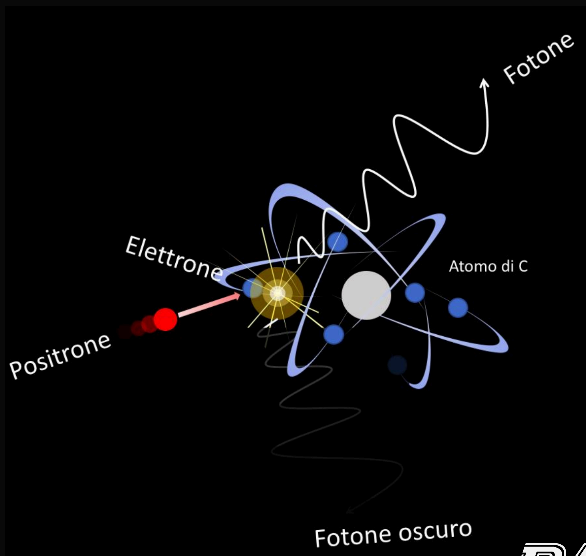
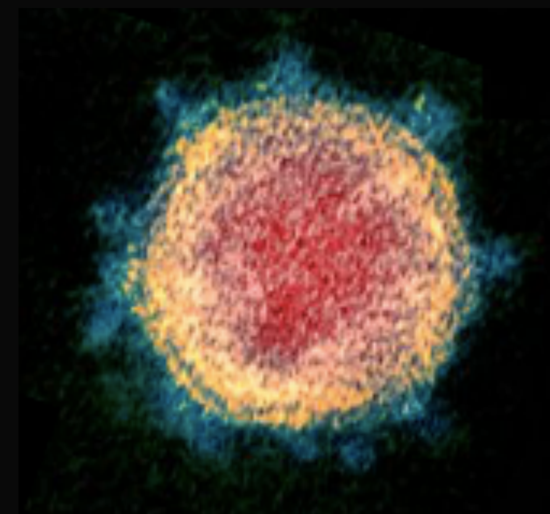
PADME status report





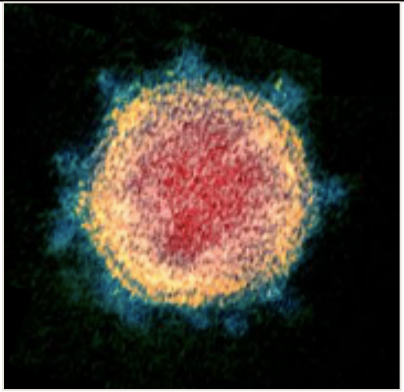
PADME VS COVID-19

Mauro Raggi,
Sapienza Università di Roma e INFN Roma

60th meeting of the LNF Scientific Committee

LNF 17/11/2020

Outline



- Consequences of COVID-19 on PADME plans
- Results of detector restart and July test run
- Status of the current Run II data taking
- Next future prospects
- Expected publications 2020 - early 2021

59th Scientific committee

Findings PADME:

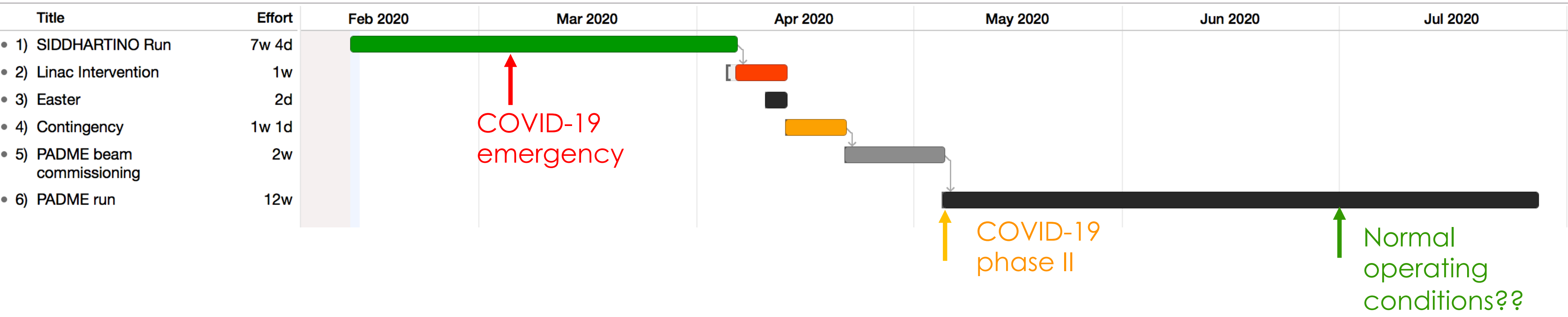
- The PADME collaboration is planning for a 2-month long RUN-2 starting in July. Before this can happen, a number of subdetectors need to be fixed or upgraded. The collaboration has prepared a detailed plan with the various hardware items, and their priorities, that need to be done starting in May. Due to travel restrictions, only Roma and LNF personnel will be able to be onsite. The BTF team also needs to update their systems in the same confined space and this will require close coordination to avoid overcrowding. The COVID-related rules will impact RUN-2 operations. Shifts can be done remotely by the full collaboration. It may require Roma people to be locally available for experimental interventions.
- The collaboration has continued improving the data reconstruction. Correlations between various detector subsystems are being done and the matching of data and MC is improving. A better simulation of pile-up may further improve data and MC agreement.
- The first technical paper on target performance has been published and three other papers related to PADME commissioning, the ECal, and trigger and timing are in preparation. The $ee \to \gamma\gamma$ cross section paper with RUN-1 data is scheduled for early 2021, other phenomenological papers are to follow.

Recommendations PADME:

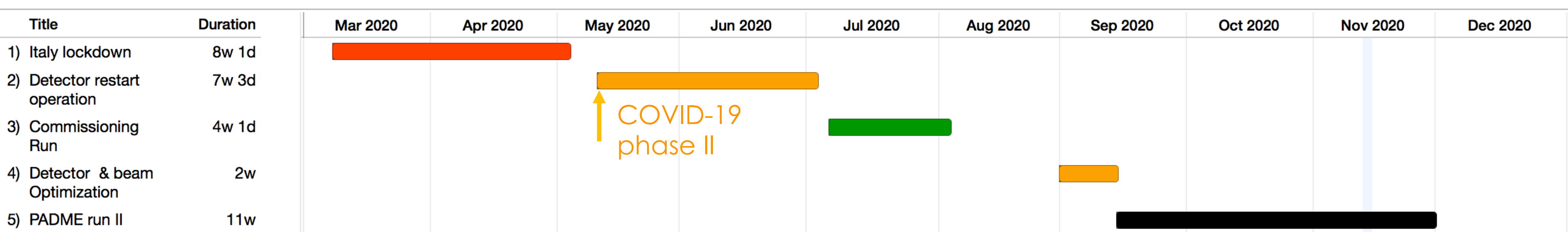
- *The SC is happy to see PADME's flexible proposal and recommends merging it with a similar BTF schedule.*
- *While the SC is very happy to see PADME publications being written, it would encourage the collaboration to focus especially on the timely release of physics results.*
- *The SC would like to see a more detailed proposal and sensitivity reach for running PADME at DAFNE.*

Covid

Plan of the last meeting of the SciCom



- Beginning of March COVID-19 emergency started
  - beam time rescheduled to match emergency rules
- Commissioning run successfully completed in July.
- Run II started September 14th still ongoing

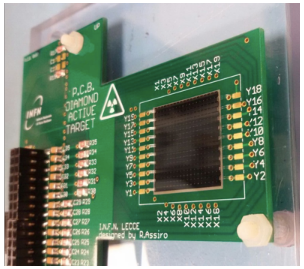


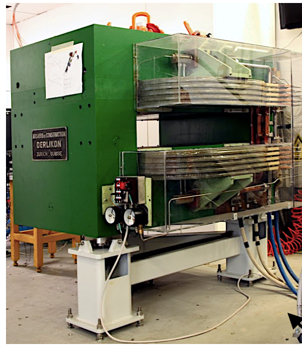
Impact on PADME restart activities

- Almost no hardware preparation activity during COVID-19 phase I
  - Need to perform some repairs and small improvements
- Activity during phase II limited to RM1 and LNF personnel only
  - Only travels from Rome to LNF
  - No help in preparation activities from Lecce, Sofia and Torino
- COVID-19 rules limit personnel access in **BTF area**, **control room**, etc.
  - Not possible to parallelize interventions in BTF area
  - Access to the area should be coordinated with accelerator division operators
- Restart operations much longer wrt to normal operating conditions
- COVID-19 rules will also affect RUN-2 operations (e.g. use of control rooms)

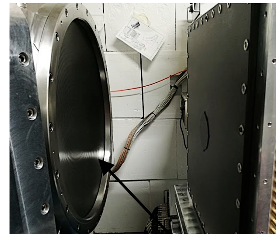
The PADME detector 1 slide

Active target
Lecce & University Salento

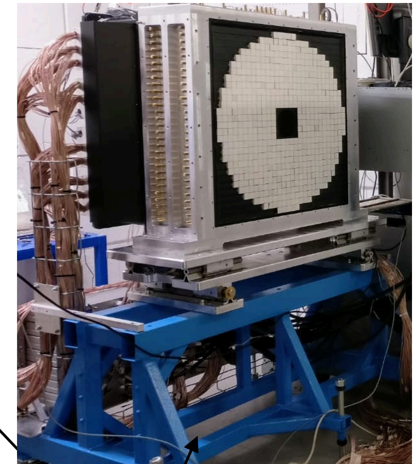




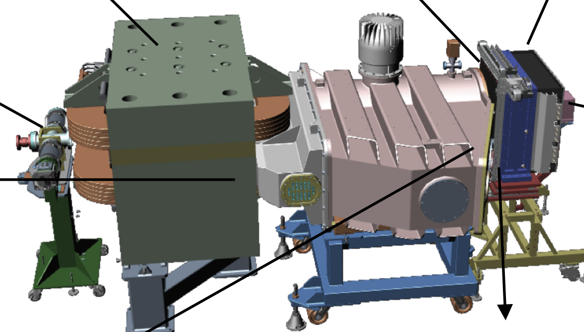
Dipole magnet
(CERN TE/NSC-MNC)

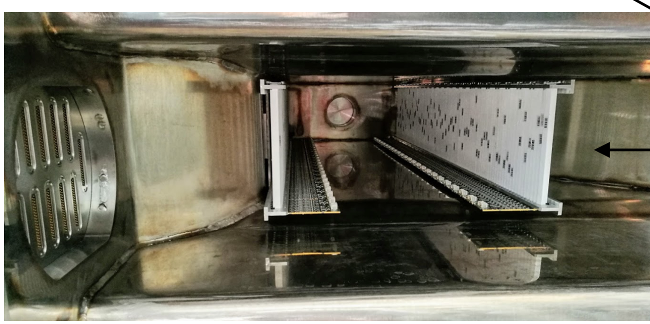


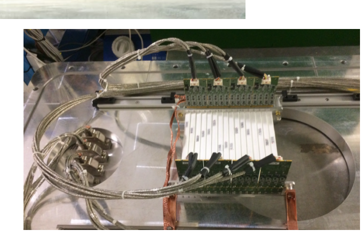
C-fiber window



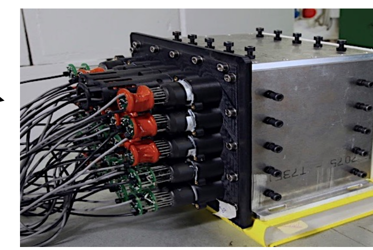
BGO calorimeter
(616 L3 endcap crystals: Roma, Cornell U., LNF, LE)



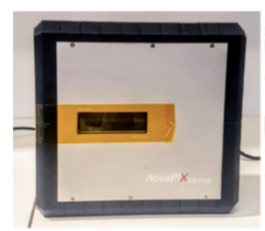




Veto scintillators
(University of Sofia, Roma)

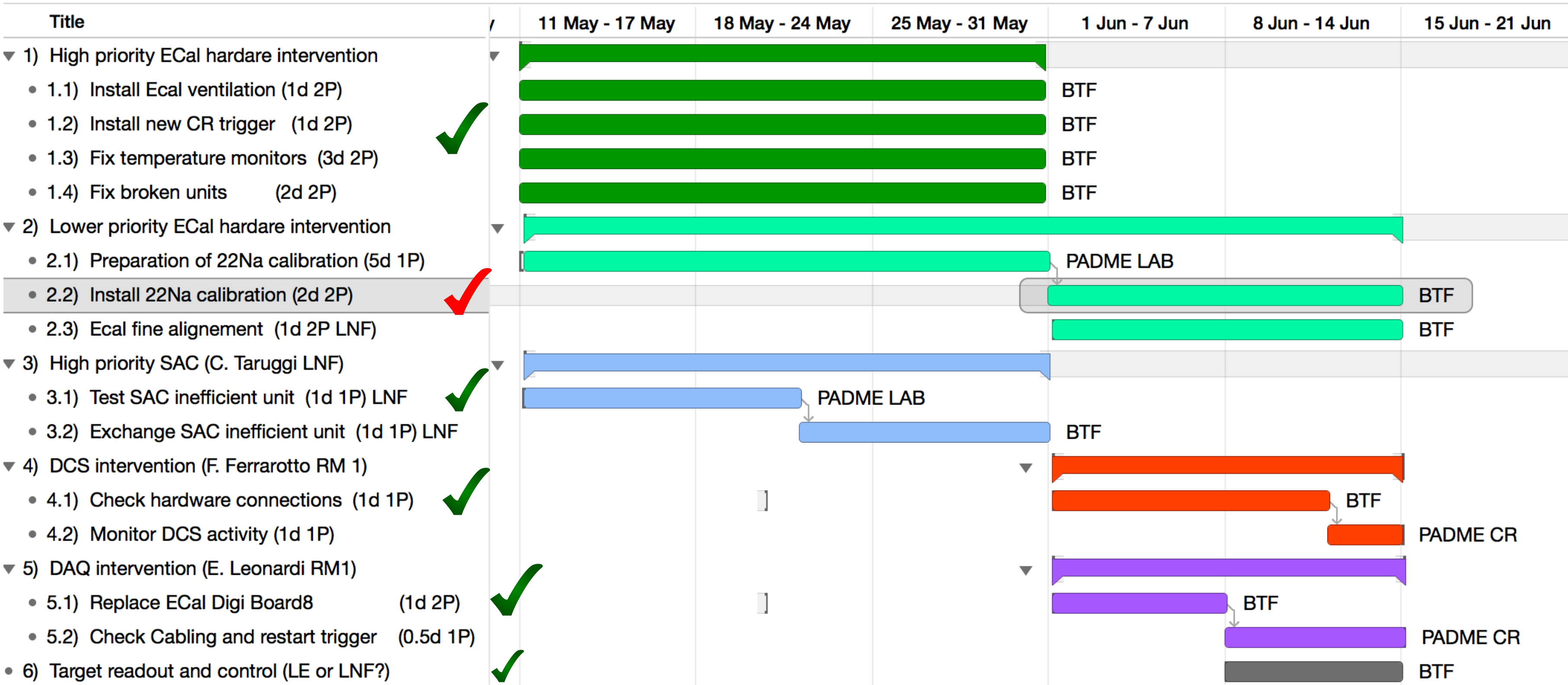


PbF_2 calorimeter
(MTA Atomki, Cornell U., LNF)



TimePIX3 array
(ADVACAM, LNF, RM1)

Hardware intervention before restart

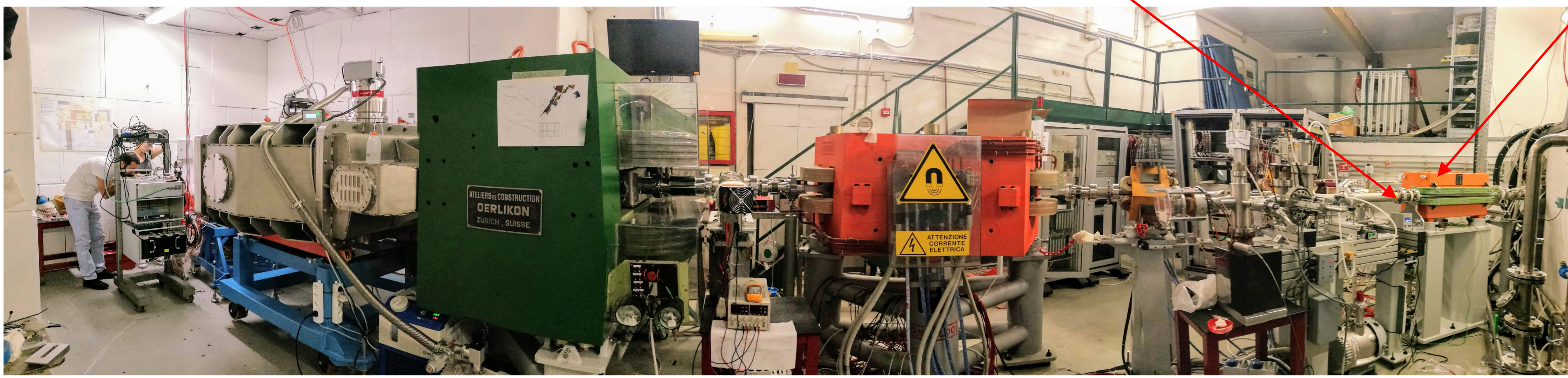


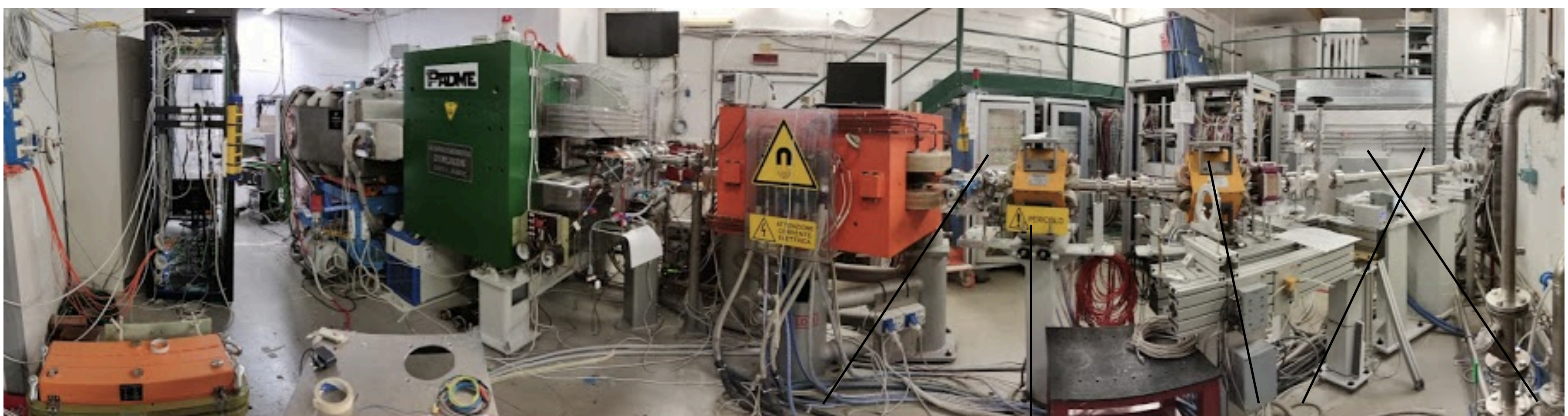
July commissioning run highlights

Beam line 2020

Finestra Be rimossa

Dipolo pulsato linea BTF-1/BTF-2 disinsta





Camera da vuoto a 2 vie di riserva

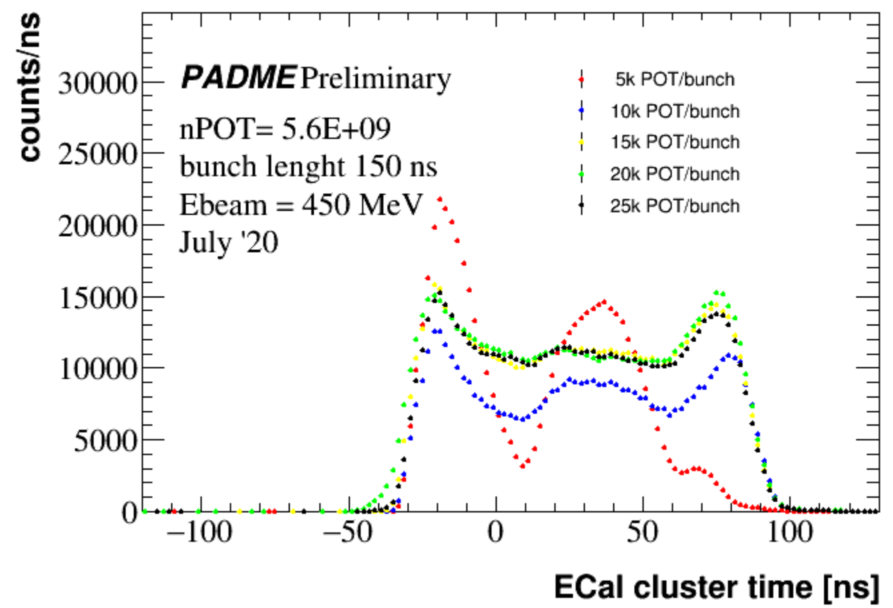
Nuovo collimatore

Nuove camere

Nuove valvole e pompaggio

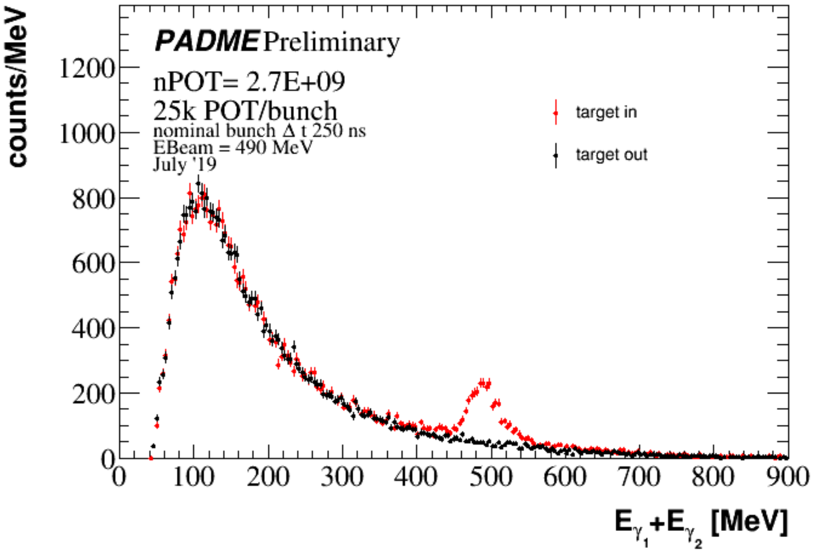
Beam timing structure using ECal

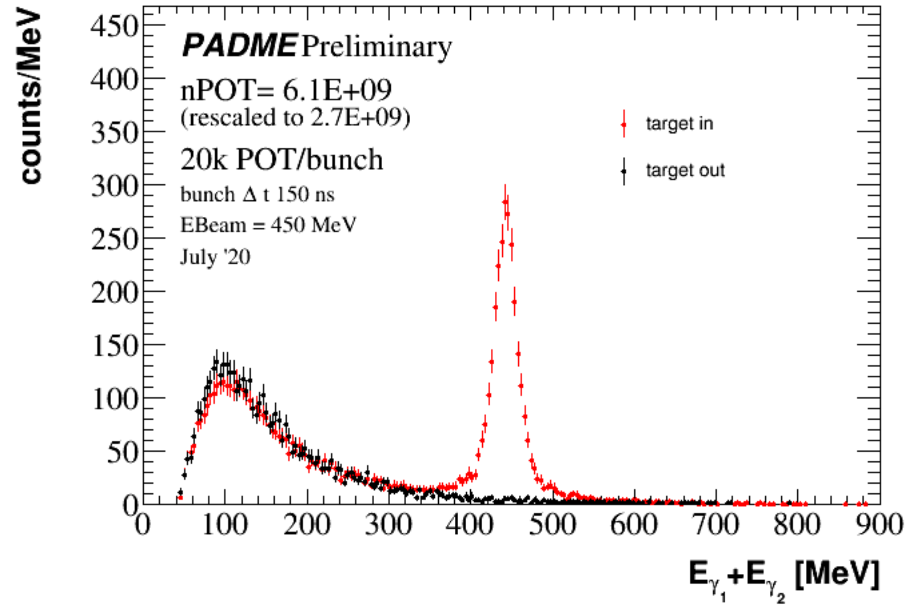
	RUN	DATE	NPOT(BTF TRIGGER)	NO TARGET RUN	DATE NO TARGET
5K	30211	2020-07-22 19:18:22	3.56518e+09	30220	2020-07-23 05:49:20
10K	30205	2020-07-22 08:16:40	3.36962e+09	30207	2020-07-22 11:58:00
15K	30201	2020-07-21 22:43:35	5.63313e+09	30202	2020-07-22 01:02:24
20K	30203	2020-07-22 03:17:23	7.74356e+09	30204	2020-07-22 05:40:45
25K	30209	2020-07-22 14:36:34	6.0939e+09	30210	2020-07-22 17:36:55



- We acquired data samples at different intensities to study the bunch time structure of the beam and the background
- We achieved 150ns bunches with almost flat structure and intensity up to 25K e+/bunch.
- Energy below the nominal 490 MeV due to modulator C problems.

ancora sul fondo… usando γγ

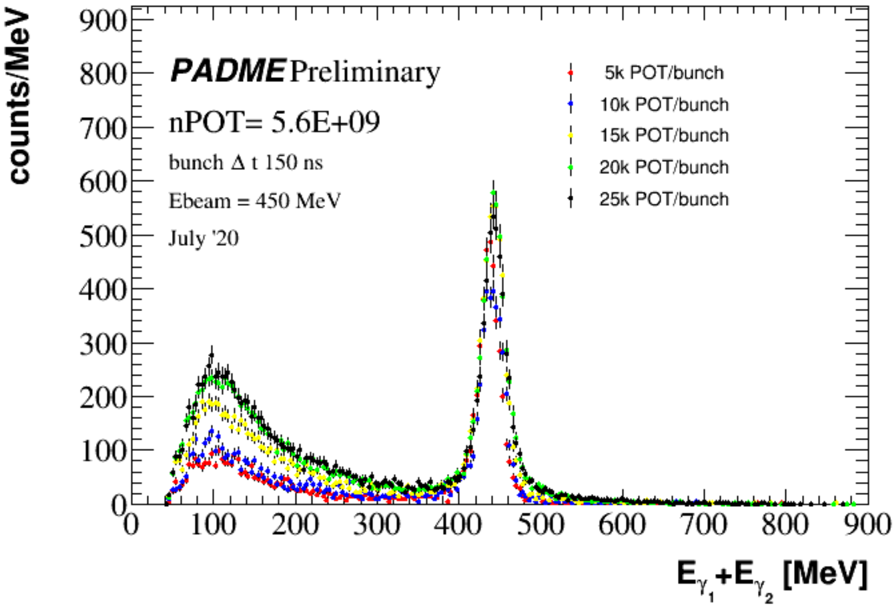


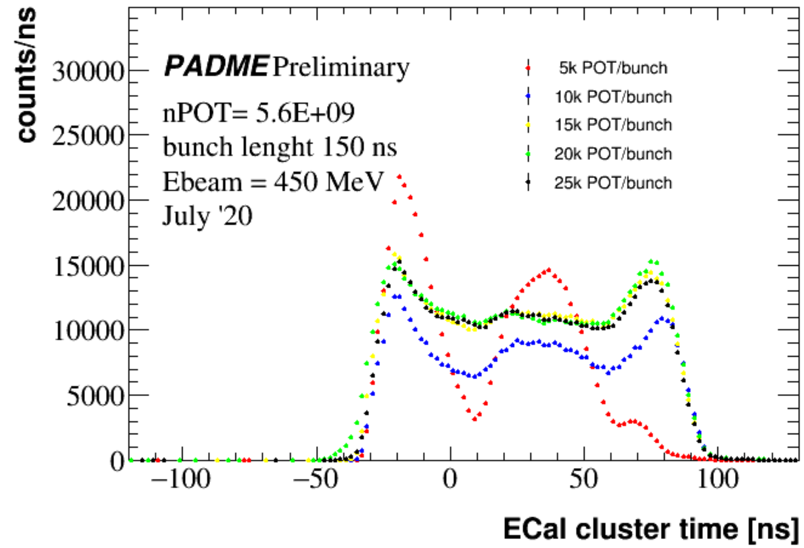


- In red data with target in the beam in black data without target
  - Comparison of the peak of γγ with loose selection cuts
  - Much better signal/BK ratio for 2020 data wrt to July 19 sample

- Improved resolution in peak region thanks to lower background.

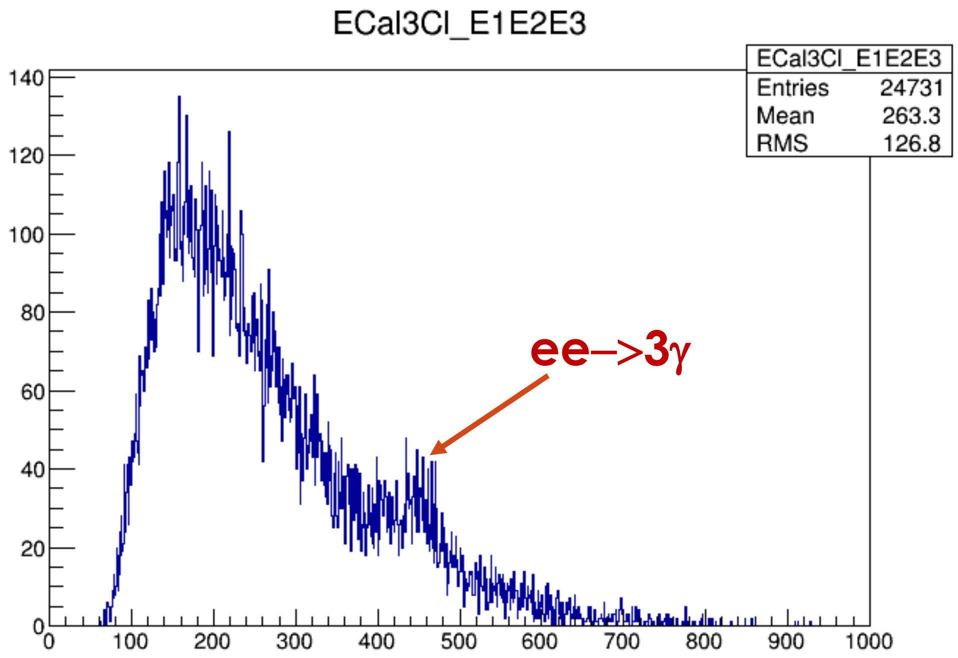
Confronto dei candidati $\gamma\gamma$





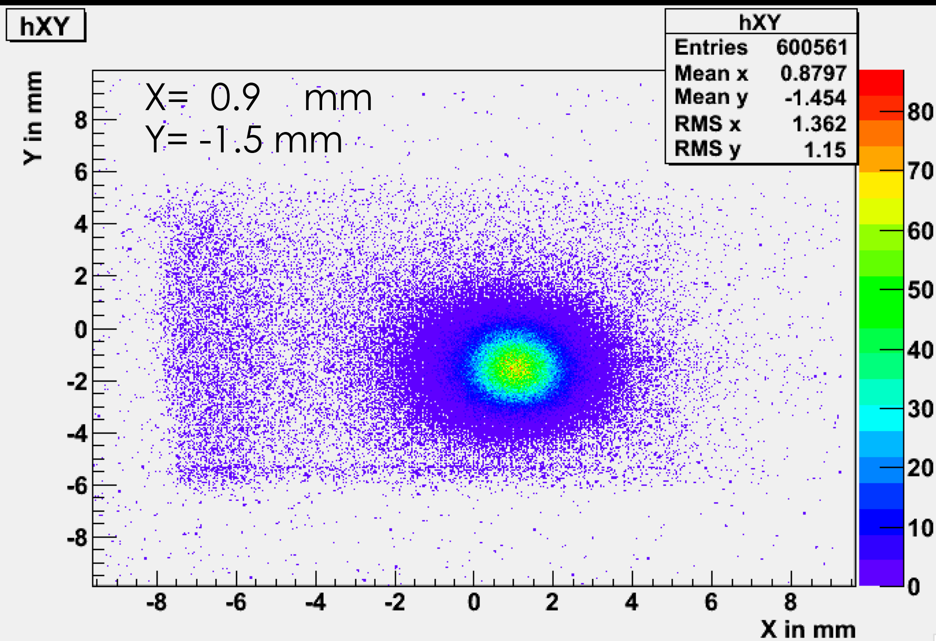
- Less background in low-multiplicity runs
- Number of candidates normalized to the same POT very similar ~10%
- Reconstruction efficiency ok up to 25K POT/bunch
- 5K-10K BG almost the same due to very similar density (bunch at 5K is shorter)

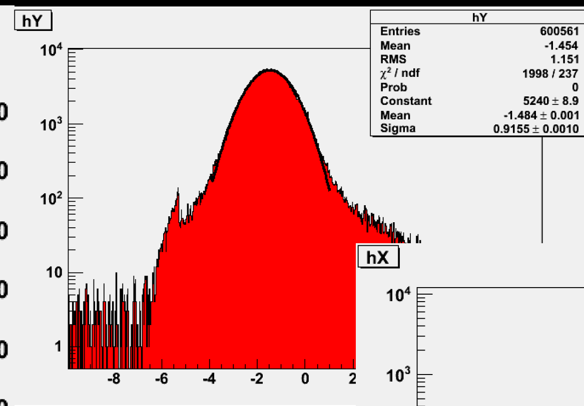
First evidence of ee –> 3γ

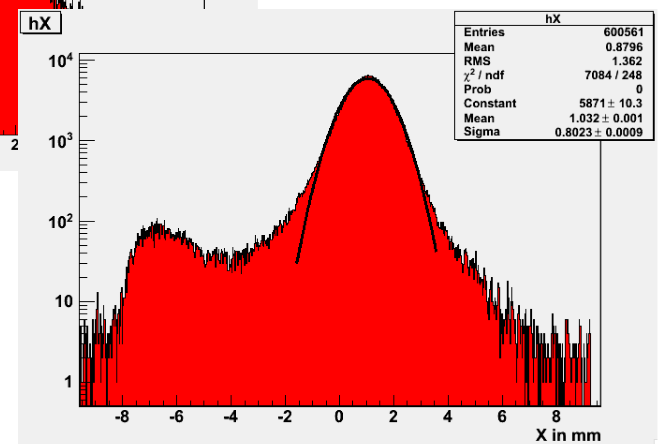


- Only 3 clusters on time in Ecal.
  - No additional analysis cuts
  - Peak already visible with correct total beam energy

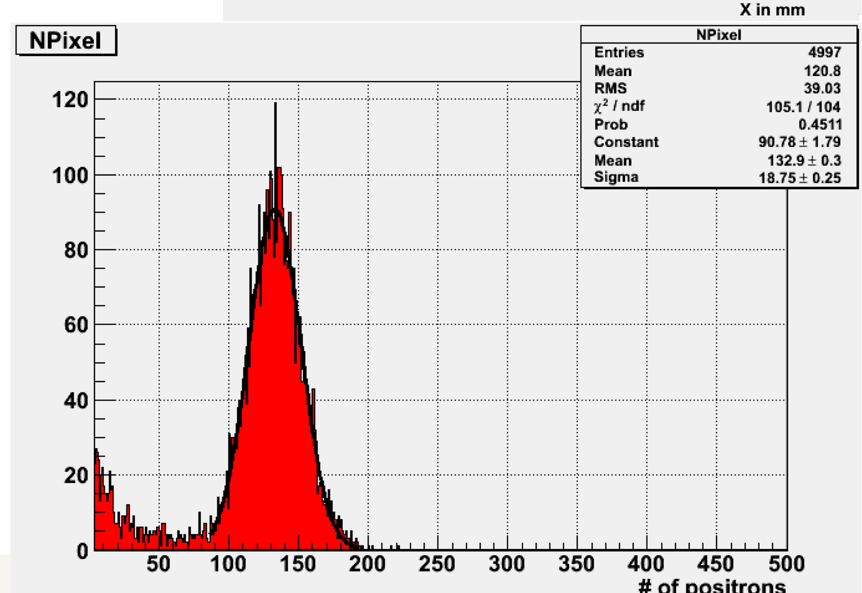
Mimosa test in July!





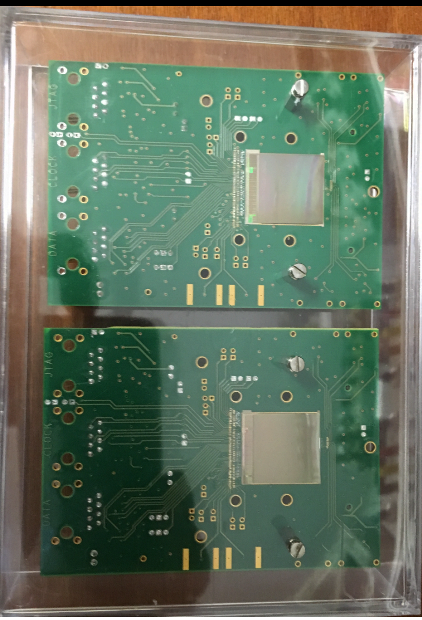


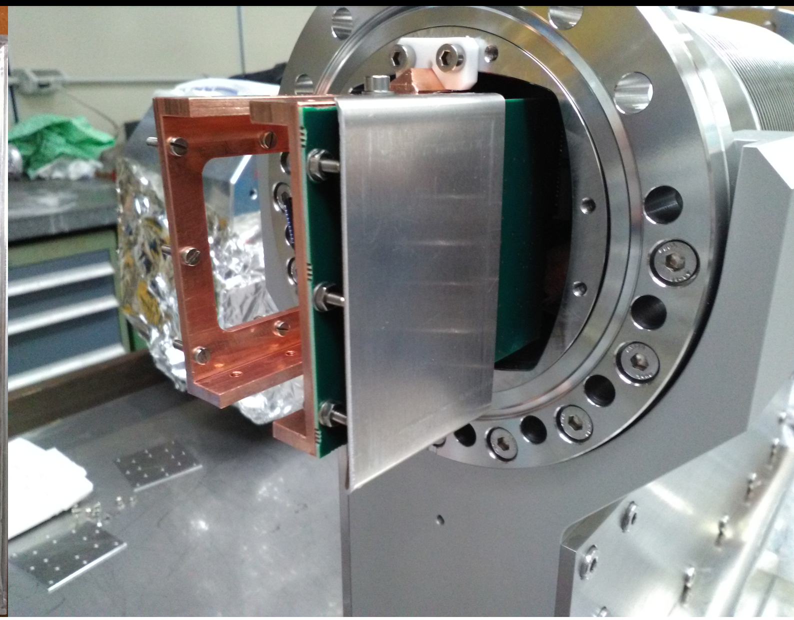
- Prima analisi dei dati di 1 dei mimosa
- Intervento per sistemazione secondo sensore
- Test di funzionalità a due canali ok!

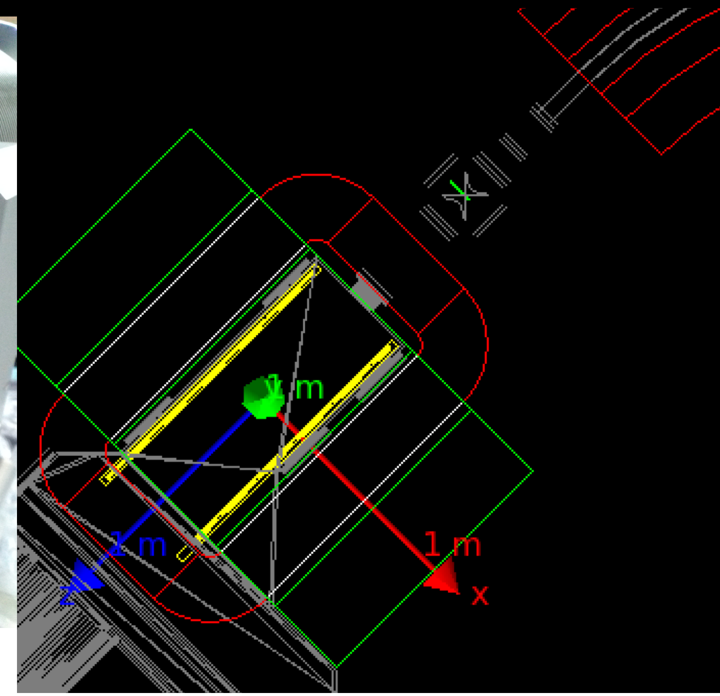


September detector fixes

Mimosa second sensor installation







- 2 sensors now mounted at 50mm distance
  - One before and one after the target.
- Can be used to measure beam direction and divergence
- Can be used to measure charged particle angle in single particle.

Early September detector interventions

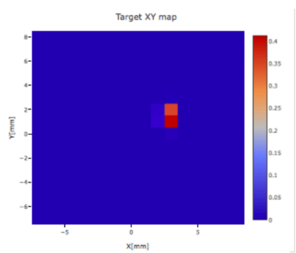
- At the end of the July run some problems to fix were identified:
  - The linearity of the target with the pencil beam.
  - Initialization fault of the second mimosa sensor
  - 16 dead channels in Eveto
- Decision to open the cross on both sides mimosa and Target for interventions on the detectors.
- It was decided to open the main vacuum for an intervention on the electron veto electronics channels.
- Intervention scheduled for the beginning of September.

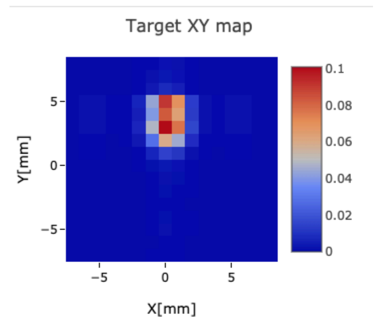
Pencil beam e saturazione target

With bunch ~150ns we were able to obtain a microbeam σ<1mm

Much smaller than the usual beam: σ ~2-3 mm

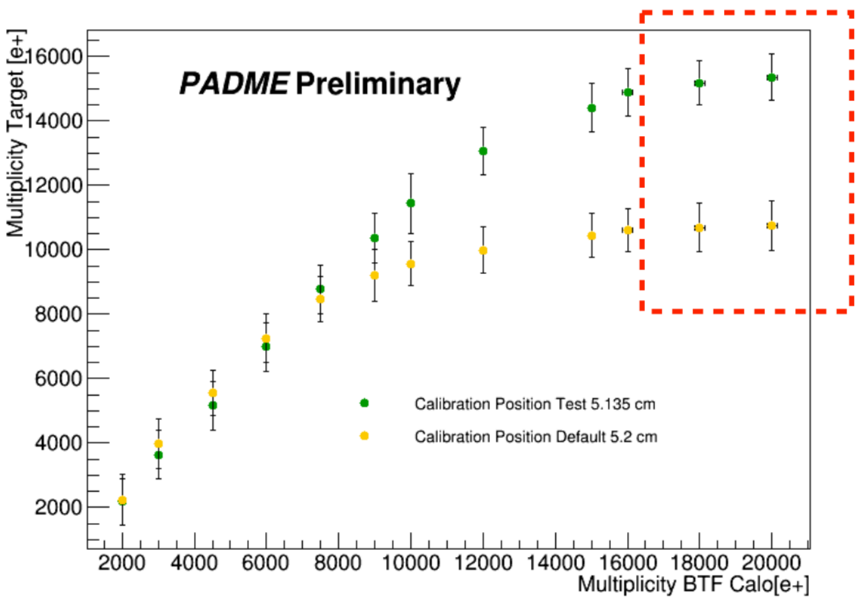
Beam too focused





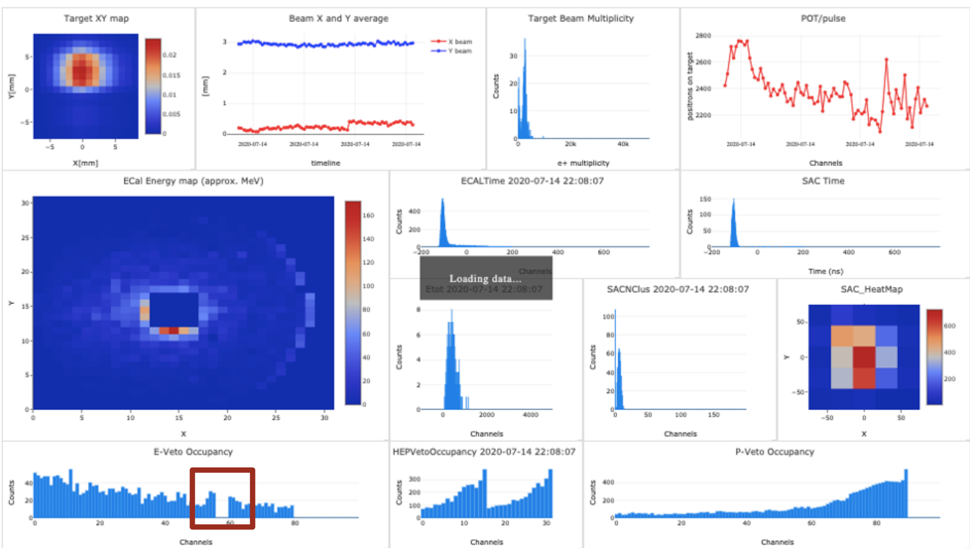
Target Challenge

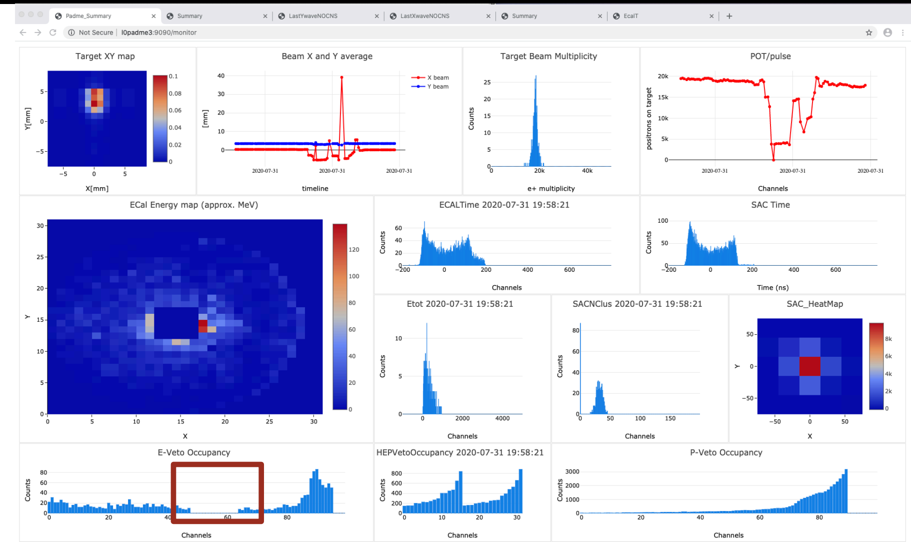
The strip hit with this beam condition saturates



In these very high positron density conditions the target does not maintain linearity above 10K-12K POT

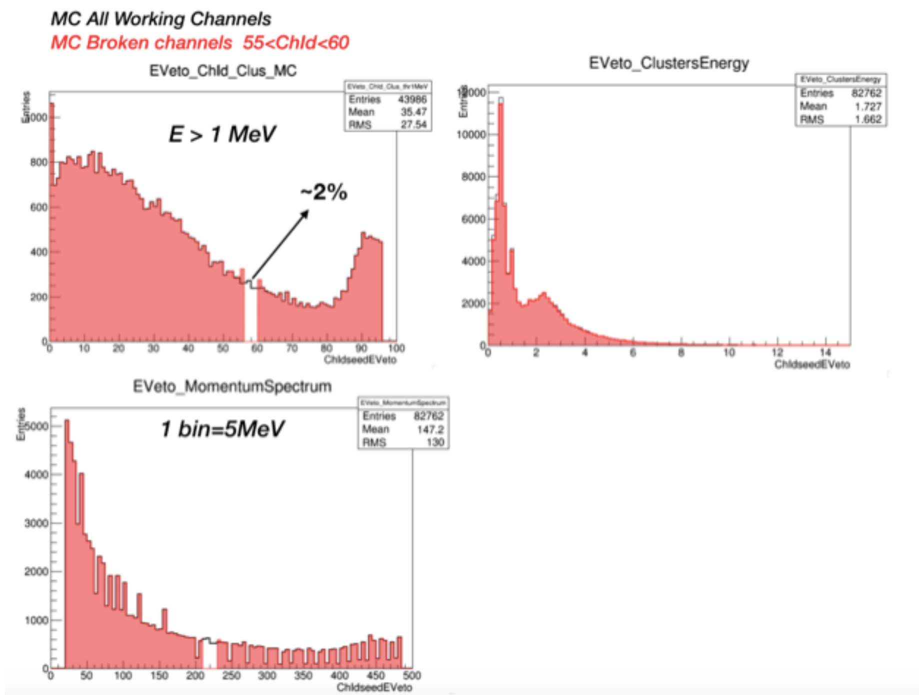
Problemi con EVeto





- At the beginning of July we had a connection problem with 4 ch of the Eveto
  - During the test run we tried an intervention but we lost 16 channels
  - The diagnosed error was due to I2C communication with mezzanines.
- Each mezzanine controls 4 ch
- External NIM controllers control 16 channels

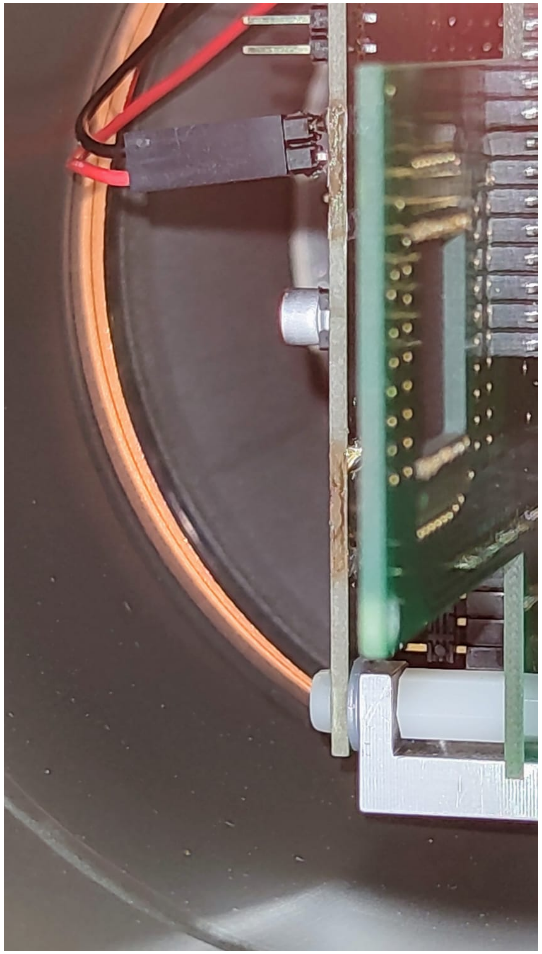
Intervento sull'eveto

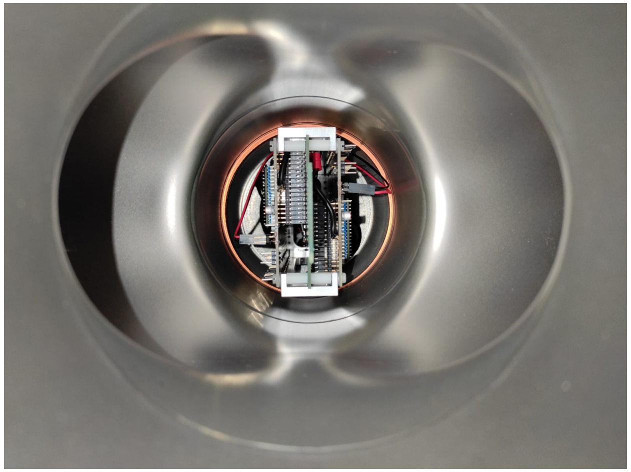


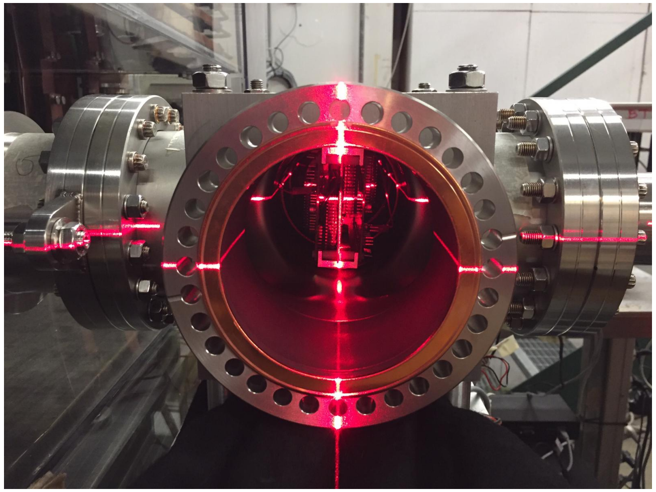
- 4 September
  - opening of rectangular flange
  - disconnection of the 4 non responding bards
  - only 1 board (4 channels) is actually broken
  - 3 boards (12 channles) have been recovered
  - just disconnecting the broken one (most likely causing a busy on the bus)
  - given the difficulty and risk of extracting the detector to replace the board, we decided to live without 4 channels

- Mercoledi' 9 Settembre
  - closing of flange
  - operation on E-Veto concluded

Diamond target operation Set 2020





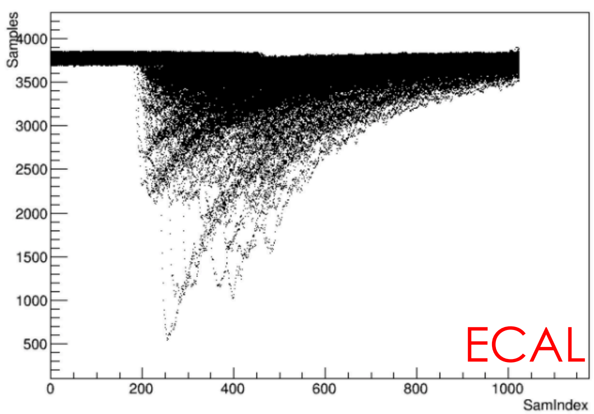


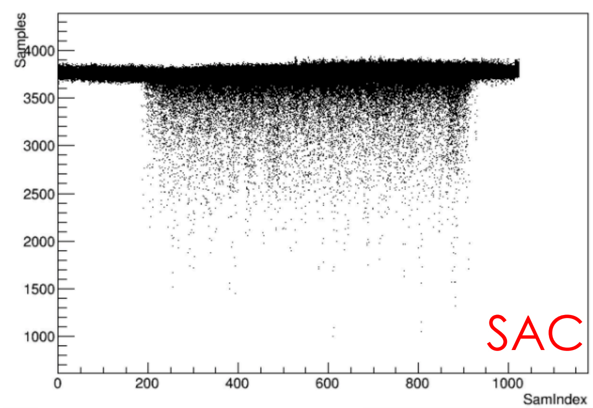
- September 8
  - Opening of the diamond target arm of the cross
  - Work on diamond electronics to increase dynamic range
  - Target vertical position measurement
  - A vertical dispacement of about -3mm confirmed
- Wednesday 9
  - Fixed the vertical position and closed the vacuum

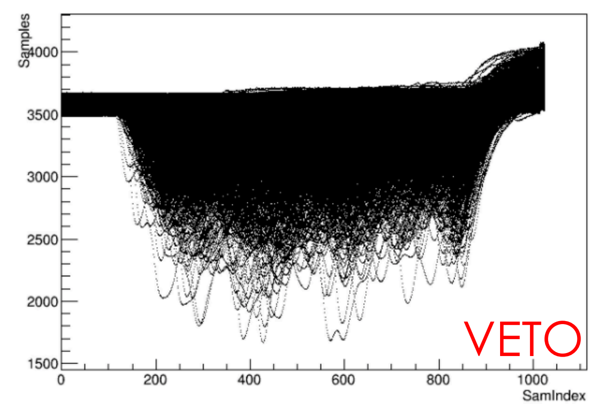
Run II autumn of 2020

Run II running conditions

- In order to cope with Modulator C problems, reduced RF power (see BTF report)
  - Trade-off between pulse length and beam energy
  - Exceeding 300 ns pulse length would cut the digitized waveforms
    - 1K samples at 1GS/s for ECAL→1μs window but with long tails of BGO scintillation
    - 1K samples at 2.5 GS/s for SAC, VETOS, and target→400 ns window
- A lower positron beam energy impacts the dark photon mass sensitivity, we have chosen to stay at least at 430 MeV → 21 MeV/c^2



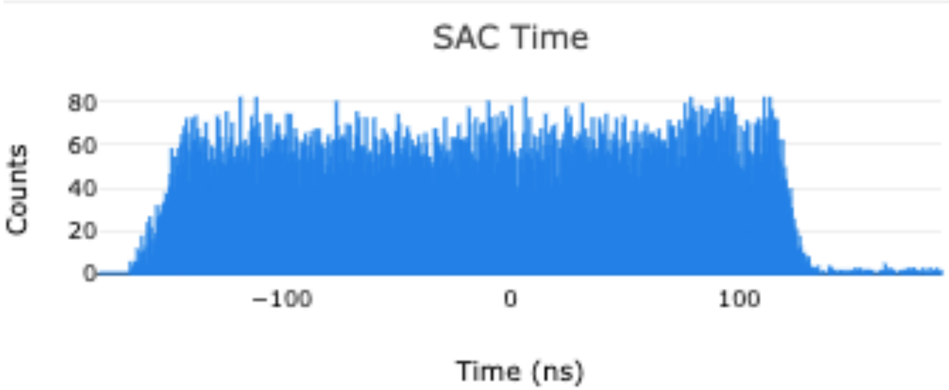


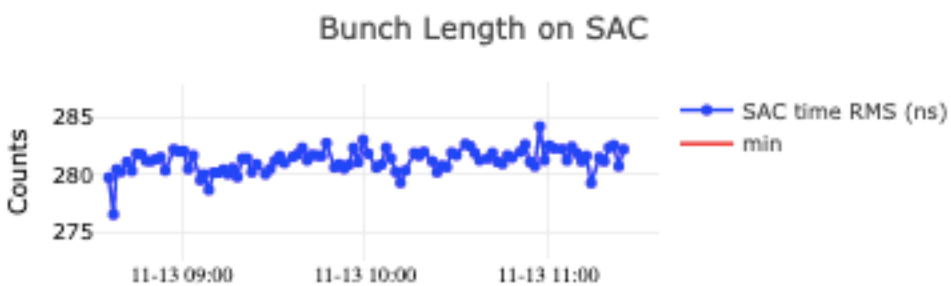


Luminosity increase during Run II

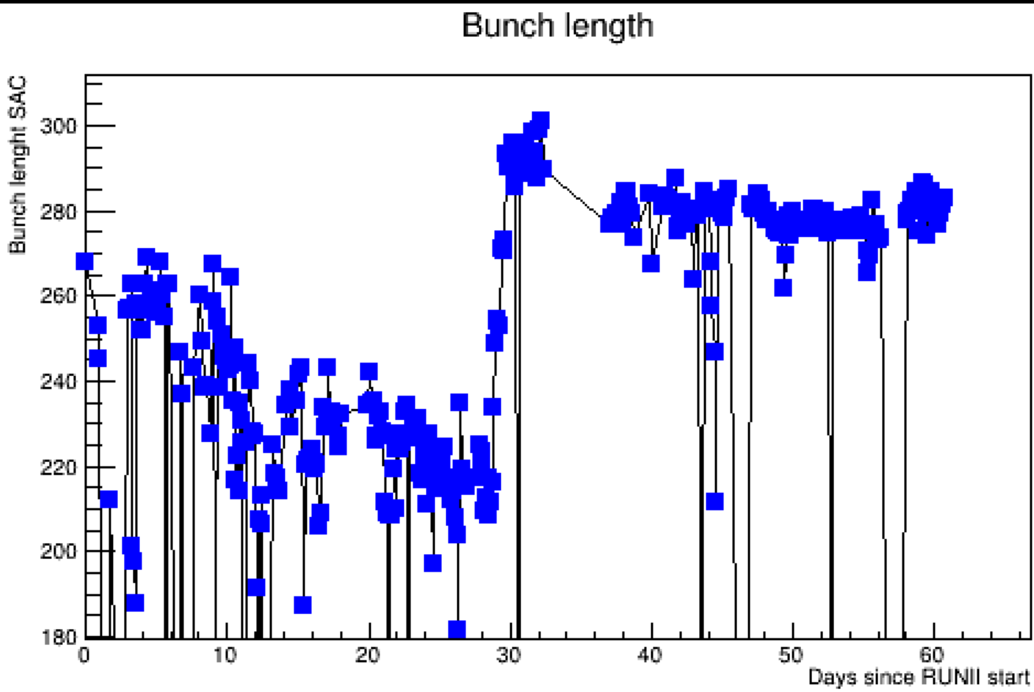
- Beam length increased during the run, from ≈150 ns at the very beginning, going to 200-220 ns in late September and then up to 320 ns in October. More stable conditions at 280-290 ns

- In order to keep the pile-up and over-veto under control, we ask a beam intensity of 100 $e^{+} \times \Delta t(ns)$, where Δt is the beam pulse length
  - $\pm 10\%$ tolerance window

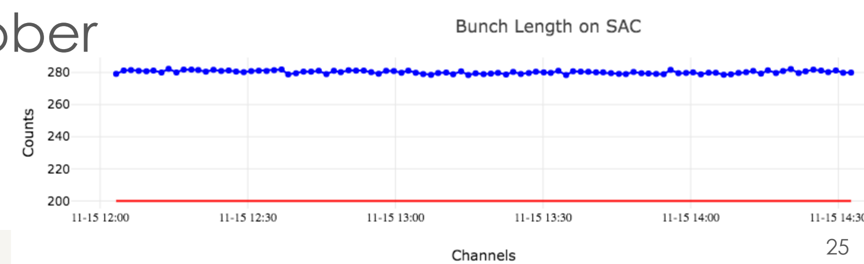




Buch length during Run II



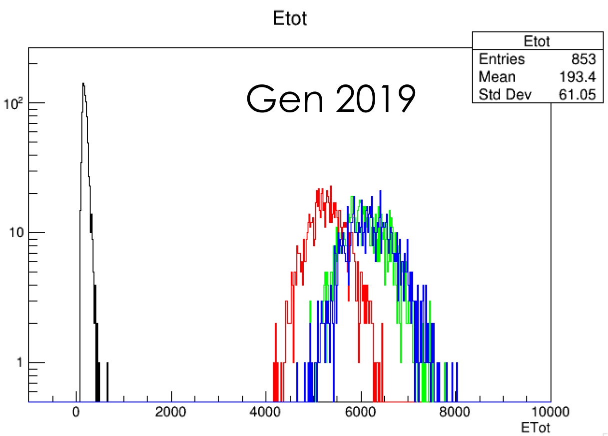
- Big step around mid October from 220 to 300ns
- Few days period around 300 ns
  - Too close to digitization window (400ns)
- Good stability at 280ns from ~18 October



Beam background history @ PADME

Background Run I

2018-19 secondary e^+

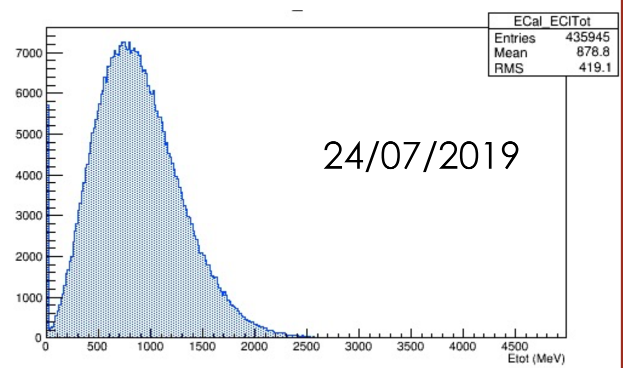


~150ns 20K pot E_{e+}=550MeV

7GeV/20K = 0.35MeV/e^+

Background test run

July 2019 primary e^+



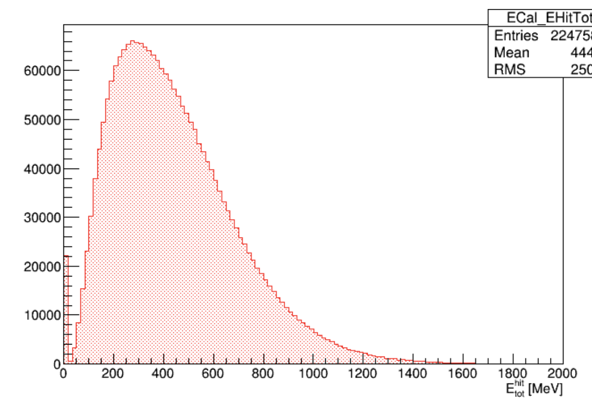
~200ns 22K pot E_{e+}= 490MeV

0.9GeV/22K = 0.04MeV/e^+

Background Run II

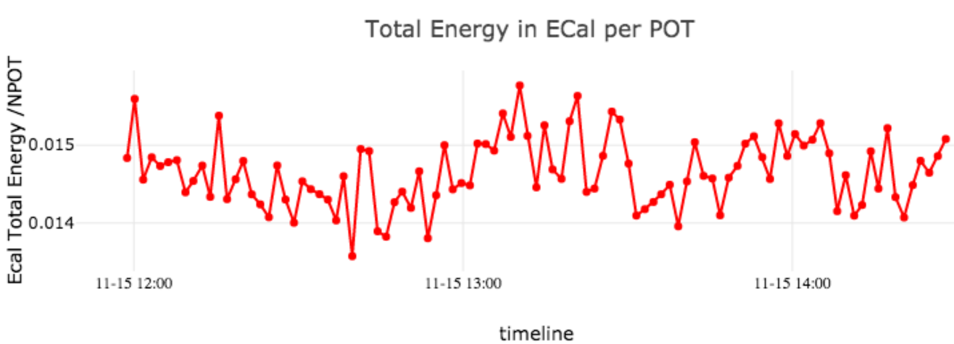
July 2020 primary e^+

No Be window

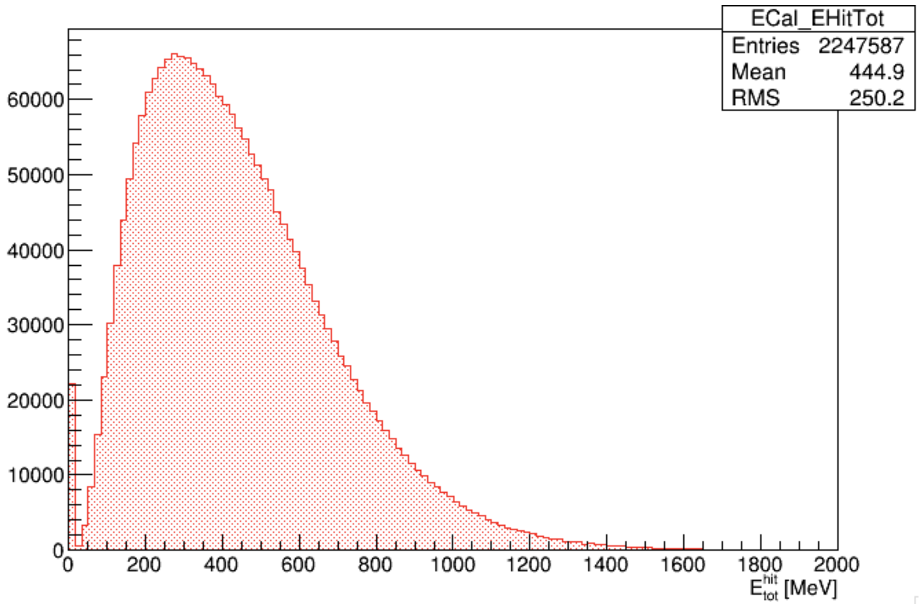


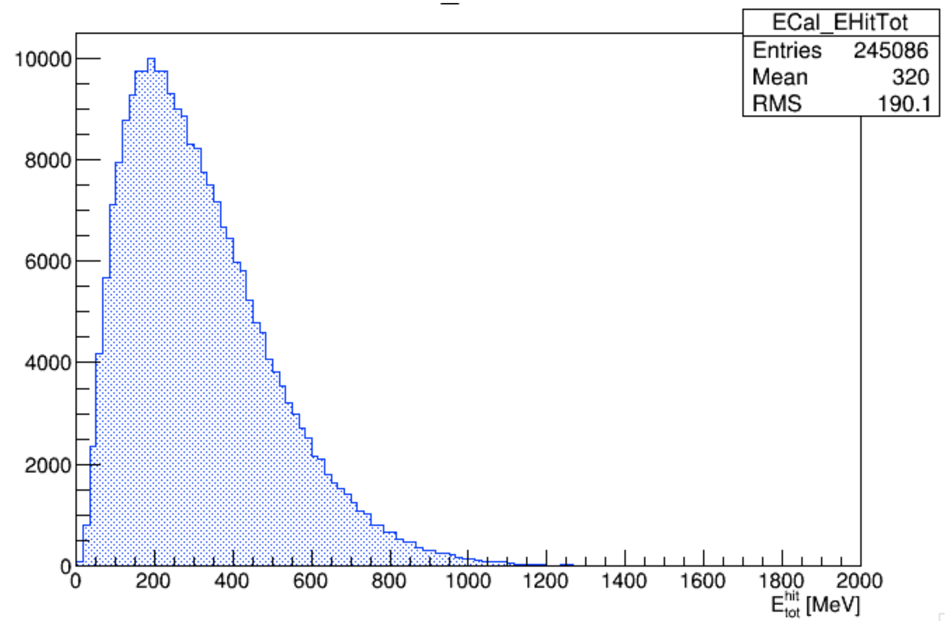
~280ns ~26K pot E_{e+}= 430MeV

0.445GeV/26K=0.017MeV/e^+



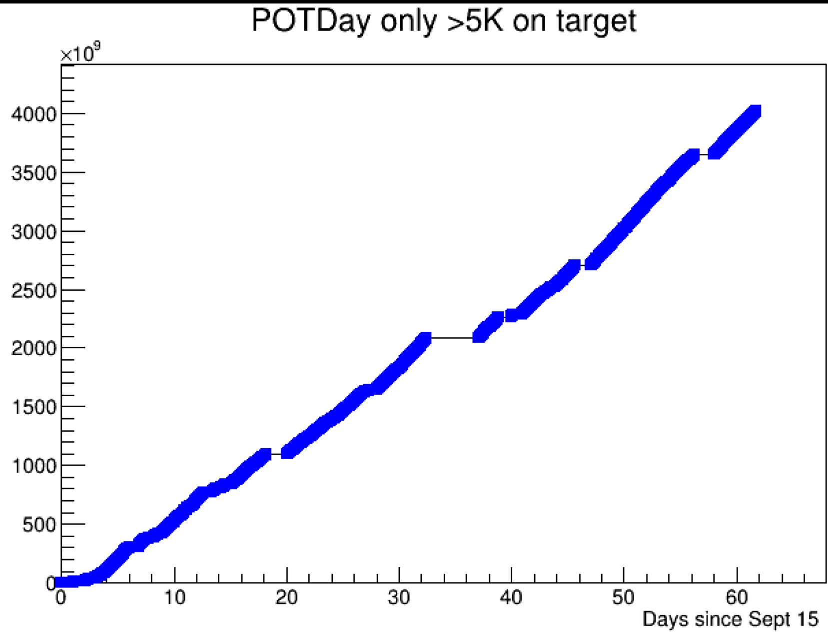
Target no target run during RunII





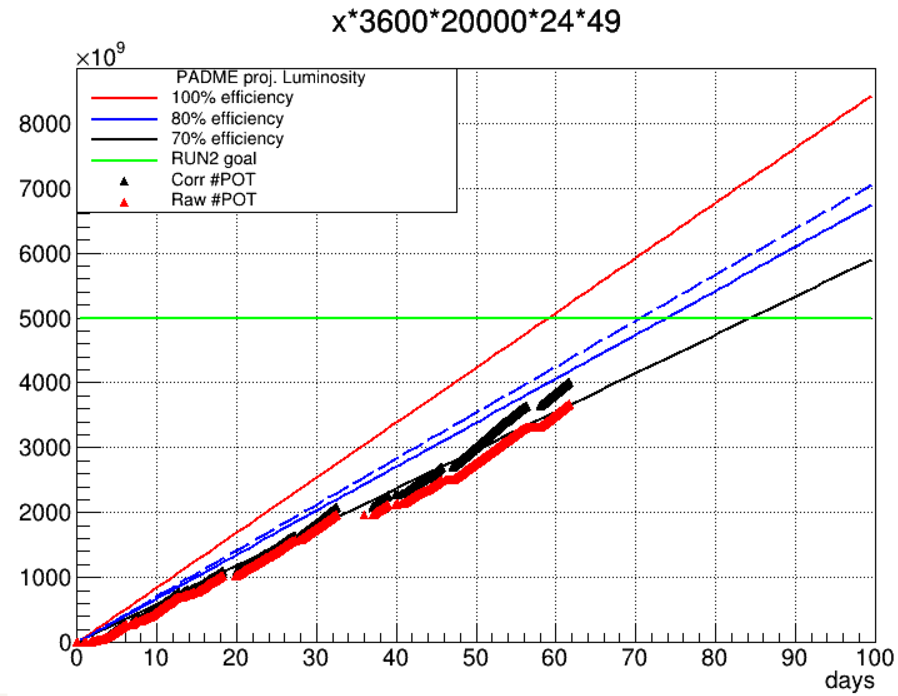
- **Target run:** average energy 450 MeV
- **No target run:** average energy 320 MeV

Integrated luminosity



we reached 4E12 POT just in this morning
Keeping now a slope of ~1E11/day

Projection using 80% efficiency curve points to reaching the 5E12 in ~10 days



Future 2021-22 physics opportunities

- Precision in the measurement of SM cross section in Run II at PADME is limited by luminosity measurement (few %).

- Several absolute SM cross section meas. are possible at PADME:
  - **Pure photon** final states: $e^+e^- \to \gamma\gamma$ $e^+e^- \to \gamma\gamma\gamma$
  - **Pure electron** final states: $e^+e^- \to e^+e^-$, $e^+e^- \to e^+e^-e^+e^-$, $e^+e^- \to e^+e^-e^+e^-e^+e^-$
  - **Mixed e-γ** final states: $e^+e^- \to e^+e^-\gamma$, $e^+N \to e^+N\gamma$

- None of these cross section is measured at sqrt(s)~20 MeV
  - Some of these channels can have dark sector related enhancement.
  - PADME can use different target material (Si and C) using mimosa or diamond

- Cross section except ($e^+e^- \to e^+e^-e^+e^-e^+e^-$) are big enough to be measured in few days scale.
  - Even with reduced bunch length to allow parasitic running

- Measuring some of these CS requires different detector operating conditions
  - Smaller N_{pot}/bunch different magnetic field value.

Possible data taking in 2021-22

- The laboratory plans is to run Siddharta in the whole 2021 and this is the clear commitment of the Lab we don't't' want to interfere with.
- PADME is a small detector and can be prepared for running in just a few days.
  - We experienced running the detector remotely with high reliability during Covid emergencies.
- We are able to profit of parasitic runs or short technical interruption of the DAFNE running for performing low statistic measurements.
- If there will be the possibility we are ready to profit of few weeks of runs in the upcoming 2 years

Discussion about the 5Y scale future

Fisica Fondamentale a Frascati

Tuesday 27 Oct 2020, 14:30 → 18:00 Europe/Rome

Description ACCEDI A RIUNIONE WEBEX

https://infn-lnf.webex.com/infn-lnf-it/j.php?MTID=mecf3d2f44761066b65fd2c41c048d98b

14:45 → 14:50 **Introduction and Overview** 5m
Speaker: Enrico Nardi (LNF)
FFF.pdf

14:50 → 15:10 **Options for a PADME phase-2** 20m
Speaker: Mauro Raggi (ROMA1)
PADMEPhysics09.2...

15:10 → 15:30 **PADME potential reach for Dark Photons & ALPs** 20m
Speaker: Luc Jean Marie Darmé (Istituto Nazionale di Fisica Nucleare)
PADMEProj.pdf

15:30 → 15:50 **Possible improvements of the LNF e+/e- beam** 20m
Speaker: Paolo Valente (ROMA1)
positrons-valente-o...

15:50 → 16:10 **Axions @ LNF: QUAX, FLASH, ...** 20m
Speaker: Claudio Gatti (LNF)
FFF_COLDLAB-All.pdf

16:10 → 16:30 **Kaons @ LNF: post-SIDDHARTA-2** 20m
Speaker: Catalina Oana Curceanu (LNF)
StrangenessPrecisi...

16:30 → 16:50 **Discussione generale** 20m

We stated to discuss some possible future option for fundamental physics at LNF

Very informal discussion and brainstorming as first step

More structured **FFF meeting** open to new ideas and contribution has been scheduled for:
Wednesday 13/01/2021

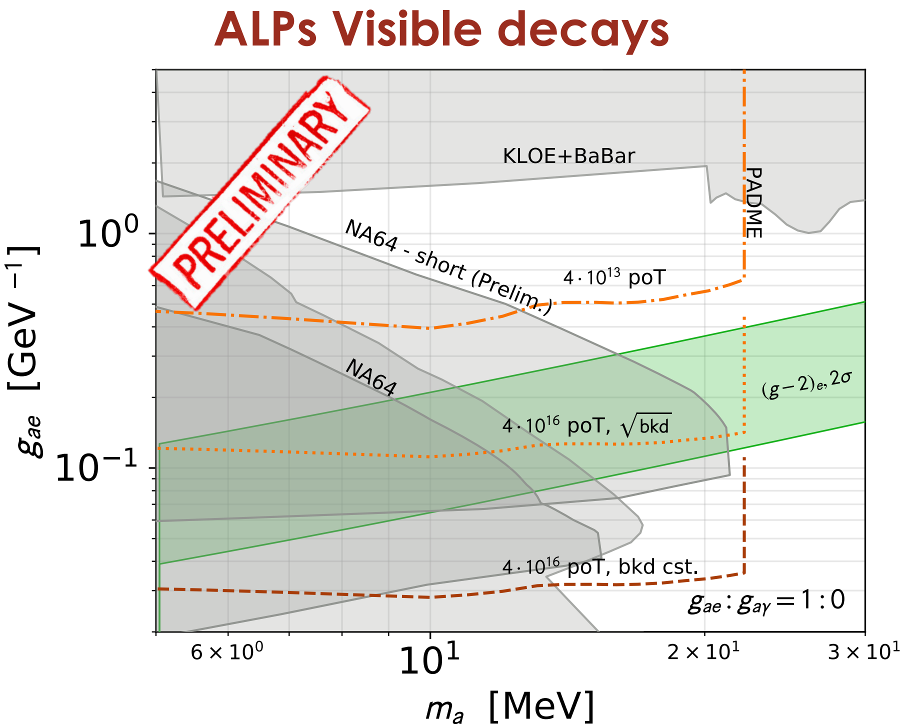
PADME @ continuous beam prospects

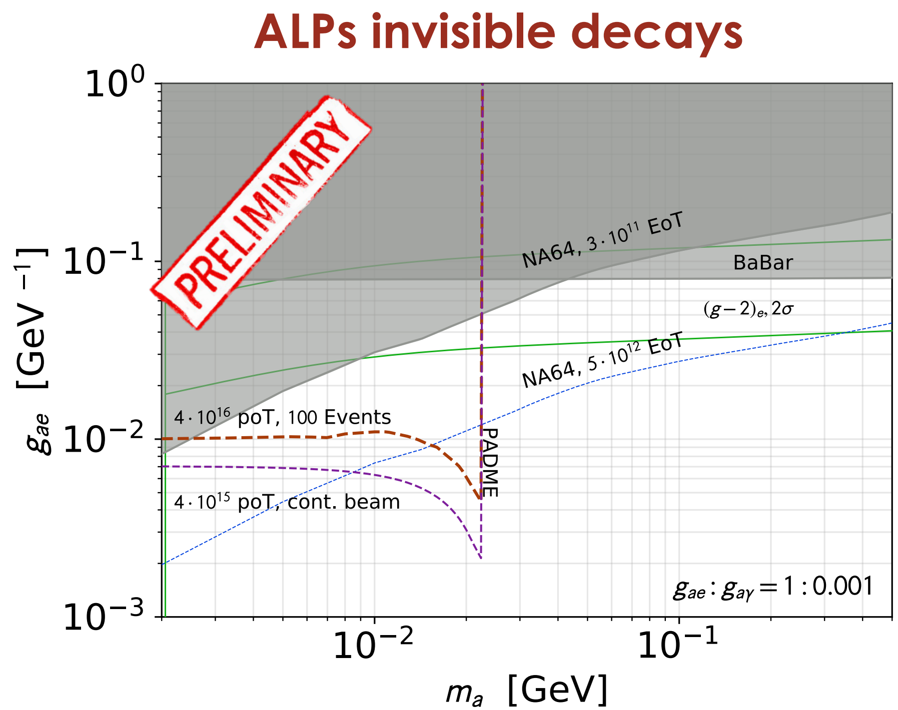
- Main limit of PADME is currently a very high instantaneous luminosity with low integrated luminosity due to 49bunch/s linac limit.
  - Current duty cycle: 300ns*49=1.5E-5; Current POT/Y ~ (1-2)E13
  - 100 e+/ns –> Max 10^{18} POT/year with continuous beam.
  - Several option under scrutiny.

Accelerator	Beam-line	Upgrades	Time-scale	RI	Pulse length	Maximum energy	Positrons on target/y	Electrons on target/y	Note
DAΦNE LINAC	BTF-1		Now		300 ns	490 MeV e+	$3\cdot10^4\times49\times10^7=1.5\cdot10^{13}$		
						650 MeV e-		$3\cdot10^{10}\times3\cdot10^7=0.9\cdot10^{18}$	(1)
DAΦNE LINAC	BTF-1	De-tuned SLED's	2 years	25%	2000 ns	300 MeV e+	$2\cdot10^5\times49\times10^7=10\cdot10^{13}$		
		LLRF modulation	2 years	50%	800 ns	400 MeV e-	$8\cdot10^4\times49\times10^7=4\cdot10^{13}$		
DAΦNE LINAC	LINAC dump	Biological shielding	4 years	10%	300 ns	650 MeV e-		$10^{11}\times49\times10^7=50\cdot10^{18}$	
	"sala accumulatore"	Dismantle damping ring	4 years	70%					
DAΦNE LINAC + positron ring	POSEYDON	Septa + extraction line	3 years	70%	$2\cdot10^5$ ns	510 MeV	$1\cdot10^9\times10^7=1000\cdot10^{13}$		(2)
		Crystal + septum + extraction line	4 years	30%	continuous		10^{12} - 10^{14}		(3)
DAΦNE LINAC + accumulator	tbd	Septa + extraction line	3 years	70%	$1\cdot10^6$ ns	510 MeV	$5\cdot10^9\times10^7=5000\cdot10^{13}$		
		Crystal + septum + extraction line	4 years	30%	continuous		10^{10} - $5\cdot10^{12}$		(3)

(1) Limited by radio-protection authorization
(2) Can be ×2 better with wigglers off
(3) Continuous beam structure, zero-background experiment

Some preliminary scaling ALPs





- First scan of parameter space for ALPs (courtesy of L. Darme' LNF)
  - With continuous beam scenarios in POT the range of 10^{16} are achievable
- Result are just scaled from old analysis of PADME proposal.
  - Need to understand background control
  - Maybe need to upgrade detector (vertex detectors)
  - Some interesting targets have in any case being identified.

Publications detector during 2020

Detector performance papers based on RUN I data set

Contents lists available at ScienceDirect
Nuclear Inst. and Methods in Physics Research, A
journal homepage: www.elsevier.com/locate/nima

Operation and performance of the active target of PADME

NIMA Volume 958, 1 April 2020, 162354
https://doi.org/10.1016/j.nima.2019.162354

Jinst
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Received: July 28, 2020
Accepted: August 14, 2020
Published: October 5, 2020

TECHNICAL REPORT

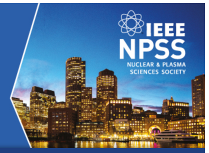
Characterisation and performance of the PADME electromagnetic calorimeter

The PADME collaboration
P. Albicocco,[a] J. Alexander,[b] F. Bossi,[a] P. Branchini,[c] B. Buonomo,[a] C. Capoccia,[a] E. Capitolo,[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. Fiore,[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. Safai 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]

Jinst, Volume 15, October 2020

https://iopscience.iop.org/article/10.1088/1748-0221/15/10/T10003/pdf

Conference System
Virtual 2020 IEEE Nuclear Science Symposium & Medical Imaging Conference
27th International Symposium on Room-Temperature Semiconductor
31 October - 7 November, 2020



IEEE 2020 ≡ Contact Privacy Emanuele Leonardi

#1204 | Oral or Poster presentation — Status : Poster

Development and deployment of the Trigger and Timing System (TTS) for the PADME experiment at the DAΦNE BTF
NSS 02 - DAQ, Trigger and Front-End Electronics Systems

EDIT | PRESENTATION/POSTER UPLOAD | VIDEO-UPLOAD

soon on IEEE Transactions on Nuclear Science

Physics and phenomenology papers in early 2021

- Paper on 2018-2019 data set
  - Measurement of the ee –> $\gamma\gamma$ cross section with the PADME experiment
- Phenomenological papers on PADME physics (preparation of RUN II)
  - A next to leading order e^+e^- –> $\gamma\gamma$ generator for the PADME experiment
  - PADME sensitivity to multi-lepton final states
  - Searching for ALPs at PADME

Multi lepton final state in e^+e^- collisions at PADME

June 2020

Abstract

Electron positron collisions are a very promising environment to search for new physics, and in particular for dark sector related observable. The most challenging experimental problem in detecting dark sector candidates is the very high associated standard model background. For this reason it is important to identify observable that are, at the same time, minimally suppressed in the dark sector and highly suppressed in the Standard Model. One example is the process $e^+e^- \to e^+e^-e^+e^-e^+e^-$ that can be mediated either by the production and subsequent decay of dark higgs (h'), $e^+e^- \to A'h' \to 6e$ [1] or produced by the Standards model process $e^+e^- \to 6e$. In the following letter we study the relative contribution to observed 6 leptons final states, coming from the h' mediated and from the Standard model processes in the contest of the PADME experiment at the INFN Laboratori Nazionali di Frascati.

Missing energy searches for the ALP-portal

[1] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, C.P. 13, 00044 Frascati, Italy*

[2] *Dipartimento di Fisica, Universita di Roma La Sapienza and INFN, Sezione di Roma, I-00185 Rome, Italy*

Abstract

Axion-like particles naturally behave as a 5-dimensional portal in presence of additional dark sector states. We study the phenomenology of this portal when both visible and invisible decays are accessible to an electro- and photo-philic ALP. We recast existing limits, extending in particular standard results from BaBar and NA64 on invisible ALP decay to include the ALP electron interaction. We furthermore underlines the prospects and possible reach of the positron fixed-target experiment PADME.

Conclusions

- Despite the COVID-19 emergency we have been able to follow the SciCom May meeting plan.
- The PADME restart program has been accomplished in May-June
  - Hardware fixes and small upgrade are foreseen in May to mid June
- Successful commissioning run completed in July
  - Detector calibrations after long shutdown
  - Beam line transport and background studies
  - Longer pulsed achieved and good data quality
- Run II started successfully and still ongoing
  - Up to 1.2E11 per fully efficient day
  - Already achieved ~4E12 POT aim to get 5 by the end of November.

And the winner is …

Many thanks to:
Accelerator operators,
BTF staff,
LNF vacuum service,
PADME shifters,
LNF servizio sicurezza,

And all the LNF Lab for a very successful run in complicated external conditions.

backup slides

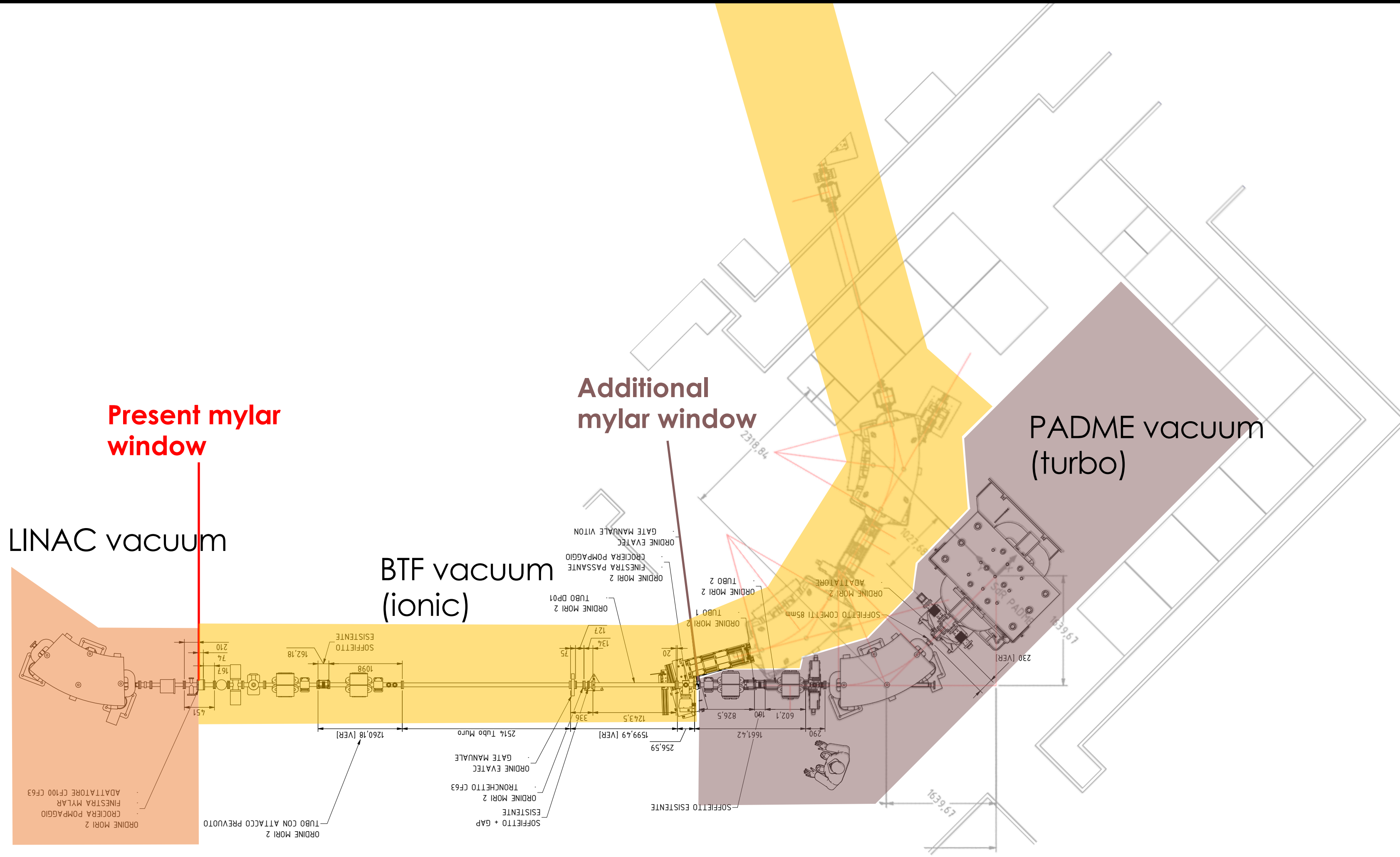
Special runs after physics data-taking

- Low multiplicity (10-1000 positrons/bunch, short bunches)
  1. MIMOSA 2nd detector testing, tracking and beam angle measurement
  2. gamma-gamma cross-section on Silicon (MIMOSA detectors as target)
  3. Electron veto timing and calibration, requires switching PADME dipole polarity

- A **few days for each point**
  - Can be done opportunistically with 10 ns bunches,
  - Can be done with BTF target IN
    - Easier and safer for getting low-intensity positron beam
    - Allows tuning the beam momentum independently

- Need to keep PADME in vacuum (turbo-molecular pump on) and **connected** to BTF-1 line
  - Add a mylar window in the position of the original Be one
  - 125 um as the existing one would be OK

Possible configuration for parasitic running



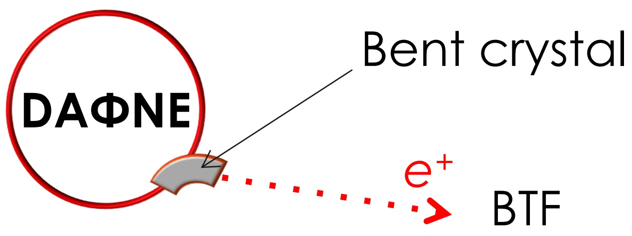
SHERPA

"Slow High-efficiency Extraction from Ring Positron Accelerator"

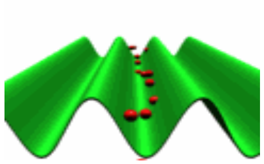
CSN5 grant, P.I.: Marco Garattini (LNF-INFN)

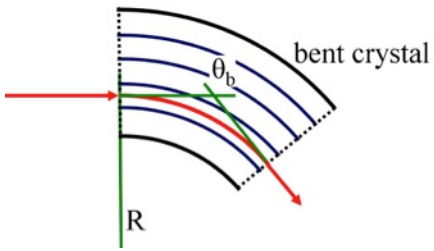
R&D study to extract a high-quality e^+ beam from the DAΦNE ring

The idea is to use a bent crystal to steer the positron beam



Channeling





Target spill parameters:
- Energy spread: $\Delta p/p < 10^{-3}$
- Emittance: $\varepsilon < 10^{-6}$ rad·m
- **Length: ms < Δt < s**

VS

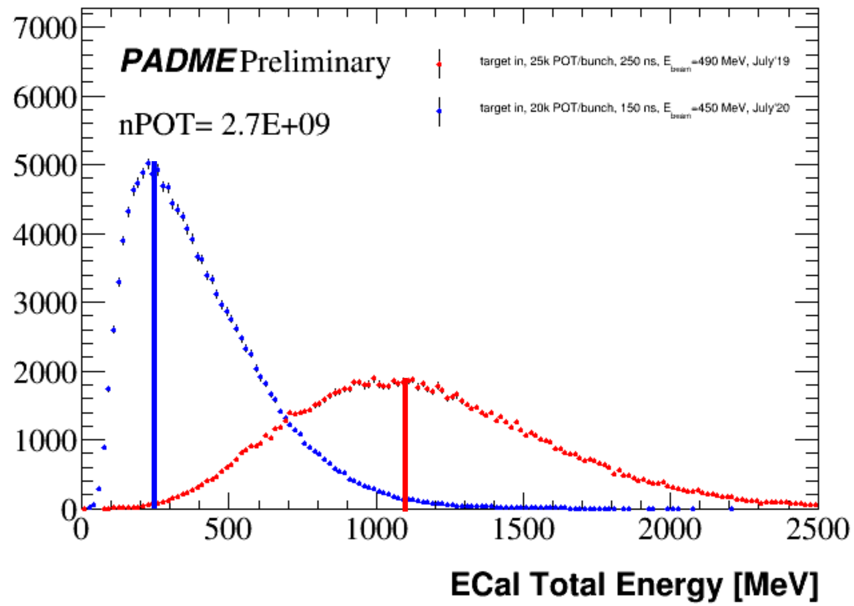
Current BTF spill parameters:
- Energy spread: $\Delta p/p < 0.5 \times 10^{-2}$
- Emittance: $\varepsilon < 10^{-5}$ rad·m
- **Length: Δt < 200 ns**

With the SHERPA beam, **PADME** could increase the statistics by a **factor 10^4** and its sensitivity by a **factor ~10^2**, largely extending the discovery potential

2 year grant (120K) by CSN5 to realize a proof of principle and a realistic design

SM and beyond in ee collisions

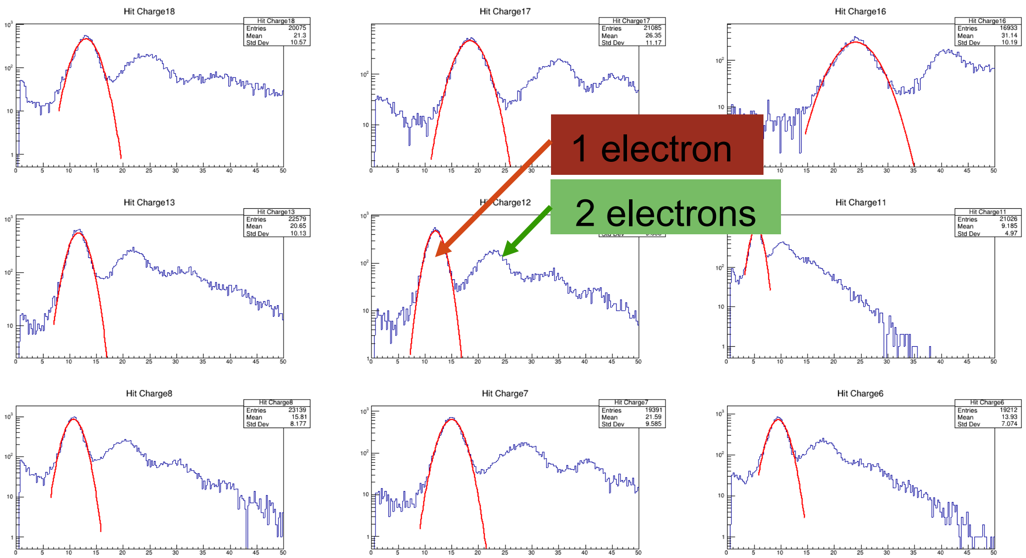
Highlight dai dati di 7/2020: fondo

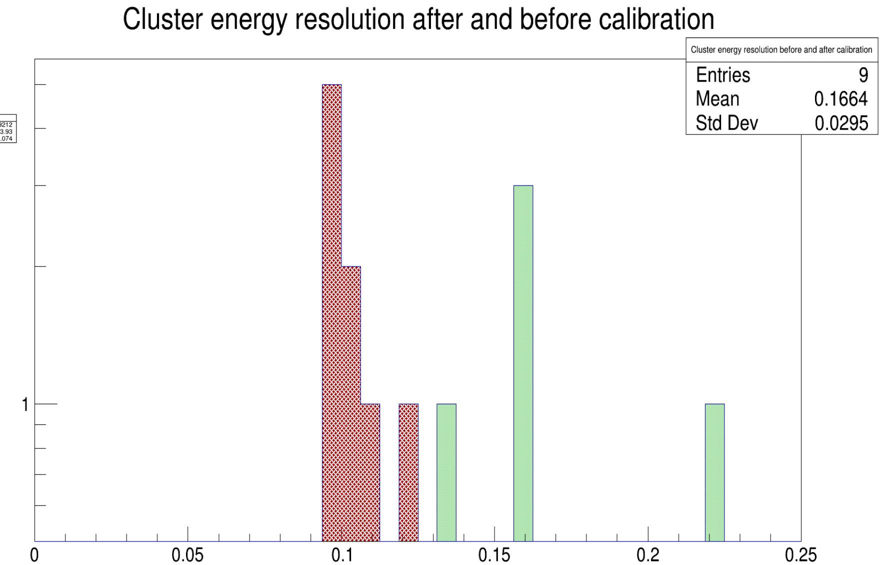


- Due run in differenti condizioni di energia e molteplicità
  - Energia totale in un bunch di 25K e+= 25K*0.490MeV = 12.2 TeV 2019
  - Energia totale in un bunch di 20K e+= 20K*0.450MeV = 9. TeV 2020
- MPV delle distribuzioni deve essere riscalato:
  - 1100 MeV nel 2019
  - ~250 MeV 2020 riscalato alle condizioni 2019 ~ 340MeV
- Riduzione del fondo di circa un fattore 3

SAC calibrazione e riparazione

- Giugno 2020: cambiato un PMT con basso guadagno e calibrazione con CR
- Luglio 2020: sparato fascio nei 9 cristalli centrali
  - studio della calibrazioni per ogni cristallo
  - Correzione dell'energia nel cluster per ogni cristallo.





- Risoluzione in energia circa il 10% a 440 MeV
  - Indipendente dal cristallo seed.

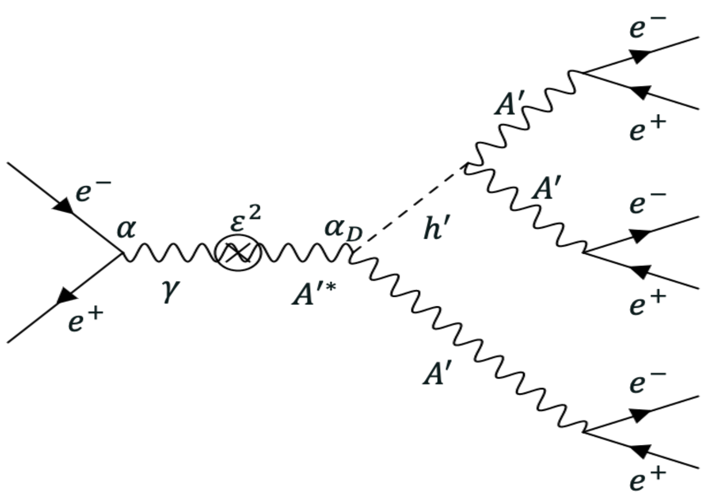
searching for DH in multi leptons

PHYSICAL REVIEW D 79, 115008 (2009)

Probing a secluded U(1) at *B* factories

Brian Batell,[1] Maxim Pospelov,[1,2] and Adam Ritz[2]

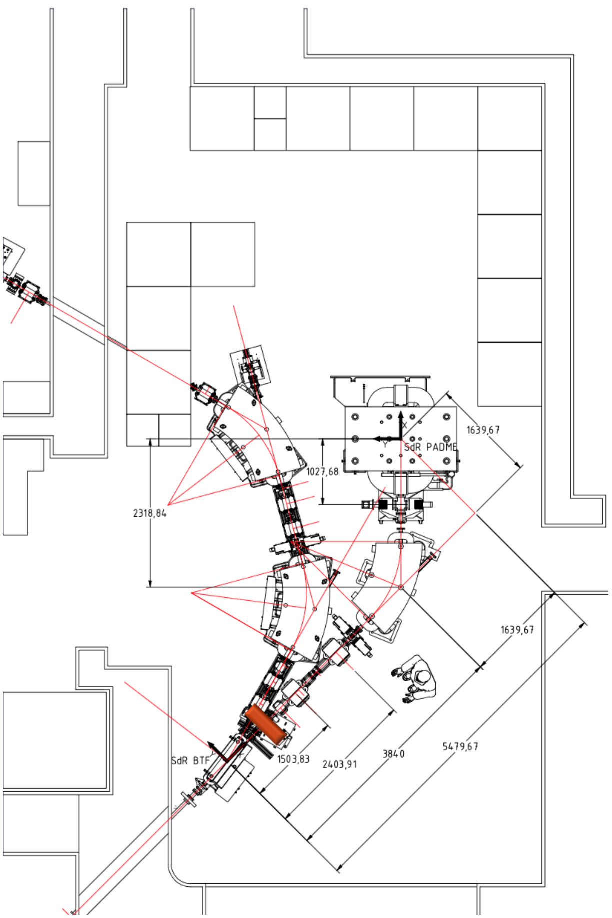
$$\sigma_{e^+e^-\to Vh'} = \frac{\pi\alpha\alpha'\kappa^2}{3s}\left(1-\frac{m_V^2}{s}\right)^{-2}\sqrt{\lambda\left(1,\frac{m_{h'}^2}{s},\frac{m_V^2}{s}\right)} \times\left[\lambda\left(1,\frac{m_{h'}^2}{s},\frac{m_V^2}{s}\right)+\frac{12m_V^2}{s}\right] \approx 20\ \text{fb}\times\left(\frac{\alpha'}{\alpha}\right)\left(\frac{\kappa^2}{10^{-4}}\right)\frac{(10\ \text{GeV})^2}{s},$$



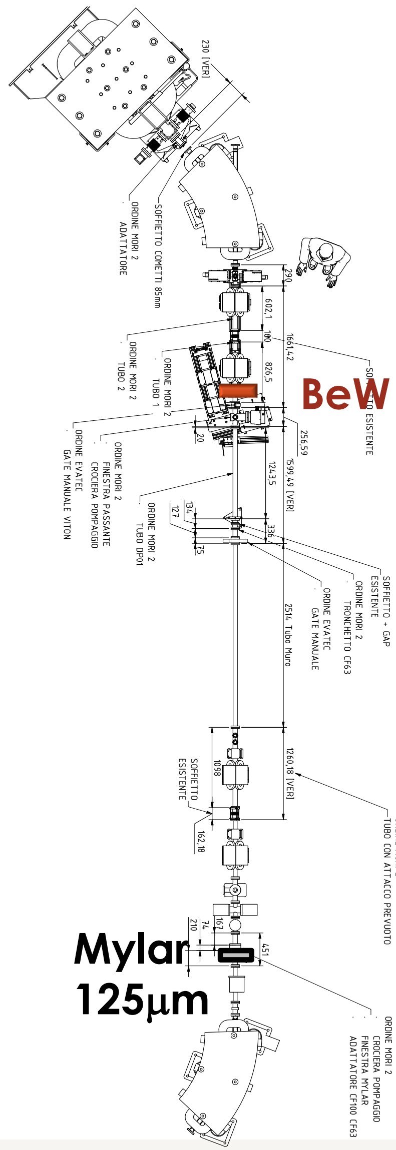
- Extended dark sector with a dark Higgs h'
  - Minimal suppression: only $\varepsilon^2\alpha_D$
  - BR(A'–>ee=1)
- Main production mechanism: higgs-strahlung
  - Main decay of h': h'→A'A'
  - Assuming A' → e^+e^-
  - Can produce $e^+e^- \to e^+e^-e^+e^-e^+e^-$

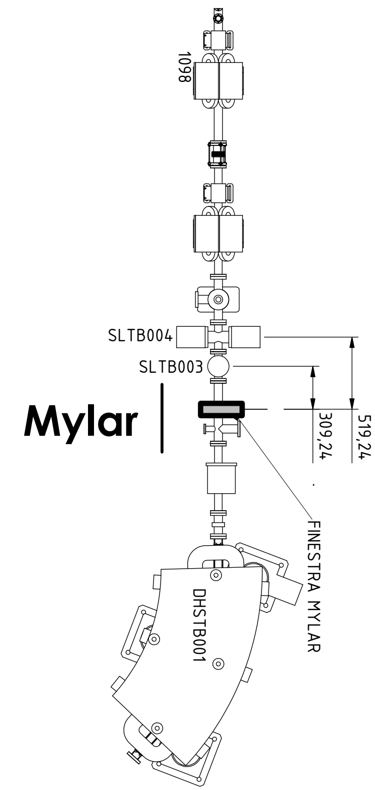
Nuovo layout della linea

Vecchia Linea



Nuova Linea





Summary of multi-lepton events

Final state	σ in pb	PADME lumi	Events/s	Events/day	Events/y	Acc/y
$e^+e^-\to 4e^\pm$	1.32E8	1.2E-8 pb^{-1}	~ 1.6	~ 136K	~ 13.7M	~ 6400
$e^+e^-\to w_D w_D$	6E3	1.2E-8 pb^{-1}	~7E-5	~ 6	~ 600	??
$e^+e^-\to 6e^\pm$	2.0E4	1.2E-8 pb^{-1}	~ 2.4E-4	~ 20.7	~ 2.07E3	~ 20
$e^+e^-\to h'A'$	485	1.2E-8 pb^{-1}	~ 6e-6	~ 0.5	~ 50	~ 30

PADME luminosity assuming (24.5K x 49) =1.2E6 POT/s

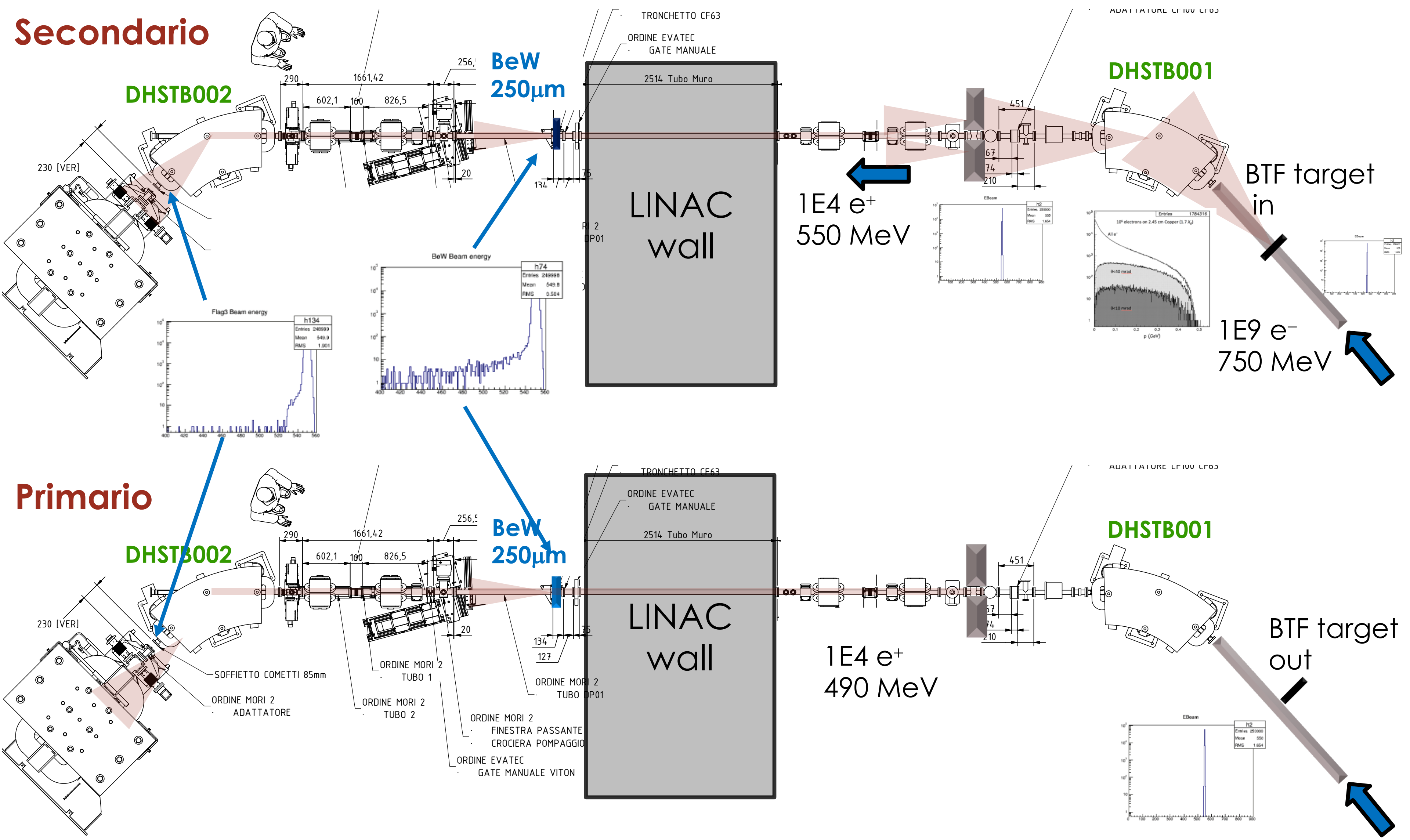
$$\mathcal{L}_1 = (1.2\times10^6)(6.0\times10^{23})\left(\frac{6\times3.5\times10^{-2}}{12.01}\right) = 1.2\times10^{28}\ \mathrm{cm^{-2}\,s^{-1}} \qquad \mathcal{L}_1 = 1.2\times10^{28}\ \mathrm{cm^{-2}\,s^{-1}}/10^{30} = 0.012\ \mu\mathrm{b^{-1}\,s^{-1}},$$

$$L_{\mathrm{int},1} = 0.012\times(3.2\times10^7)/10^6 = \boxed{0.384\ \mathrm{pb^{-1}}},$$

- In Events/y column 1y=100 days at 100% efficient data taking
  - The dark sector related calculation are for ε^2=1E-6 and α_D=0.1
- In the Acc/y a cut on the E_{min}>50 MeV is applied
  - 4e scales down by ~2000 (Calchep), 6e scales by only ~100 (phase space)
  - DH scales by 0.6 (phase space)
- Seem that DH contribution to 6 leptons production cross section could be **sizable**, even with $\boldsymbol{\varepsilon^2}$ as low as $\mathbf{10^{-6}}$

PRELIMINARY

Due diversi tipi di fascio e di fondo

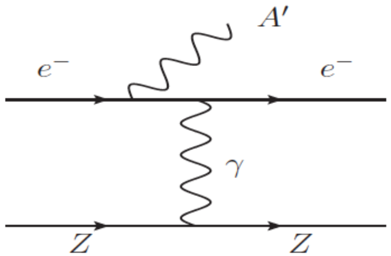


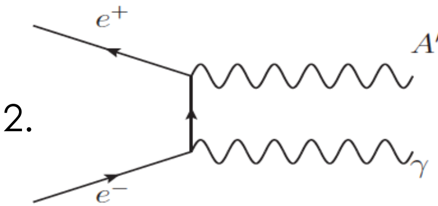
Origine del fondo

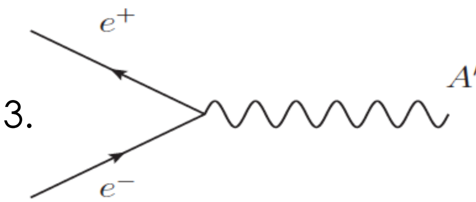
- **Fascio secondario**
  - 1E9 e^- generano e^+ e fotoni di qualunque energia.
  - Fotoni creati al collimatore in uscita dal primo magnete colpiscono il secondo magnete creando un fondo diffuso di fotoni ~7 GeV su ECAL dovuti a sciami sul secondo magnete
  - Se si spegne il secondo magnete si vede ancora molto fondo quindi fondo dominato dal collimatore

- **Fascio primario**
  - Niente bersaglio BTF
  - Molti meno primari e tutti dell'energia giusta passano attraverso la linea senza creare fondi importanti
  - All'attraversamento della finestra di Be si creano piccole code di positroni fuori energia che colpiscono la parte interna del magnete creando fondo nel calorimetro
  - Questo fondo può essere mitigato migliorando il fascio e spostando la finestra

A' visible decays at PADME

1. 

2. 

3. 

Process	Name	a^X	Fin. state	Detectors	Main BG	Sens. Est.
1. $e^+N \rightarrow e^+NA' \rightarrow e^+Ne^+e^-$	A'-stra.	3	$e^+e^+e^-$	Vetos	PileUp+Trident	None
2. $e^+e^- \rightarrow \gamma A' \rightarrow \gamma e^+e^-$	2γ-ann	2	γe^+e^-	Ecal+Veto	Rad-BhaBha	
3. $e^+e^- \rightarrow A' \rightarrow e^+e^-$	Res.an	1	e^+e^-	Vetos	BhaBha	X boson

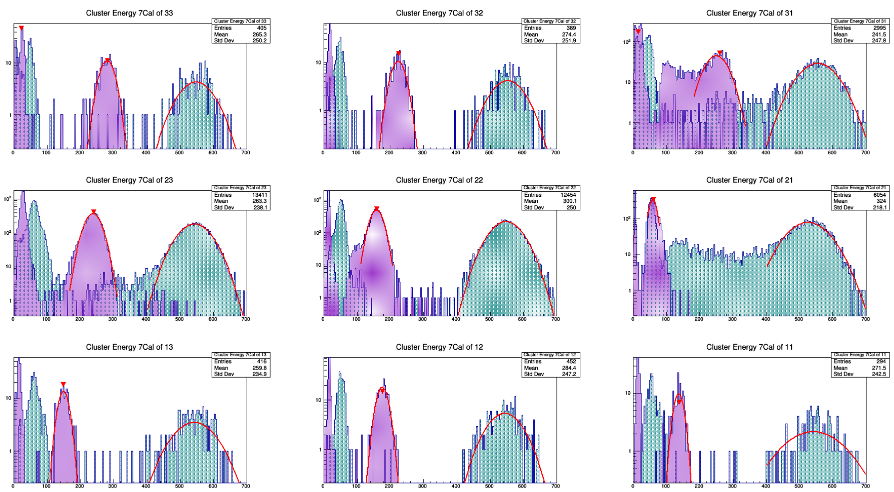
1. **A-stra.:** Production cross section high, but very high background from QED
   1. Need to measure e^+e^- invariant mass distribution.
   2. Strong competition from electron based experiment A1, APEX, HPS.
   3. In principle masses up to >100 MeV are accessible
2. **2γ-annihilation:** lower cross section but can use Ecal to measure A' mass.
   1. Bump hunt possible by computing missing mass to the recoil γ
   2. Helps in rejecting radiative BhaBha, γ–conversion and trident BG.
   3. Mass reach limited to 23.7 MeV for 550MeV beam
3. **Resonant Annihilation:** very high cross section but a very narrow mass region
   1. Need to know the particle mass in advance. (Xboson)

Novità da Torino

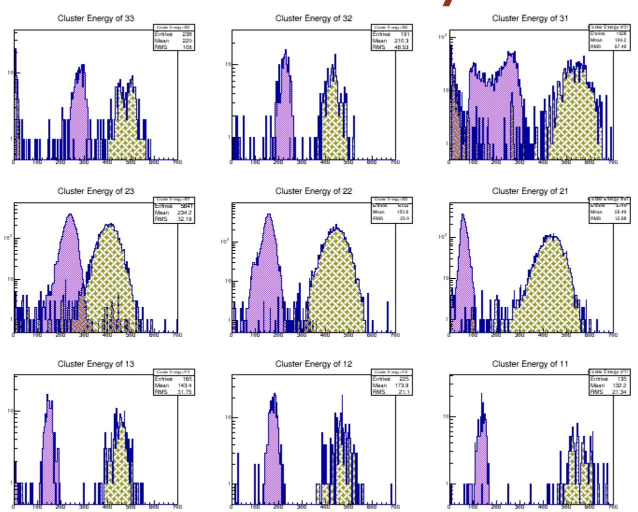
- Gruppo di Numen interessato ad entrare in PADME
  - Primi contatti allo scorso PADME collaboration meeting
- Il gruppo è del politecnico ed è composto da
  - Iazzi Felice PO, Pinna Federico RTDa, Capirossi Vittoria PHD
- Interesse a lavorare nei rivelatori di fascio al silicio di PADME
  - TimePix e Mimosa primi contatti e raccolta di informazioni
- Sarebbero anche interessati a partecipare al RUN di quest'anno
  - Inclusi nello sblocco di SJ di 120gg

SAC calibration status

SAC calibration beam



SAC cosmic rays

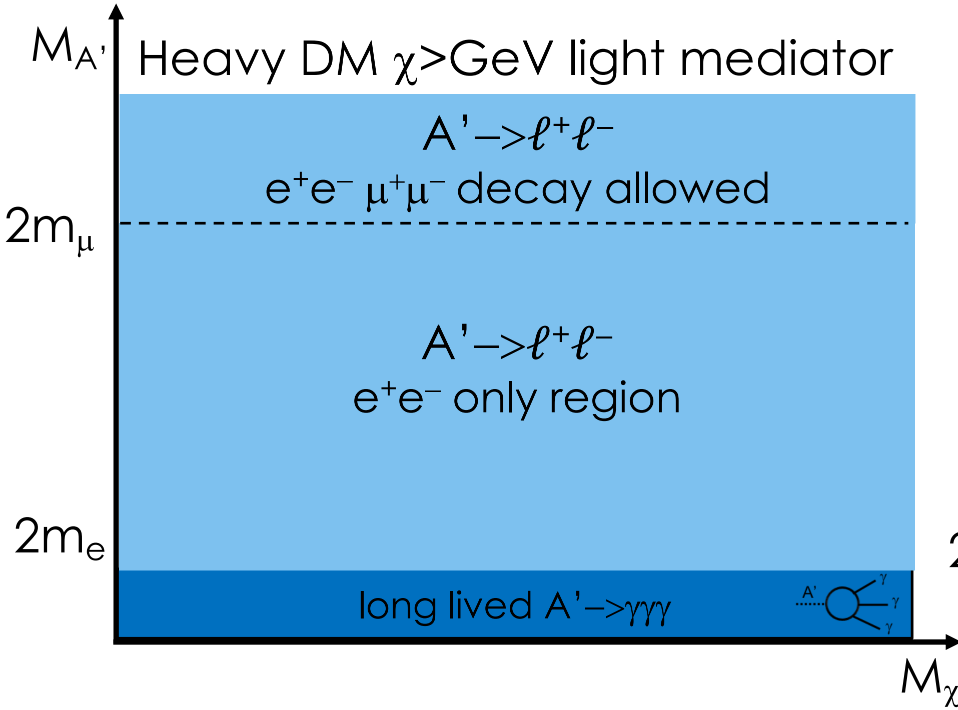


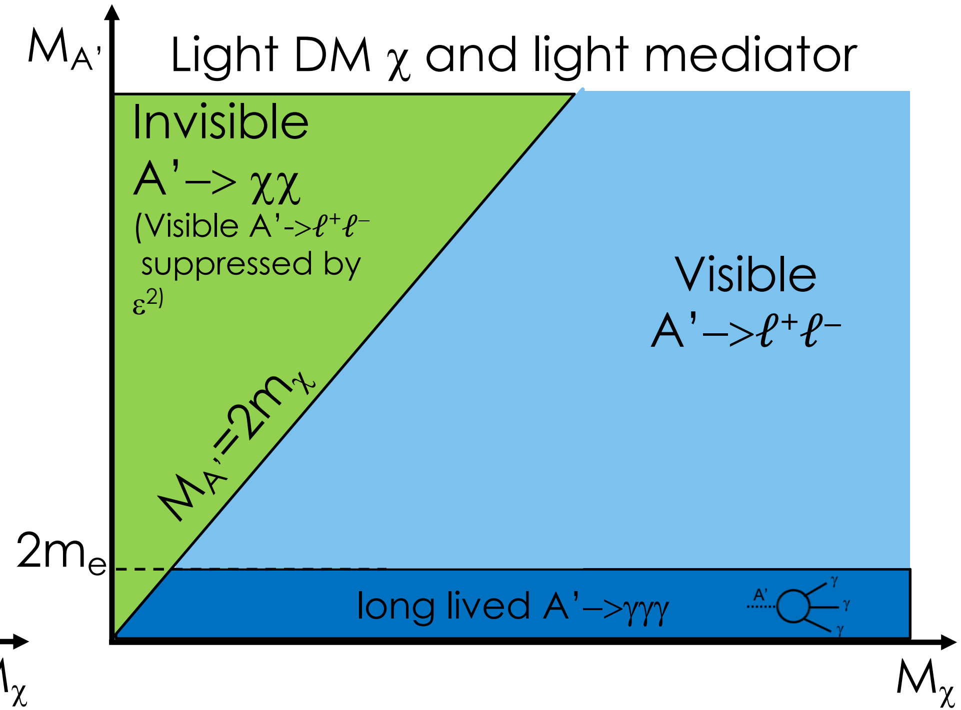
CR results on calibration are encouraging:
- better with a fixed-energy source beam
- need data for all the 25 crystals (9 so far)

Positron runs with the beam into each crystal is needed

Parasitic secondary beam in Ok for this task
9 crystals few hours
- 1-2 days of data taking should be enough

A' decay modes MeV-GeV scale





- If 1MeV < $M_{A'}$ < $2m_\chi$ dilepton "visible" decays (at PADME energy just ee)
  - Min $M_{A'}$>1MeV lifetime depends mostly on ε^2 long lived
- $2m_\chi < M_{A'}$ dark matter decays "invisible" decays
  - Min $M_{A'}$<1MeV lifetime depends mostly on α_D^2 short lived
- Decays in 3γ are not interesting for the accelerator searches

X17 dal ^{8}Be al ^{4}He

23 Oct 2019

New evidence supporting the existence of the hypothetic X17 particle

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We observed electron-positron pairs from the electro-magnetically forbidden M0 transition depopulating the 21.01 MeV 0$^-$ state in ^{4}He. A peak was observed in their e^+e^- angular correlations at 115° with 7.2σ significance, and could be described by assuming the creation and subsequent decay of a light particle with mass of m_Xc^2=16.84±0.16($stat$) ± 0.20($syst$) MeV and Γ_X= 3.9 × 10^{-5} eV. According to the mass, it is likely the same X17 particle, which we recently suggested [Phys. Rev. Lett. 116, 052501 (2016)] for describing the anomaly observed in ^{8}Be.

arXiv:1910.10459v1

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NUCLEAR PHYSICS

Rekindled Atomki anomaly merits closer scrutiny

A large discrepancy in nuclear decay rates spotted four years ago in an experiment in Hungary has received new experimental support, generating media headlines about the possible existence of a fifth force of nature.

In 2016, researchers at the Institute of Nuclear Research ("Atomki") in Debrecen, Hungary, reported a large excess in the angular distribution of e$^+$e$^-$ pairs created during nuclear transitions of excited ^{8}Be nuclei to their ground state (^{8}Be* → ^{8}Be γ; γ → e$^+$e$^-$). Significant peak-like enhancement was observed at large angles measured between the e$^+$e$^-$ pairs, corresponding to a 6.8σ surplus over the expected e$^+$e$^-$ pair-creation from known processes. The excess was soon interpreted by theorists as being due to the possible emission of a new boson X with a mass of 16.7 MeV decaying into e$^+$e$^-$ pairs.

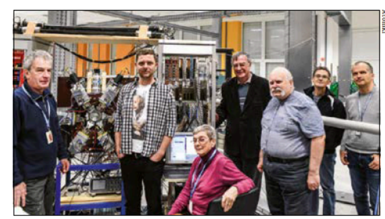
In a preprint published in October 2019, the Atomki team has now reported a similar excess of events from the electro-magnetically forbidden "M0" transition in ^{4}He nuclei. The anomaly has a statistical significance of 7.2σ and is likely, claim the authors, to be due to the same "X17" particle proposed to explain the earlier ^{8}Be excess.

Future view *Atomki's new high-resolution LaBr$_3$ spectrometer, which will record gamma–gamma pairs from excited nuclei.*

Quality control

"We were all very happy when we saw this," says lead author Attila Krasznahorkay. "After the analysis of the data a really significant effect could be observed." Although not a fully blinded analysis, Krasznahorkay says the team has taken several precautions against bias and carried out numerous cross-checks of its result. These include checks for the effect in the angular correlation of e$^+$e$^-$ pairs in different regions of the energy distribution, and assuming different beam and target positions. The paper does not go into the details of systematic errors, for instance due to possible nuclear-modeling uncertainties, but Krasznahorkay says that, overall, the result is in "full agreement" with the results of the Monte Carlo simulations performed for the X17 decay.

While it cannot yet be ruled out, the existence of an X boson is not naively expected, say theorists. For one, such a particle would have to "know" about the distinction between up and down quarks and thus electroweak symmetry breaking. Being a vector boson, the X17 would constitute evidence for a new force. It could also be related to the dark-matter problem, write Krasznahorkay and co-workers, and has the right properties to help resolve the discrepancy between measured and predicted values of the muon anomalous magnetic moment.



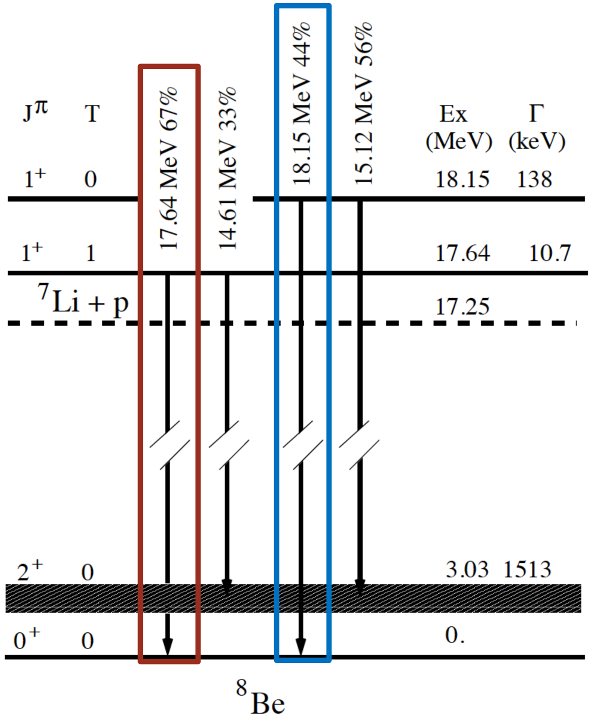
X-factor *The Atomki team with the apparatus used for the latest ^{8}Be and ^{4}He results, which detects e$^+$e$^-$ pairs from the de-excitation of nuclei produced by firing protons at different targets.*

Last year, the NA64 collaboration at CERN reported results from a direct search for the X boson via the bremsstrahlung reaction eZ → eZX, the absence of a signal placing the first exclusion limits on the X–e$^-$ coupling in the range (1.3–4.2) × 10^{-4}. "The Atomki anomaly could be an experimental effect, a nuclear-physics effect or something completely new," comments NA64 spokesperson Sergei Gninenko. "Our results so far exclude only a fraction of the allowed parameter space for the X boson, so I'm really interested in seeing how this story, which is only just beginning, will unfold." Last year, researchers used data from the BESIII experiment in China to search for direct X-boson production in electron–positron collisions and indirect production in J/ψ decays – finding no signal. Krasznahorkay and colleagues also point to the potential of beam-dump experiments such as PADME in Frascati, and to the upcoming Dark Light experiment at Jefferson Laboratory, which will search for 10–100 MeV dark photons.

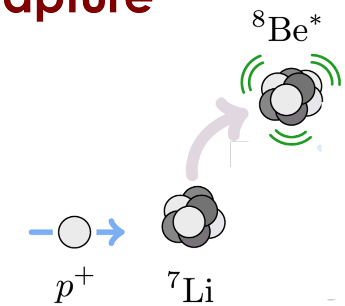
Theorist Jonathan Feng of the University of California at Irvine, who's group proposed the X-boson hypothesis in 2016, says that the new ^{4}He results from Atomki support the previous ^{8}Be evidence of a new particle – particularly since the excess is observed at a slightly different e$^+$e$^-$ opening angle in ^{4}He (115 degrees) than it is in ^{8}Be (135 degrees). "If it is an experimental error or some nuclear-physics effect, there is no reason for the excess to shift to different angles, but if it is a new particle, this is exactly what is expected," says Feng. "I do not know of any inconsistencies in the experimental data that would indicate that it is an experimental effect."

In 2017, theorists Gerald Miller at the University of Washington and Xilin Zhang at Ohio State concluded that, if the Atomki data are correct, the original ^{8}Be excess cannot be explained by nuclear-physics modelling uncertainties. But they also wrote that a direct comparison to the e$^+$e$^-$ data is not feasible due to "missing public information" about the experimental detector efficiency. "Tuning the normalisation of our results reduces the confidence level of the anomaly by at least one standard deviation," says Miller. As for the latest Atomki result, the nuclear physics in ^{4}He is more complicated than ^{8}Be because ▷

The 8Be nucleus



Resonant proton capture



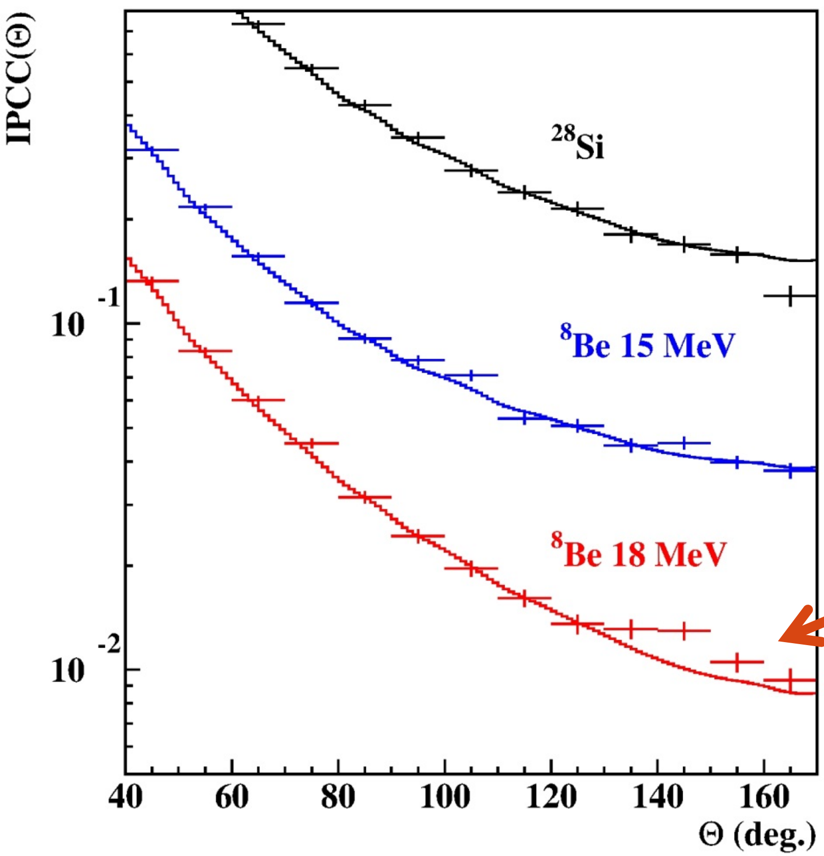
8Be decay

HAD EM IPC

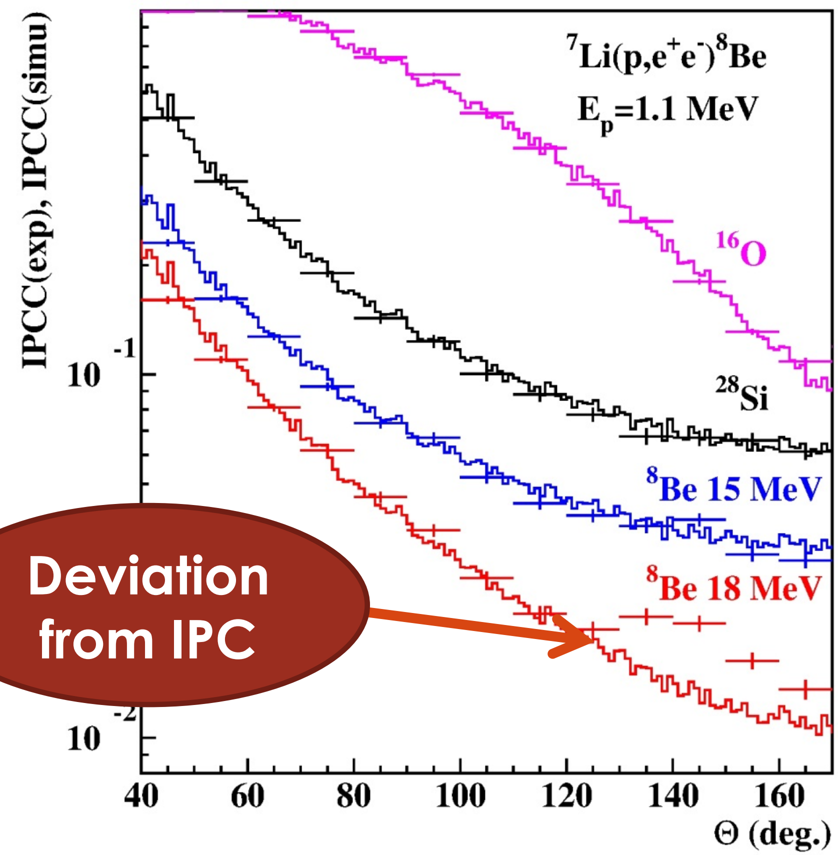
- Can excite the ^{8}Be(18.15 MeV) by using proton capture E_p=1030 KeV
- The Be is a peculiar nuclei having high energy transitions to the ground state
  - 1^+0 T=0 has 18.15 MeV if it goes directly to ground state 0^+0 E_p= 1030 KeV
  - 1^+0 T=1 has 17.64 MeV if it goes directly to ground state 0^+0 E_p= 441 KeV

On resonance measurements

Ep=1.04 MeV

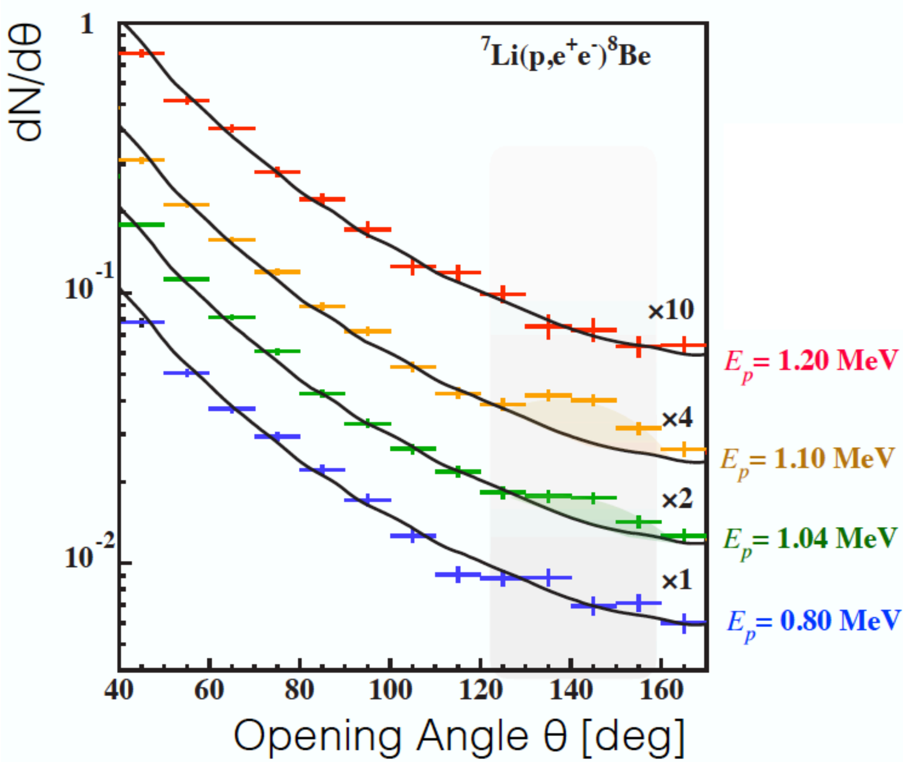


Ep=1.10 MeV

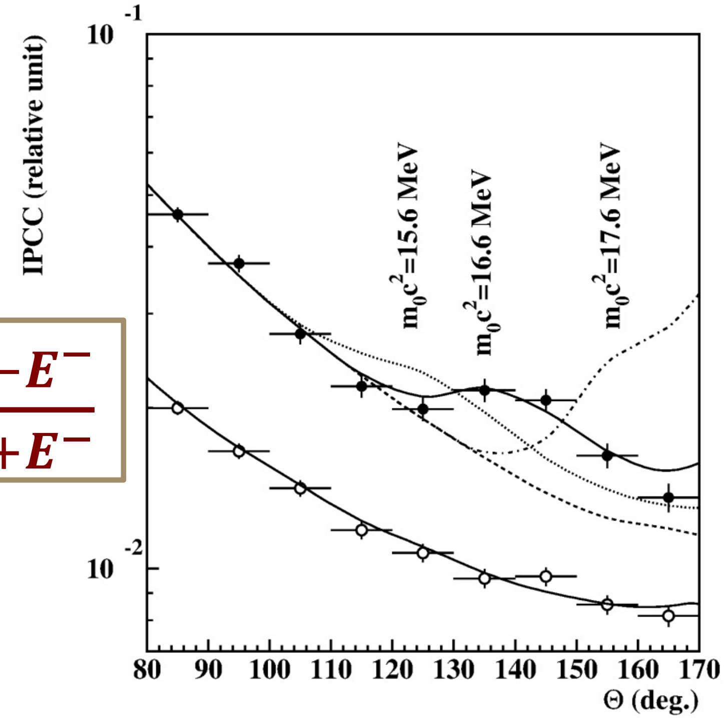


Deviation from IPC

Scanning the resonance with Ep

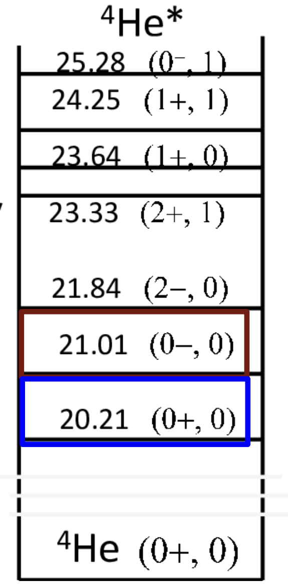


$$y=\frac{E^{+}-E^{-}}{E^{+}+E^{-}}$$



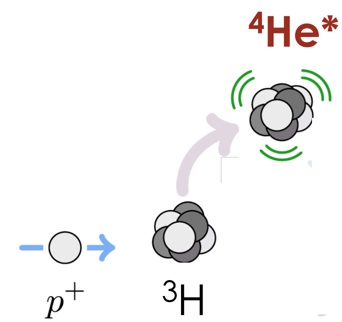
Experimental angular e^{+}e^{-} pair correlations measured in the ^{7}Li(p,e^{+}e^{-}) reaction at Ep=1.10 MeV with -0.5< y <0.5 (closed circles) and |y|>0.5 (open circles). The
results of simulations of boson decay pairs added to those of IPC pairs are shown for different boson masses.

The ^{4}He anomaly



The ^{3}H was absorbed in a 3 mg/cm^2 thick Ti layer evaporated onto a 0.4 mm thick Mo disc. The density of the 3H atoms was 2.66x10^{20} atoms/cm^2. The disk was cooled down to liquid N^2 temperature to prevent ^{3}H evaporation.

Resonant proton capture

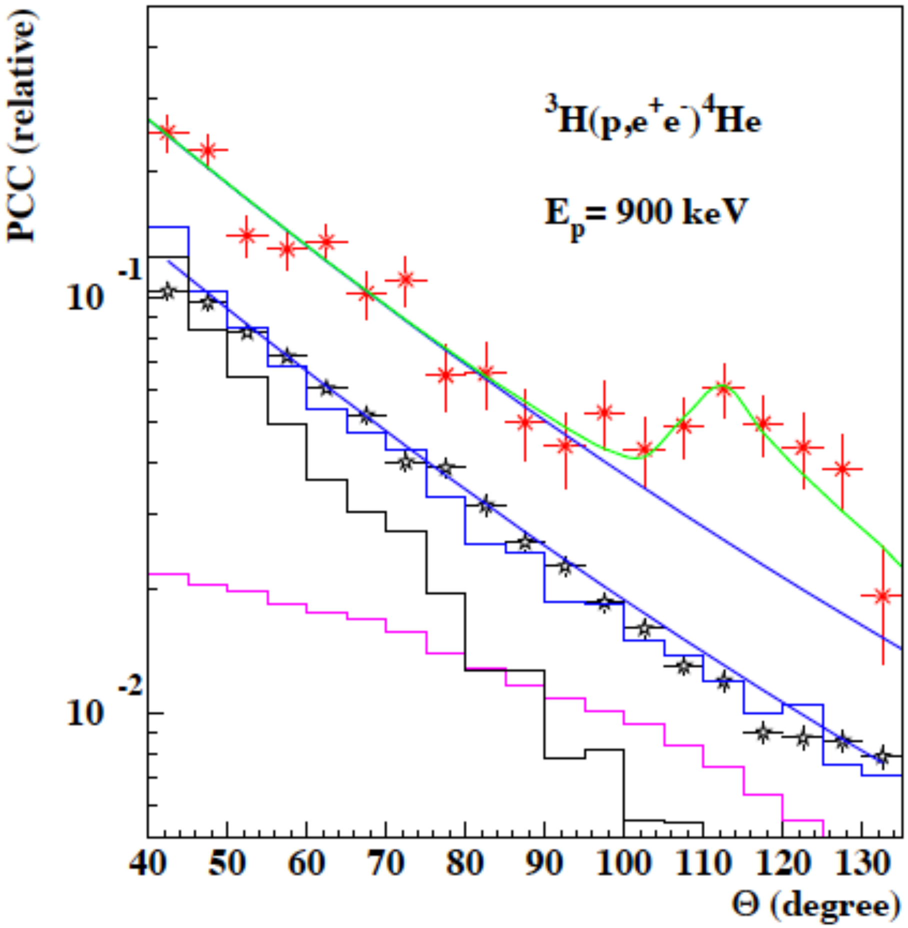


E_p=900 keV

The 3 H(p,γ)4 He reaction at Ep =900 keV bombarding energy was used to populate the wide (Γ = 0. 84 MeV) 0− second excited state in ^{4}He, located at Ex = 21.01 MeV.

The investigated 0− state overlaps with the first excited state in ^{4}He (J=0+, Ex=20.21 MeV, Γ=0.50 MeV), which was also excited but but give only a managable background to the e+e− spectra.

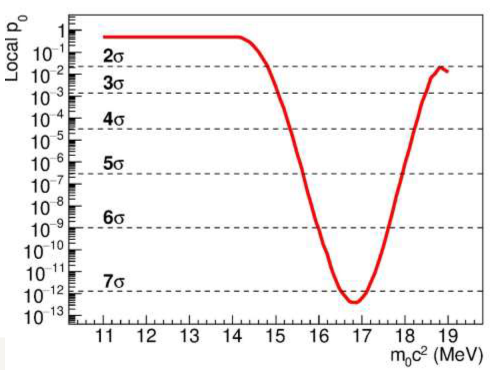
The ^{4}He anamaly peak



External pair creation

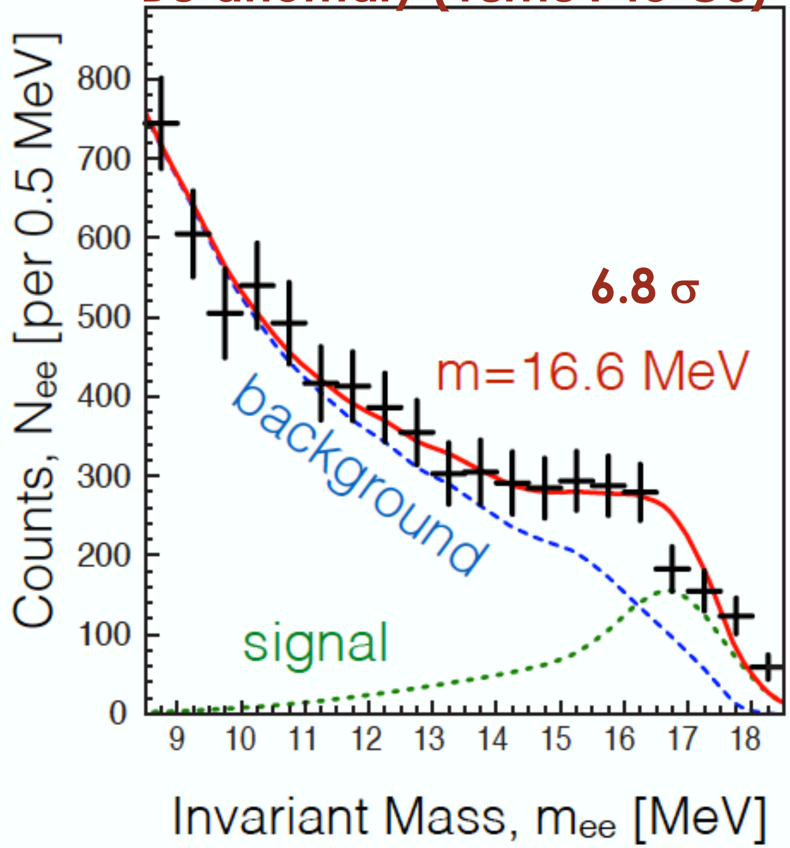
IPC e^+e^- pairs crated in the J =0+ -> 0+ gs E_0 transition

The data measured for the background were fitted by a 4-th order exponential polynomial, and the result is shown in a blue full curve. This blue curve was rescaled to fit the background of the angular correlation shown in red in the range of 40◦ < θ < 90◦ .

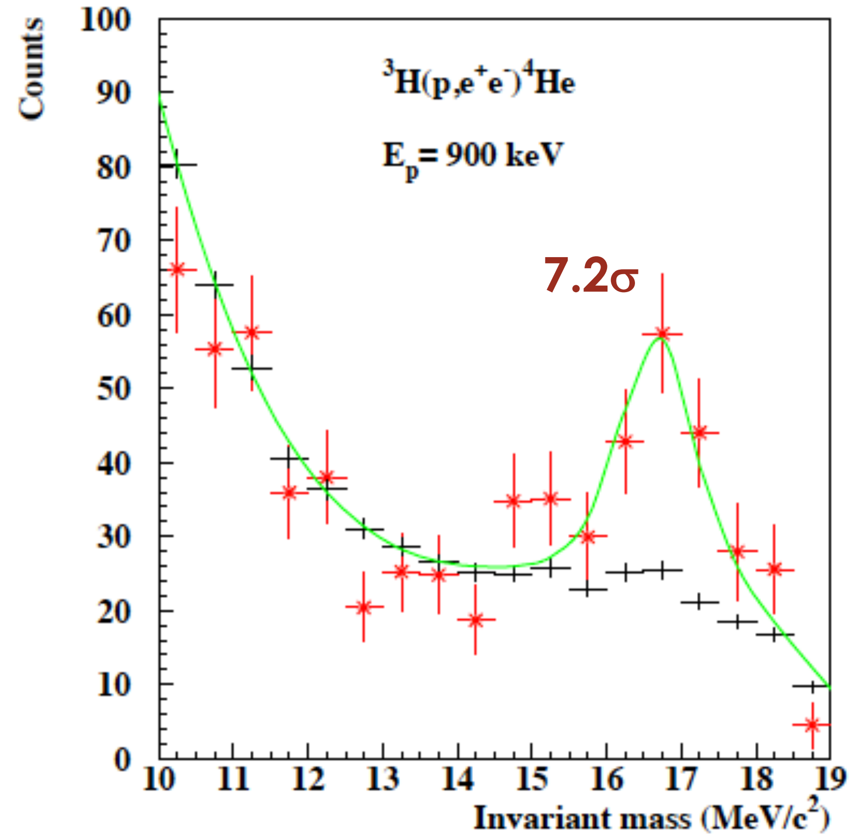


Comparing anomaly peaks

^{8}Be anomaly (18MeV to GS)



^{4}He anomaly (21MeV to GS)



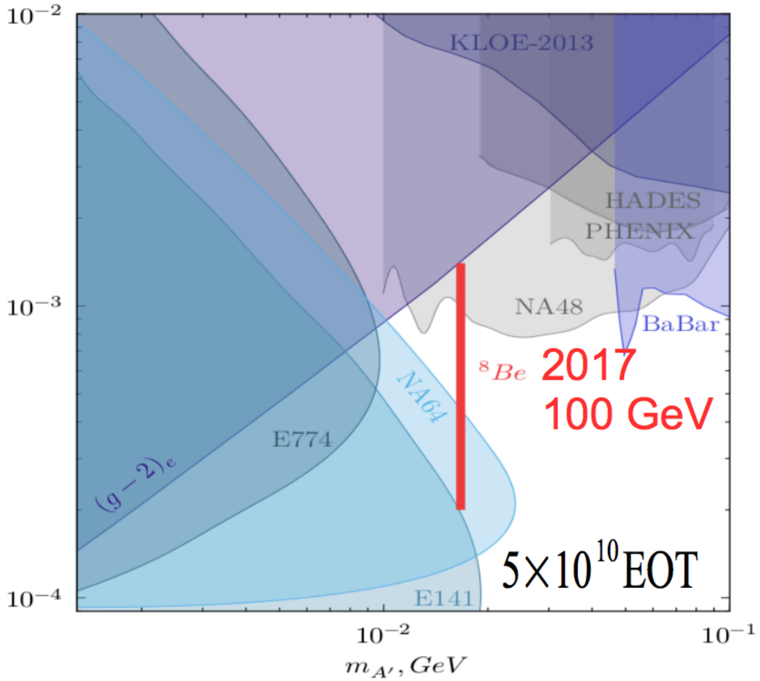
M_X =16.70±0.35.stat.± 0.5.syst. MeV

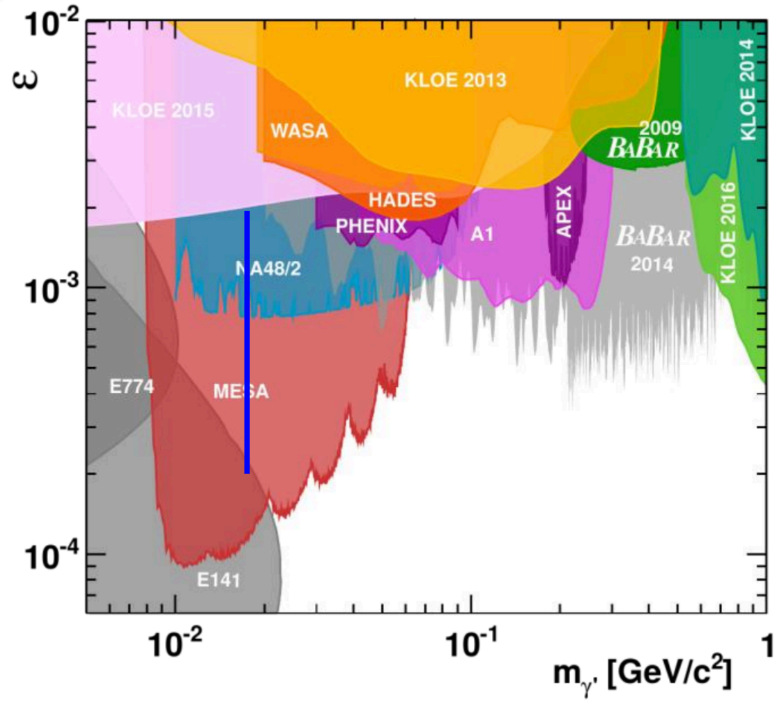
$\Gamma_X=\Gamma_\gamma x B_x$=1.9x6x10^{-6} eV= 1.2x10^{-5} eV

M_X=17.00 ± 0 .13 ± 0 .2 MeV

Γ_X= 3.9x10^{-5} eV

The experimental constraints A'





- Na64 no beam up to end of 2021
- Mesa no beam before 2024
- Interesting target for PADME mass is within reach.
  - Unfortunately PADME is not designed to search for visible decay.

Veto di PADME

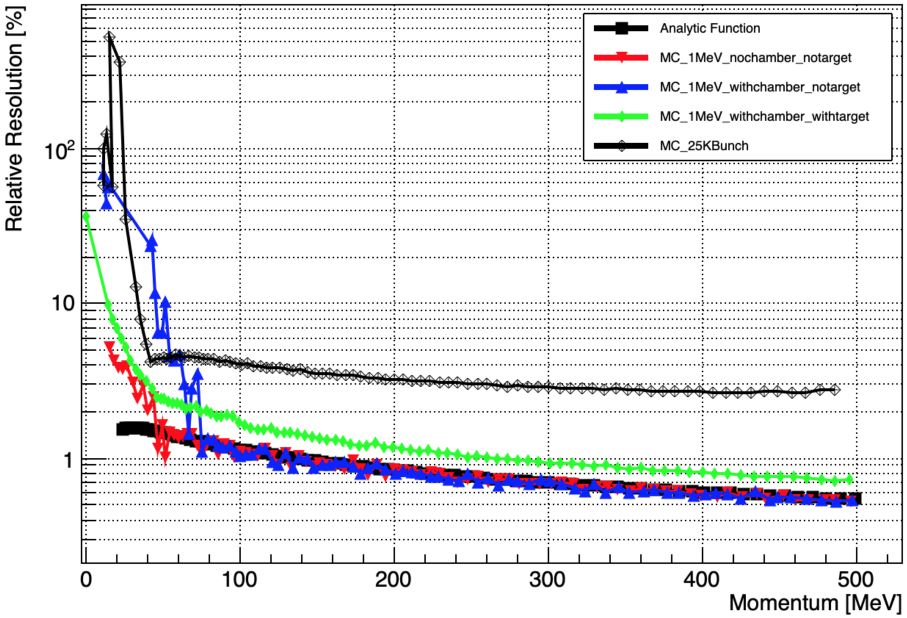
Active diamond target

Positron Veto system
(PVeto)

Electron Veto system
(EVeto)

PADME spectrometer inside the vacuum chamber from the calorimeter point of view

the acceptance of the veto



- Particle with momentum <50 MeV do not enter the PADME vacuum chamber due to bending of the fringe field of the magnet