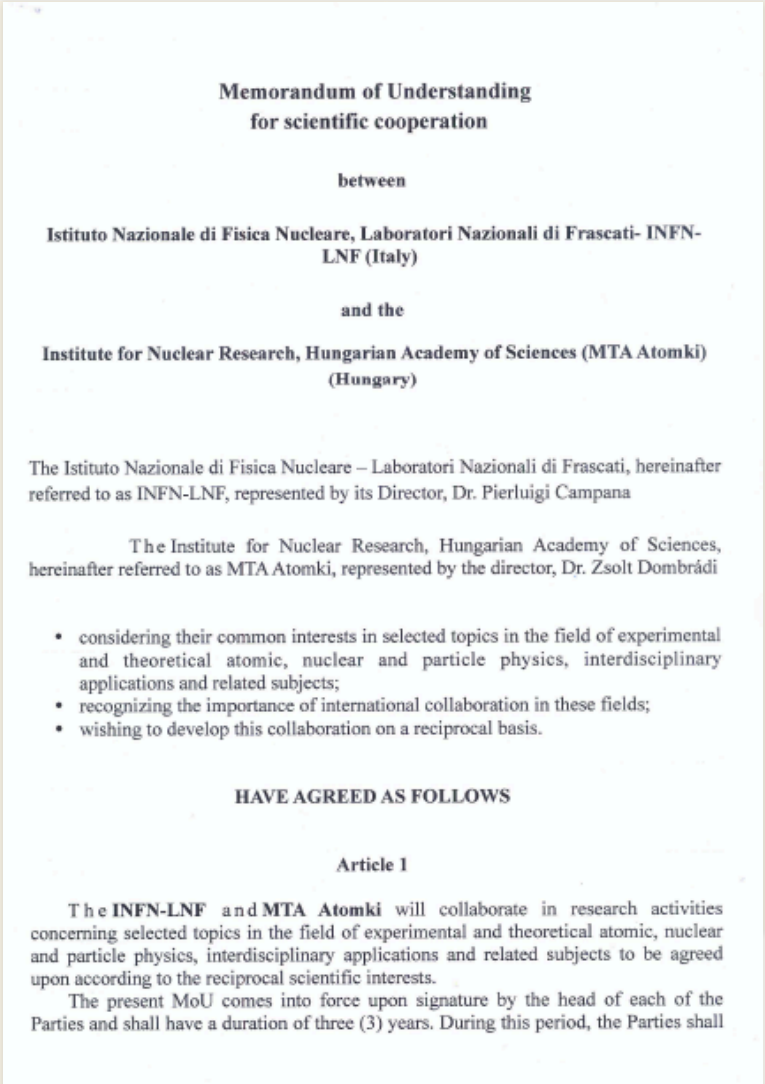
Conference or workshop	Title	Author	File
ICHEP, Chicago, Aug. 2016	The PADME experiment at the Frascati LINAC	P. Valente	
IDM 2016, Sheffield, Jul. 2016	The PADME Experiment	G. Piperno	
BEACH, Jun. 2016	The PADME experiment at INFN LNF	S. Fiore	
Vulcano Workshop, May 2016	New projects on dark photon search	V. Kozhuharov	
Cavendish Laboratory Seminar, Cambridge, May 2016	The PADME experiment at the DAFNE LINAC	M. Raggi	
Frascati Spring School, LNF, May 2016	The PADME experiment at LNF	G. Piperno	
Rencontres de Blois, May 2016	Searching for dark photons with the PADME experiment at the Frascati LINAC	F. Ferrarotto	
Dark Sectors Workshop, SLAC, Apr. 2016	LNF experiment	M. Raggi	
IAXO Meeting, LNF, Apr. 2016	The PADME experiment at LNF	M. Raggi	
New Vistas in LEPP, Mainz, Apr. 2016	Dark photon searches in positron annihilations with the PADME experiment	P. Valente	
Seminar at Detector School "F.Bonaudi", Cogne, Feb. 2016	Dark photon searches with PADME	P. Valente	
LAPP Seminar, Annecy, Jan. 2016	The PADME experiment at LNF	M. Raggi	

12 talks already given by PADME members in 2016

+1 talk at CHEP +2 Posters
+1 talk at the Symposium
+1 talk at KLOE workshop

Convener of the PADME Conference committee: Stefania Spagnolo.

Agreement with MTA Atomki lab (Hungary)



Memorandum of Understanding
for scientific cooperation

between

Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati- INFN-LNF (Italy)

and the

Institute for Nuclear Research, Hungarian Academy of Sciences (MTA Atomki) (Hungary)

The Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali di Frascati, hereinafter referred to as INFN-LNF, represented by its Director, Dr. Pierluigi Campana

The Institute for Nuclear Research, Hungarian Academy of Sciences, hereinafter referred to as MTA Atomki, represented by the director, Dr. Zsolt Dombrádi

- considering their common interests in selected topics in the field of experimental and theoretical atomic, nuclear and particle physics, interdisciplinary applications and related subjects;
- recognizing the importance of international collaboration in these fields;
- wishing to develop this collaboration on a reciprocal basis.

HAVE AGREED AS FOLLOWS

Article 1

The **INFN-LNF** and **MTA Atomki** will collaborate in research activities concerning selected topics in the field of experimental and theoretical atomic, nuclear and particle physics, interdisciplinary applications and related subjects to be agreed upon according to the reciprocal scientific interests.

The present MoU comes into force upon signature by the head of each of the Parties and shall have a duration of three (3) years. During this period, the Parties shall

- Mutual agreement to be signed this week
  - Exchange of researchers students
  - Lasts 3 years
  - Defining the Atomiki collaboration to PADME and the contribution they would give us.
- Invited seminar at MTA Atomki in Debrecen

Agreement with Cornell University

- Visit to Cornell (Valente) this summer, in the framework of MAECI project PGR-226
  - Defined common activities on simulation, calorimeter development, readout, background studies, etc.
- Visit to Italy (J. Alexander + students)
  - Joint test-beam in November at BTF (MMAPS CsI calorimeter)
  - Joint workshop in Messina in October
- Plan to sign mutual agreement with **CLASSE** on the model of the ones with Sofia and Atomki
  - Exchange of researchers students
  - Last … years
  - Defining:
    - Cornell collaboration to PADME
    - Possibility of a PADME II moving our detector to the 5.3 GeV positron beam in Cornell
  - Request to NSF for 1 M$ for the extraction beam-line will be submitted by Cornell
  - **Contacts between LNF and Cornell directors to fix details**
  - Involvement of significant resources would of course require a higher-level agreement

Cornell University

CORNELL LABORATORY FOR ACCELERATOR-BASED SCIENCES AND EDUCATION — CLASSE

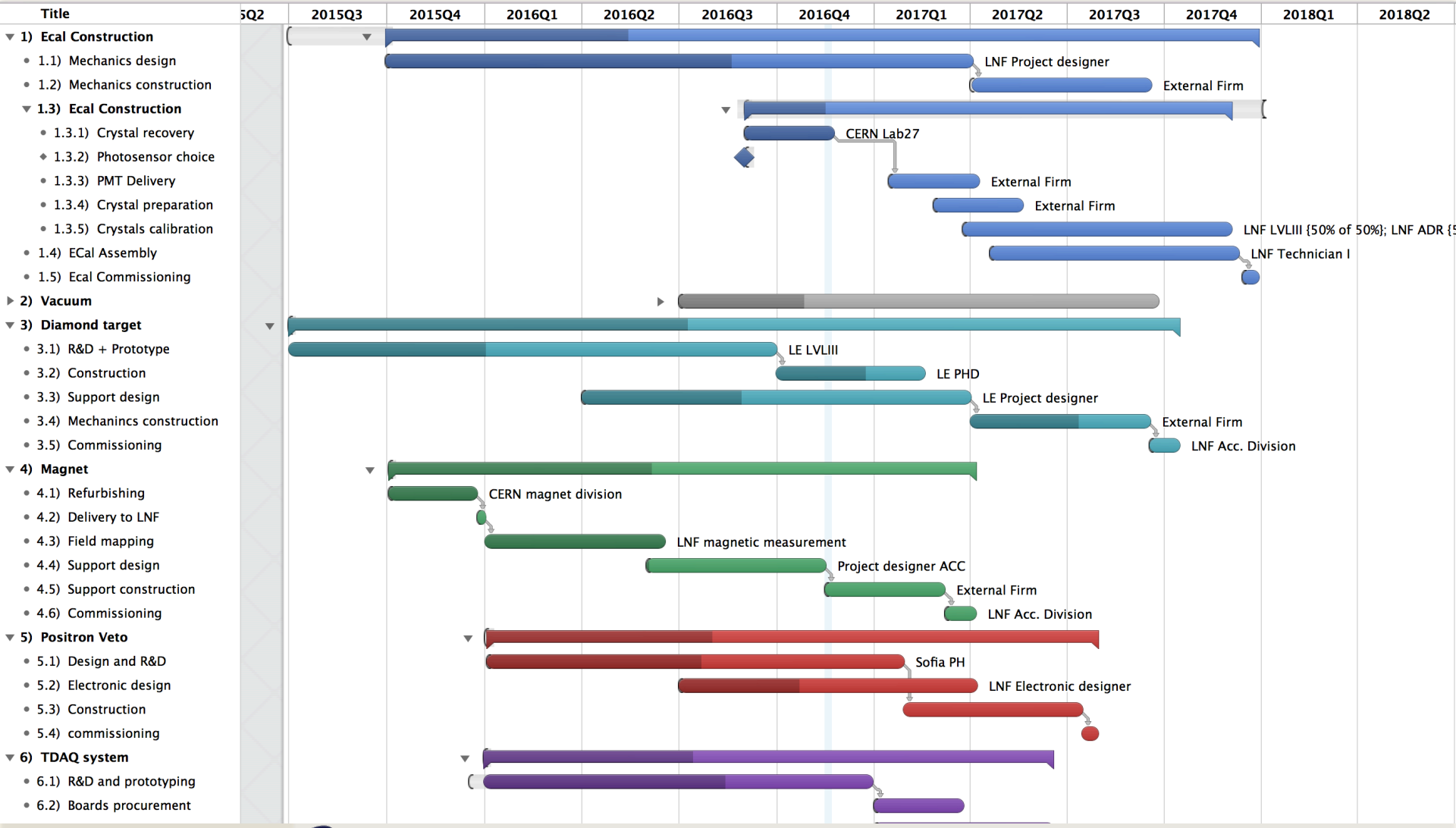
J. Ritchie Patterson, Director

James Alexander, MMAPS PI

Peter Wittich, David Rubin (CESR), Maxim Perelstein, …

FAI funds will be requested to help in the participation of

PADME updated schedule



Beam time 2017-2018

2017 possible plan

- A PADME **beam commissioning run** could profit by summer DAFNE collider shutdown in the hottest period, i.e. **July 2017**
- **~3 weeks for:**
  - Beam commissioning with **PADME target** and **beam monitoring system**
  - Aiming at **beam spot & divergence optimization**
  - Study and possibly optimize energy spread at **250 ns pulse length**
  - **Further pulse length extensions**

2018 PADME request

- PADME aims at collecting **$1x10^{13}$** positrons on target **by the end of 2018**
- **With such a data-set PADME will be able to cover the (g-2)μ band**
  - This is equivalent **for example** to a 6 months run at 65% efficiency with 250 ns pulse length: $1.5*10^{7}$s*49 pulses/s*20000 e+/pulse*0.65 = 10^{13} e^{+} on target

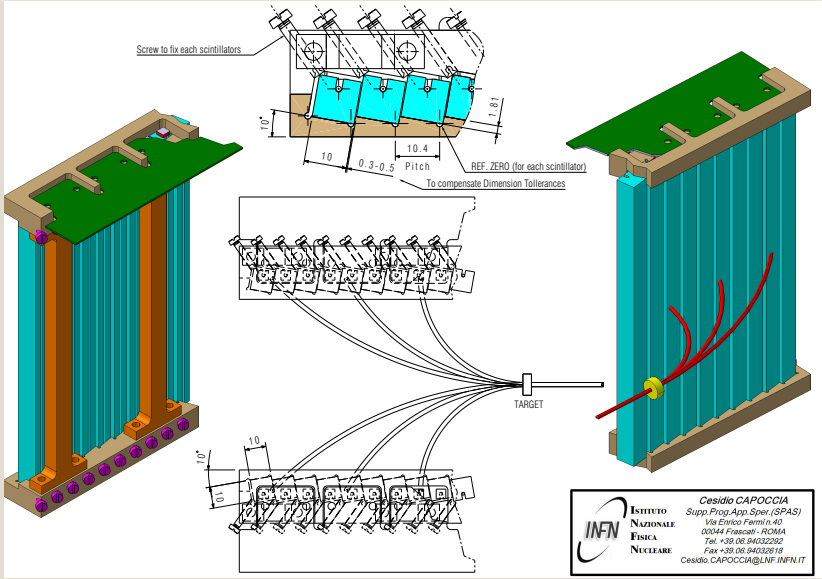
Conclusions

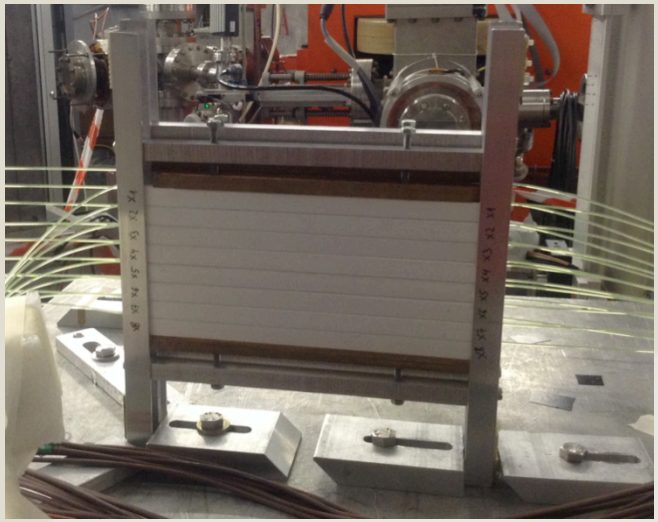
- PADME experiment is **extending the physics case to other dark sector models**
  - Dark Photons, ALPs searches & fifth force
- Also **extending the Collaboration**
- **Successful improvement of the bunch length obtained by LINAC+BTF staff**
  - **Bunch length from 40ns → 250ns**
- Successful 5x5 prototype calorimeter beam-tests in July & November:
  - Energy resolution $\sigma(E)/E = 2.\%/\sqrt{E}+1.1\%$
- Mechanical design of the experiment advanced
  - Details on glue, paint, support, etc. being refined
  - Vacuum vessel defined
- Other main components in good shape:
  - Veto detectors being finalized, also proceeding on the electronics
  - Small angle first test successful
  - Active diamond target practically ready (including readout electronics)
- Core 2016 used to procure all the materials for calorimeter construction
- Core 2017 already secured by CSN1 in September meeting
- **In line for starting physics data-taking at the beginning of 2018**

SPARE SLIDES

PADME charged particle veto

- Extruded plastic scintillator bars 10x10x200 mm^3
- 3 sections for a total of 250 channels:
  - Electrons (100), positrons (100), and high energy positrons (50)
- Inside vacuum and magnetic field region
- Main requirement:
  - Time resolution ≃ 300-500 ps
  - Momentum resolution of few % based on Z impact position
  - Efficiency better than 99.5% for MIPs

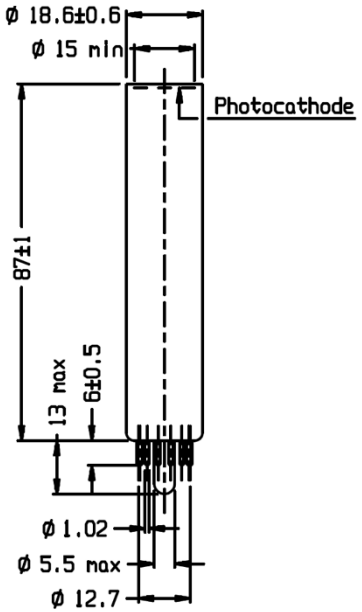


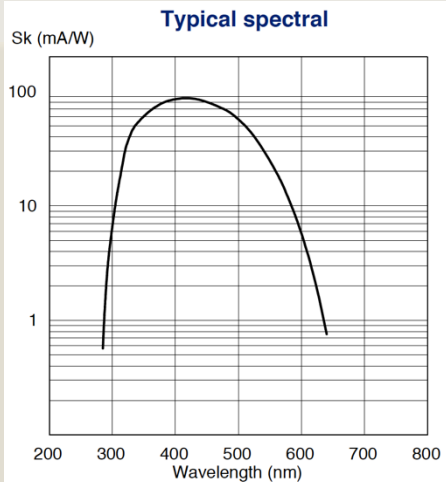


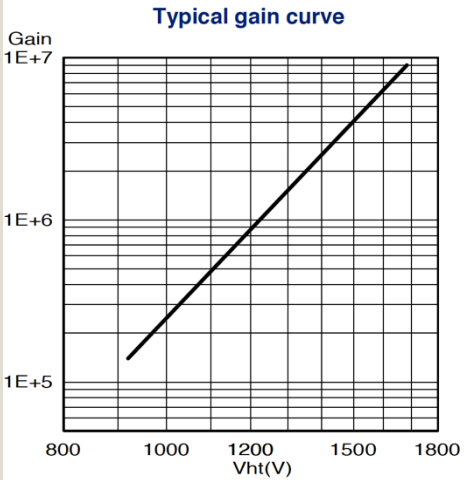
- Prototype tested at BTF with multi-anode PMT and fibers

HZC XP1912

HZC PHOTONICS







Description	
Window material	Lime glass
Photocathode	Bi-alkali
Refr. Index at 420nm	1.54
Multiplier structure	Linear focused

Photocathode characteristics	Min	Typ	Max	Unit
Spectral range :		290-650		nm
Maximum sensitivity at :		420		nm
Sensitivity :				
Luminous :		100		μA/lm
Blue * :		11		μA/lmf
Radiant, at 420nm		85		mA/W
Characteristics with voltage divider A	**Min**	**Typ**	**Max**	**Unit**
Gain slope (vs supp. Volt., log/log)		6.8		
For an anode blue sensitivity of		10		A/lmF
Supply voltage *	920	1200	1280	V
Gain		$9x10^5$		
Anode dark current *		5	20	nA
Mean anode sensitivity deviation :				
Long term (16h) :		1		%
After change of count rate :		1		%
Pulse amplitude resolution for ^{22}Na (511 keV)		16		%
Gain halved for a magnetic field of :				
Perpendicular to axis "n" :		0.3		mT
Parallel to axis "n" :		0.2		mT
For a supply voltage of : 1500V	**Min**	**Typ**	**Max**	**Unit**
Gain		$7.5x10^6$		
Linearity (2%) of anode current up to :		20		mA
Anode pulse :				
Rise time :		2.3		ns
Duration at half height :		3.5		ns
Transit Time :		20.5		ns
Transit Time Different centre of photocathode up to 7mm from it :		1.5		ns

Item No.	Description	Qty. (Sets)	Unit Price (EURO)	Total Price (EURO)
1	Photomultiplier Tube：XP1912	25	1,40.00	3,500.00
2	Voltage Divider Type B: VD108 (Negative)	25	10.00	250.00
3	Voltage Divider Type A: VD108 (Negative)	5	10.00	50.00
4	Tube Socket: FE1004	50	10.00	300.00
	Total FOB Price			4,100.00

PMT catalog prices

Model	PMT (1Pcs) no VAT	Base (1Pcs) no VAT
Hamamatsu R1166P	356	168
ET 9078B	245	47
HZC XP1912	160	included