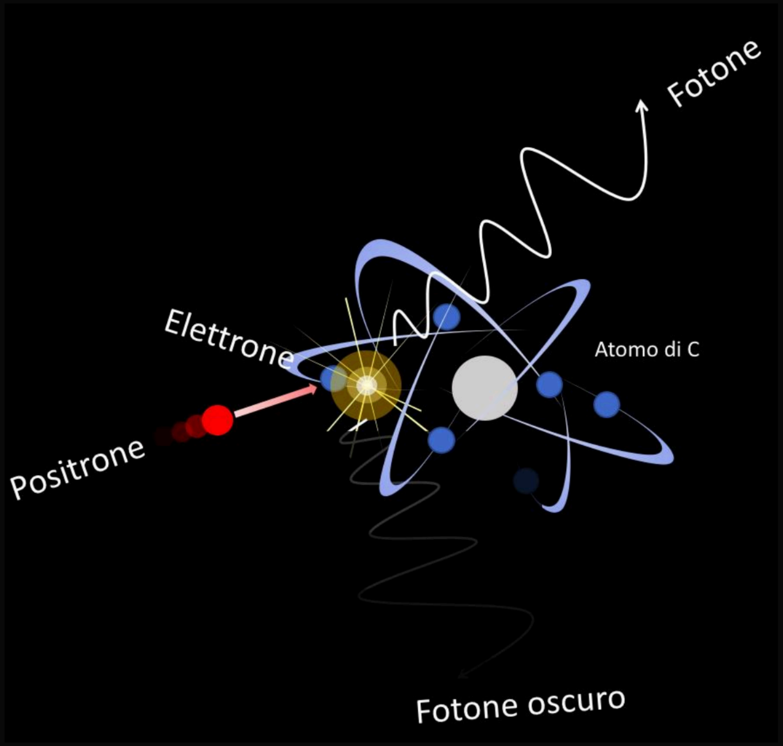
# FFF dark sector searches at LNF



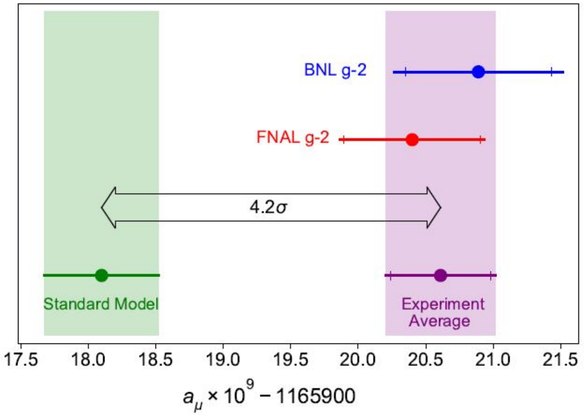

**M. Raggi & P.Valente,**
**Sapienza Università di Roma e INFN Roma**
**On behalf of the PADME collaboration**

# Outline

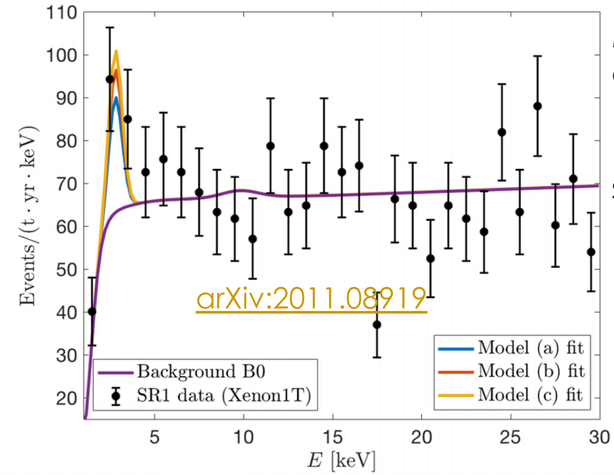
- Current low energy anomalies and dark sectors (3)
- Why positrons?(1)
- Prospects for an high luminosity extracted beam from DAΦNE. (4)
  - Solutions, time line, and expected luminosity. (3)
  - The SHERPA project status (1)
- Possible dark sectors searches with high luminosity positron beams
  - Dark Photons, ALPs, Dark Higgs (visible and invisible decays) (3)
  - Possible experimental techniques (missing energy and missing mass) (2)
  - Competitors (1)
- Standard model measurements with positron at LNF (2)
  - Photons only final states, charged tracks and photons, only charged tracks
  - Prospects for a 1E16 POT experiment
- The case of the 8Be and 4He anomaly (3)
  - why the 8Be is a good physics case for LNF?
- When, where, what, why, who (1)

# Low energy anomalies

## *(g-2)μ* *Phys.Rev.Lett.* 126 (2021) 14, 141801

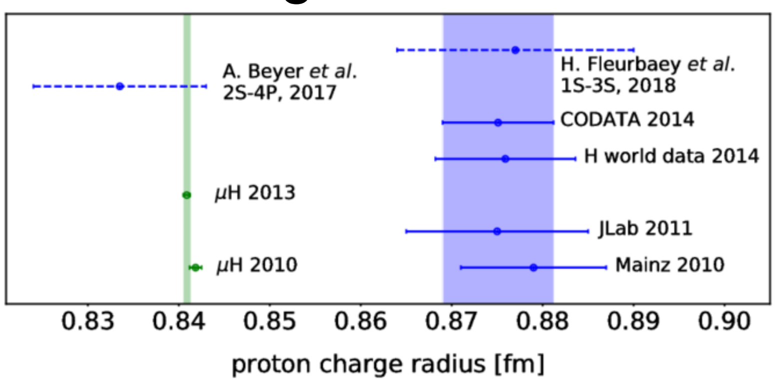



## Xenon1T Phys. Rev. D **102**, 072004




Monoenergetic peak at **(2.3±0.2) keV** (68% C.L.) **3.0σ global** (4.0σ local) significance

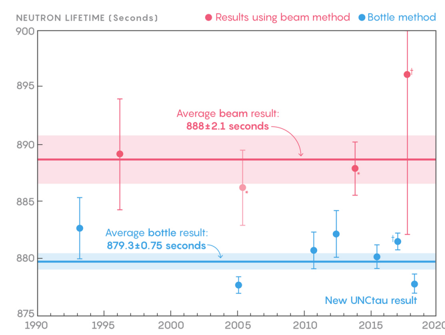
## Proton charge radius

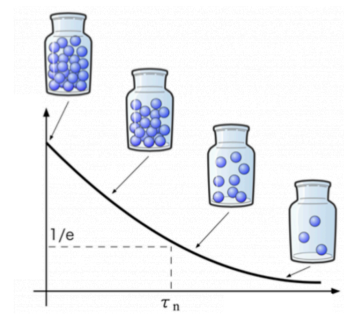


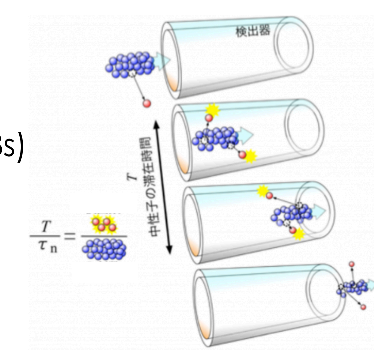

Using the Lamb shift of muonic hydrogen versus electron scattering experiments.

https://arxiv.org/pdf/1011.3519.pdf

## Neutron lifetime puzzle



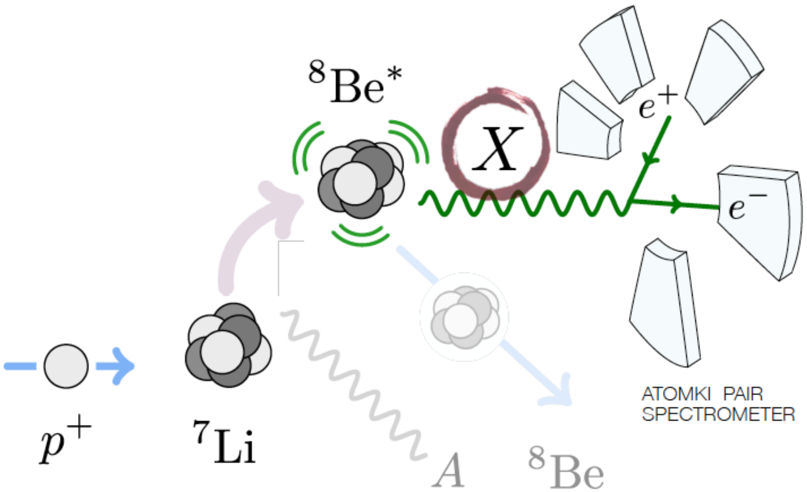

Neutrons in bottles decay faster (-8s) wrt neutron in beams

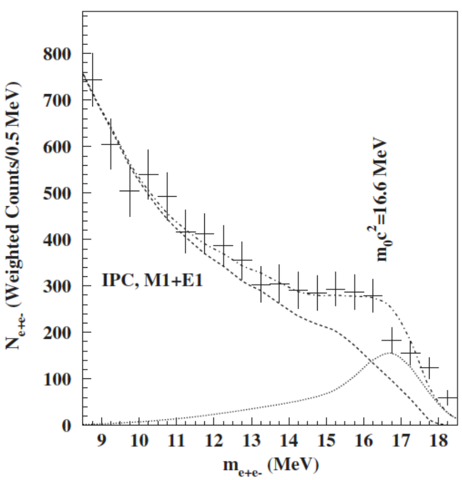
# Recently $^8$Be and $^4$He X17 anomaly

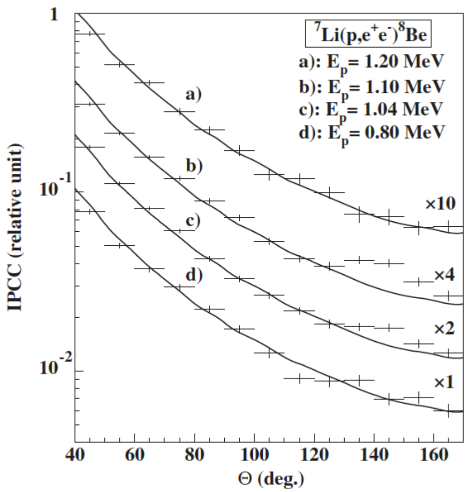
## $^8$Be anomaly 2016

PRL **116**, 042501 (2016) PHYSICAL REVIEW LETTERS week ending 29 JANUARY 2016

**Observation of Anomalous Internal Pair Creation in $^8$Be: A Possible Indication of a Light, Neutral Boson**

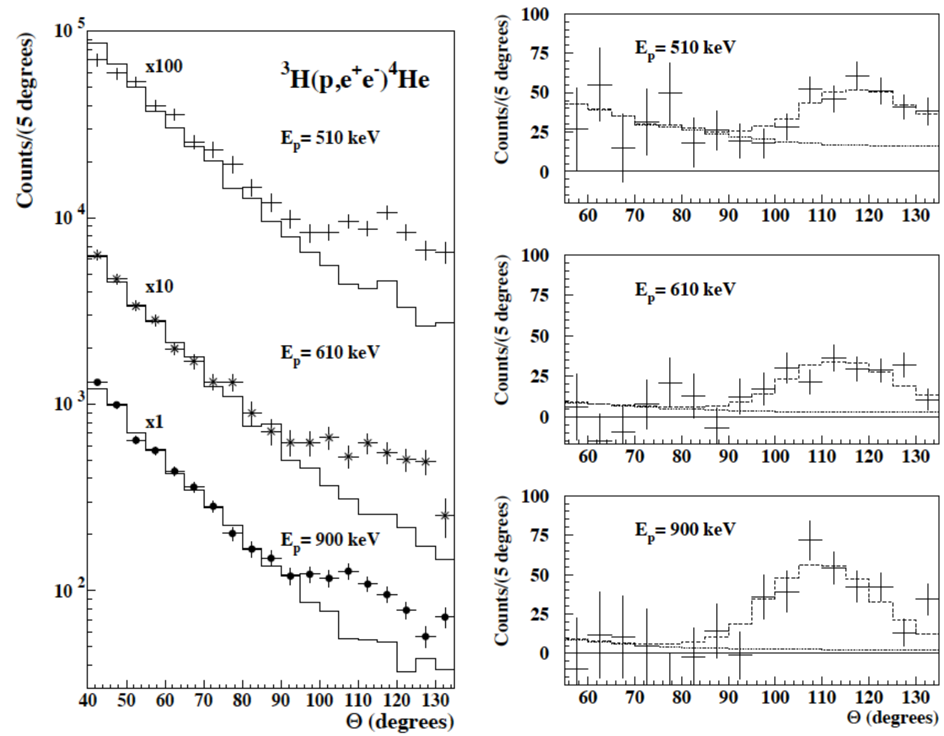



## $^4$He anomaly update. 20/04/2021

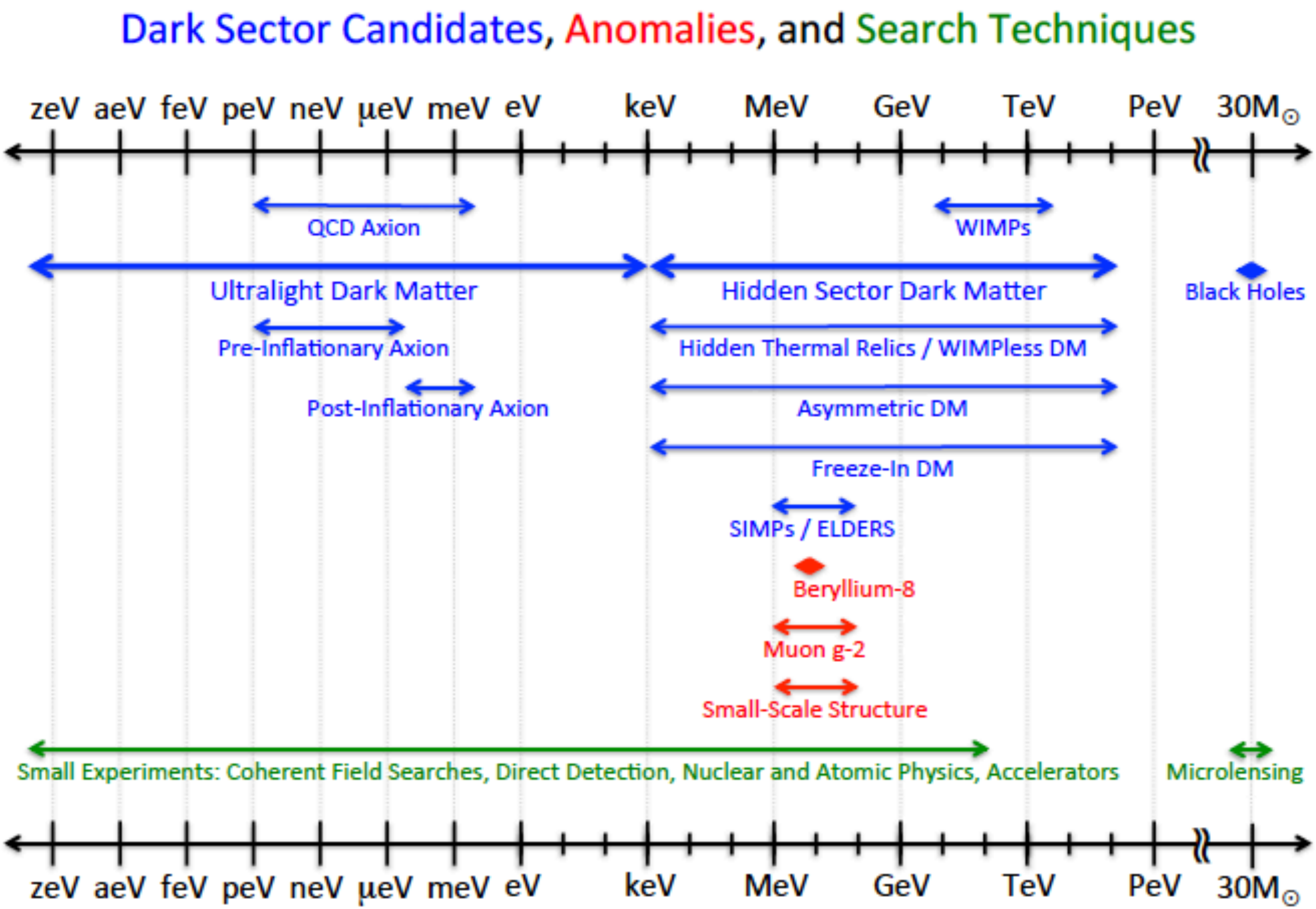
https://arxiv.org/abs/2104.10075v1




| $E_p$ (keV) | IPCC $\times 10^{-4}$ | $B_x$ $\times 10^{-6}$ | Mass (MeV/c$^2$) | Confidence |
|---|---|---|---|---|
| 510 | 2.5(3) | 6.2(7) | 17.01(12) | 7.3$\sigma$ |
| 610 | 1.0(7) | 4.1(6) | 16.88(16) | 6.6$\sigma$ |
| 900 | 1.1(11) | 6.5(20) | 16.68(30) | 8.9$\sigma$ |
| Averages | | 5.1(13) | 16.94(12) | |
| $^8$Be values | | 6 | 16.70(35) | |

SAPIENZA UNIVERSITÀ DI ROMA

# A large panorama with some hints?




SAPIENZA
UNIVERSITÀ DI ROMA

# Why positrons?

- With e+ beams 3 production mechanisms allowed:
  - a) A-strahlung same as electrons:

$$\frac{d\sigma}{dx\,d\cos\theta_{A'}} \approx \frac{8Z^2\alpha^3\epsilon^2E_0^2x}{U^2}\mathcal{L}og \times\left[\left(1-x+\frac{x^2}{2}\right)-\frac{x(1-x)m_{A'}^2(E_0^2x\theta_{A'}^2)}{U^2}\right]$$

- Two additional production mechanisms in e+ beams
  - b) Associated production O(α²)

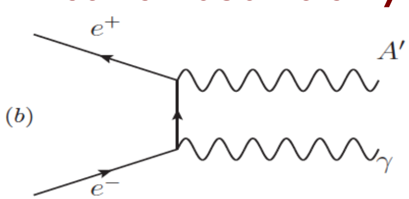
$$\sigma_{nr}=\frac{8\pi\alpha^2}{s}\left[\left(\frac{s-m_{A'}^2}{2s}+\frac{m_{A'}^2}{s-m_{A'}^2}\right)\log\frac{s}{m_e^2}-\frac{s-m_{A'}^2}{2s}\right]$$

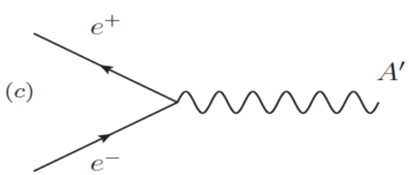
  - c) Resonant annihilation O(α)

$$\sigma_{\rm res}(E_e)=\sigma_{\rm peak}\frac{\Gamma_{A'}^2/4}{(\sqrt{s}-m_{A'})^2+\Gamma_{A'}^2/4}$$

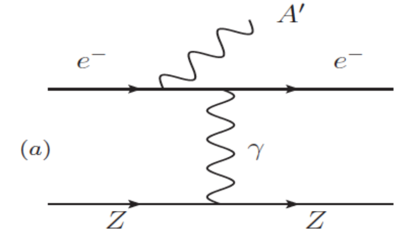
$$\sigma_{\rm peak}=12\pi/m_{A'}^2 \qquad \Gamma_{A'}=\tfrac{1}{3}m_{A'}\varepsilon^2\alpha$$

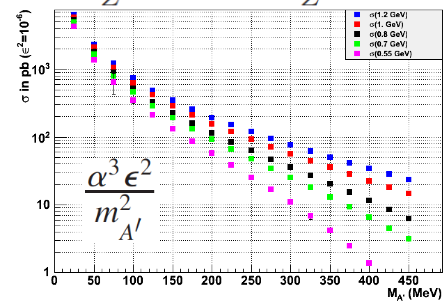
**Positron beams only**

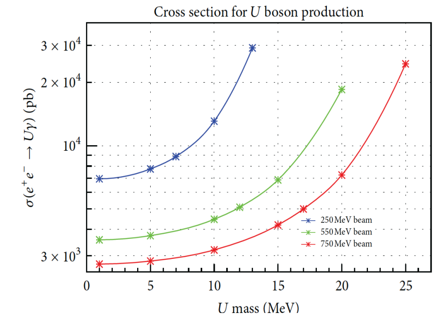


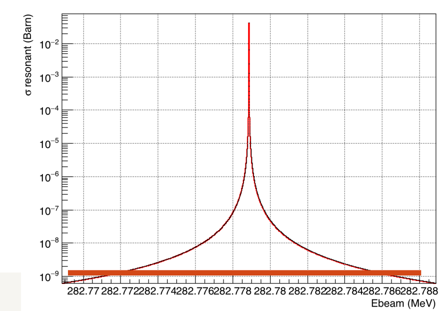




**Electron and positron beams**



# Prospects for an high luminosity extracted beam from DAΦNE

Mostly based on:
P. Valente @ FFF 13 Jan 2021:
https://agenda.infn.it/event/25299/contributions/127690/attachments/78156/100879/positrons-valente-13jan2021-final.pdf

SAPIENZA
UNIVERSITÀ DI ROMA

# Options for extracting the beam

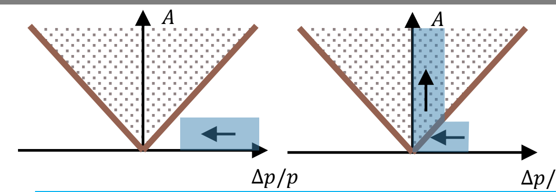
Options (briefly) described in January:

- **Modify the LINAC** in order to get [even] longer pulses
  - Implies some hardware modification on LINAC RF, but limited by modulator and gun pulser to <5 $\mu s$
  - At the price of a **lower energy**: could impact X17 searches (need to go comfortably above 300 MeV)
  - Allows using PADME in its current location in BTF-1
- Use the **positron main ring** (MRp) as pulse stretcher of the LINAC (as it is)
  - Using the **synchrotron radiation loss** to drive the $n+1/3$ resonance: $\Delta E/E$ fixes the **spill length**
  - Requires **new** electrostatic (ES) and magnetic (M) **septa**
  - Also requires an extraction line towards the experiment
  - Requires a **direct injection** to the MRp both for
    - Having **maximum energy spread** (allowed by ring acceptance)
    - And **inject faster than 2 Hz** (50 Hz [−1 Hz for spectrometer measurement])
- Use the **damping ring** (DR) as pulse stretcher of the LINAC (as it is)
  - Similar scheme as for extraction from MRp with additional pros and cons
    - **Shorter spill** due to length=1/3 $L_{\mathrm{MR}}$ and smaller acceptance when trying to get large $\beta$ at ES/crystal
    - Extraction (M) **septa** (2°+34°) **already existing**
    - **Much simpler** (and cheaper to run) wrt MRp; beam from LINAC already with large $\Delta E/E$
    - Inside a very small building; need to find a **location for the experiment**. This drives the **repetition rate** since the **pulsed magnets** of the transfer line work at 2 Hz.

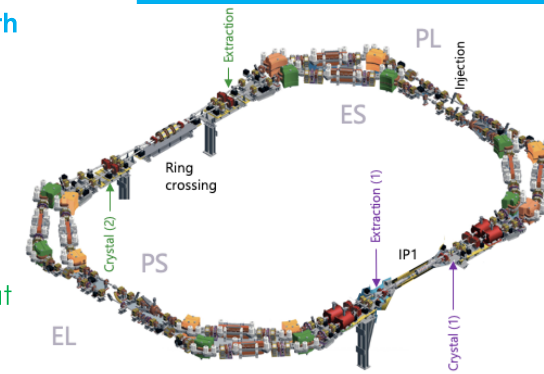
For the extraction **both from MRp and DR**:

- **Crystal channeling** is an interesting alternative to the ES septum (non-local extraction)
- **Slowing down** the transfer of particles to the septum would produce even **longer pulses**
  - Apply a technique similar to the "RF knock-out" used in proton machines (e.g. using a kicker)
  - Very interesting since a truly **continuous beam** can be produced and also:
    - Overcomes the 2 Hz limitation
    - Allows controlling the **spill uniformity**
    - Works with a small $\Delta E/E$

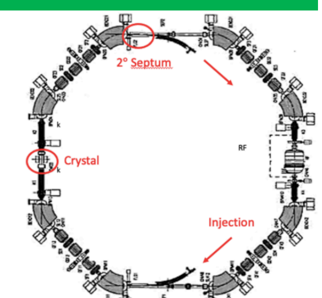
## Resonant extraction driven by synchrotron loss



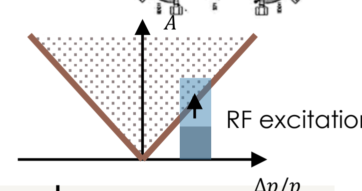

works well in the main ring…




… and also in the accumulator




Controlling the extraction rate would be of paramount importance



# Positrons from DAΦNE: parameters

| Accelerator | Beam-line | Upgrades | Time scale | Pulse length | Maximum energy† | Positrons on target/year# |
|---|---|---|---|---|---|---|
| **LINAC** | BTF-1 | *none* | Now | 300 ns | 490 MeV e+ | $3\cdot10^4\times49\times10^7=\mathbf{1.5\cdot10^{13}}$ |
| | | De-tuned SLED's | 2 years | 3 $\mu s$ | 300 MeV e+ | $3\cdot10^5\times49\times10^7=\mathbf{1.5\cdot10^{14}}$ |
| | | LLRF modulation | 2 years | 800 ns | 420 MeV e+ | $8\cdot10^4\times49\times10^7=\mathbf{4\cdot10^{13}}$ |

Present configuration

| Accelerator | Beam-line | Upgrades | Time scale | Pulse length | Maximum energy† | Positrons on target/year# |
|---|---|---|---|---|---|---|
| **LINAC + main ring*** | POSEYDON | ES septum [or crystal] + M septum + extraction line + direct injection | 3 years | 0.45 ms | 510 MeV e+ | $4.5\cdot10^7\times49\times10^7=\mathbf{2\cdot10^{16}}$ |
| | | | | 2 ms | 300 MeV e+ | $2\cdot10^8\times49\times10^7=\mathbf{10^{17}}$ |

* Wigglers off

† Energy range with a circulating positron beam: probably 250-520 MeV

| Accelerator | Beam-line | Upgrades | Time scale | Pulse length | Maximum energy† | Positrons on target/year# |
|---|---|---|---|---|---|---|
| **LINAC + accumulator** | *tbd* | Extraction line [+ crystal] [+ Pulsed dipoles] | 3 years | 60 (120) $\mu s$ | 510 MeV e+ | $6\cdot10^6\times49\times10^7=\mathbf{3\ (6)\cdot10^{15}}$ |
| | | | | 0.3 (0.6) ms | 300 MeV e+ | $3\cdot10^7\times49\times10^7=\mathbf{1.5\ (3)\cdot10^{16}}$ |

At 2 Hz: **1 (2)·10^14**

At 2 Hz: **0.6 (1.2)·10^15**

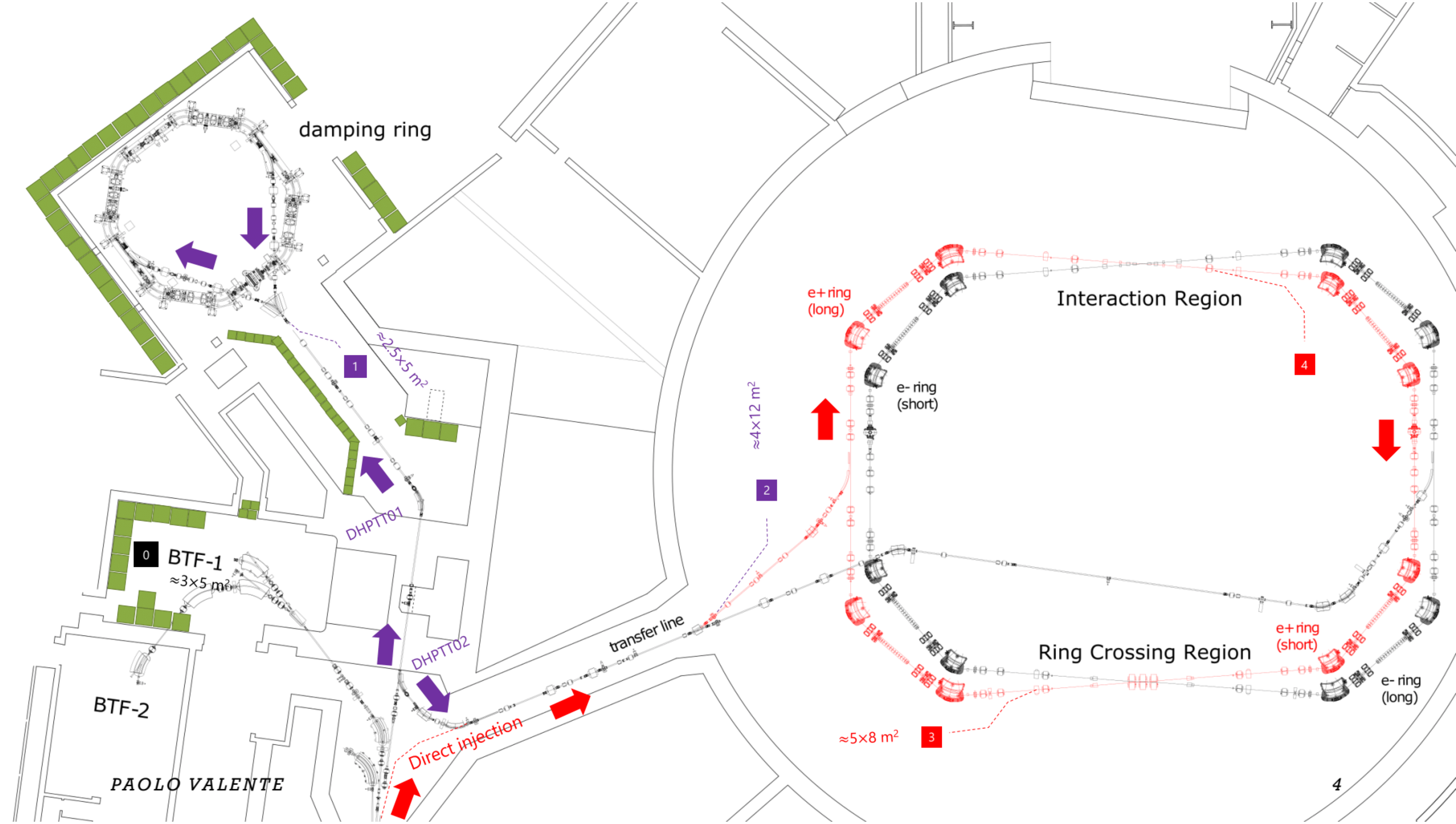
\# Assuming **$10^2$ particles/ns**.

Divide by $10^3$ to get «single particle» or **1 particle/10 ns**

Divide by $10^2$ to get «low-density» or **1 particle/1 ns**

- Very short conservative summary (100e+/ns current PADME intensity):
  - **LINAC+ BTF : ~$1.5\cdot10^{13}$ POT/Y**
  - **LINAC+DAΦNE ring : ~ $2.0\cdot10^{16}$ POT/Y**
  - **LINAC+Accumulator : ~ $1.0\cdot10^{15}$ POT/Y** (potential problem with injection)

# Experiment location



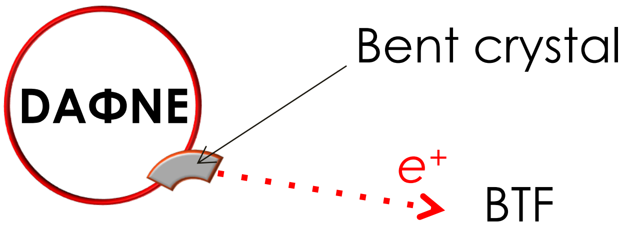
# *SHERPA*

*"Slow High-efficiency Extraction from Ring Positron Accelerator"*

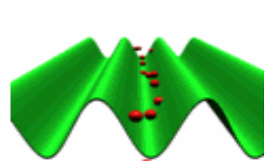
CSN5 grant, P.I.: Marco Garattini (LNF-INFN)

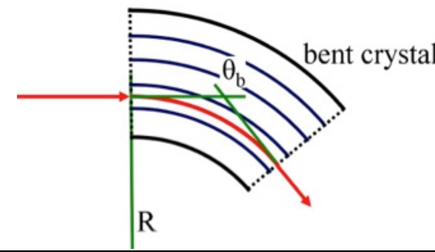
R&D study to extract a high-quality $e^+$ beam from the DAΦNE ring

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



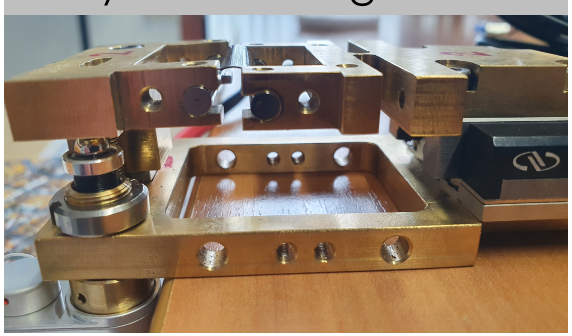

***Channeling***



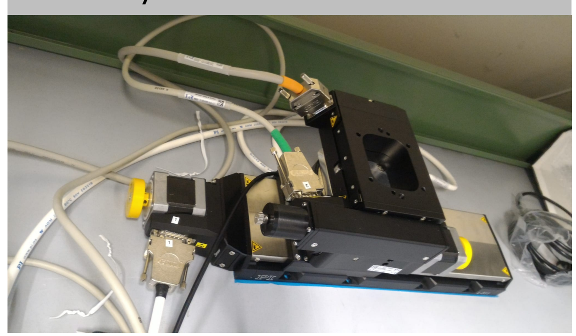



| **Current BTF spill parameters:** | | **SHERPA target spill parameters:** |
|---|---|---|
| - Energy spread: $\Delta p/p < 0.5 \times 10^{-2}$ | | - Energy spread: $\Delta p/p < 10^{-3}$ |
| - Emittance: $\varepsilon < 10^{-5}$ rad·m | **VS** | - Emittance: $\varepsilon < 10^{-6}$ rad·m |
| - **Length: $\Delta t < 200$ ns** | | - **Length: ms < $\Delta t$ < s** |

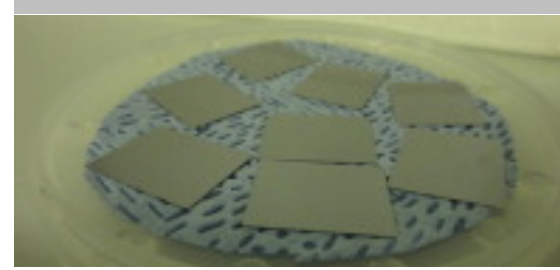
Crystal bending holder



Crystal Goniometer



Crystal under construction at INFN-Fe

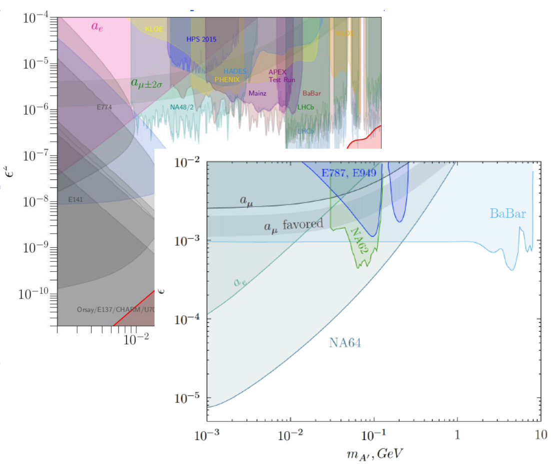


# Dark sectors candidates at PADME II

Mostly based on:
L. Darme'@ FFF 13 Jan 2021:
https://agenda.infn.it/event/25299/contributions/127685/attachments/78132/100857/ProspectsLNF2.pdf
and Arxiv:2012.07894

# Dark sectors candidates at PADME

## Dark Photon A’



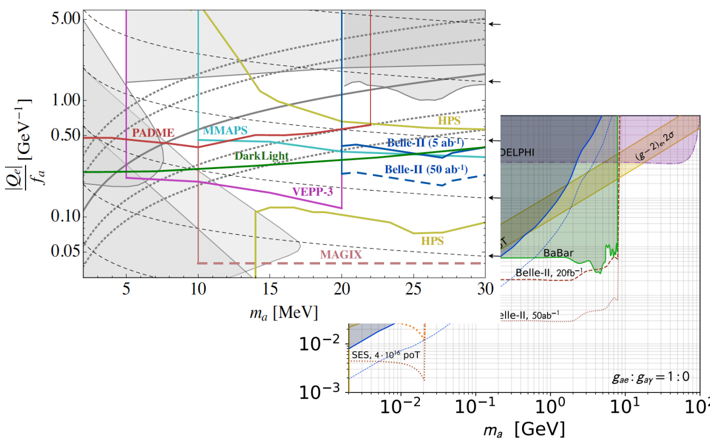

**$e^+e^- \to \gamma A'$**

**Visible, invisible decays:**

**$A' \to \chi\chi$, ee**

## Axion Like Particles

JHEP07(2018)092, Arxiv:2012.07894



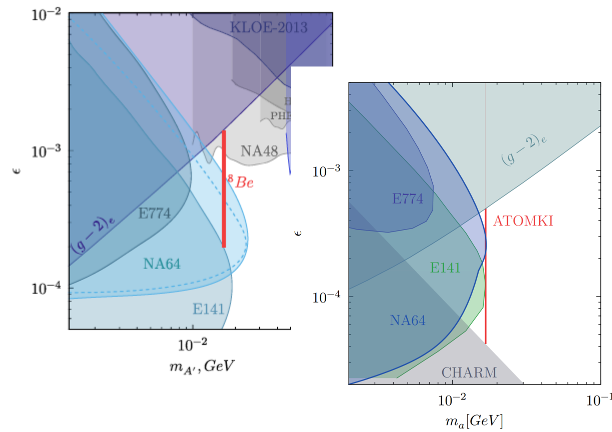

**$e^+e^- \to \gamma ee$**

**ALPs final states:**

$a \to \gamma\gamma$, ee, $\chi\chi$

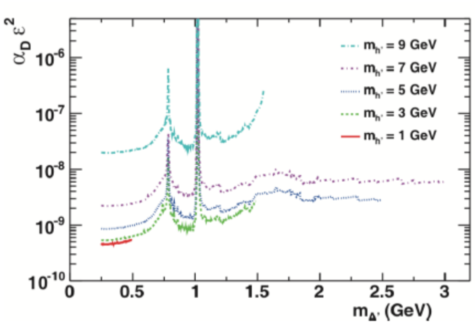
## BE anomaly- X boson

Axiv: 2104.13342




**$e^+e^- \to \gamma X_{17}$**

**Final state $X_{17} \to ee$**

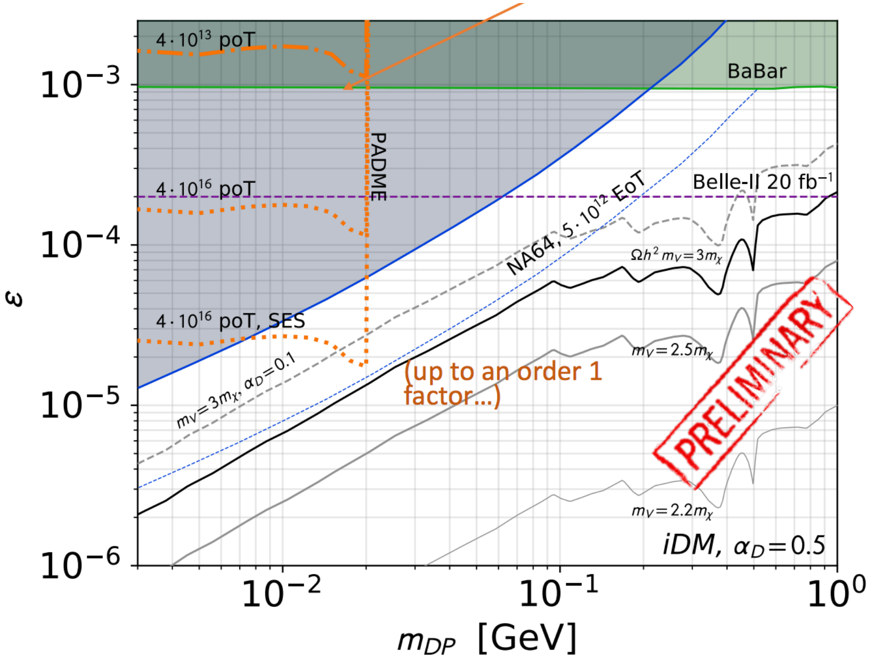


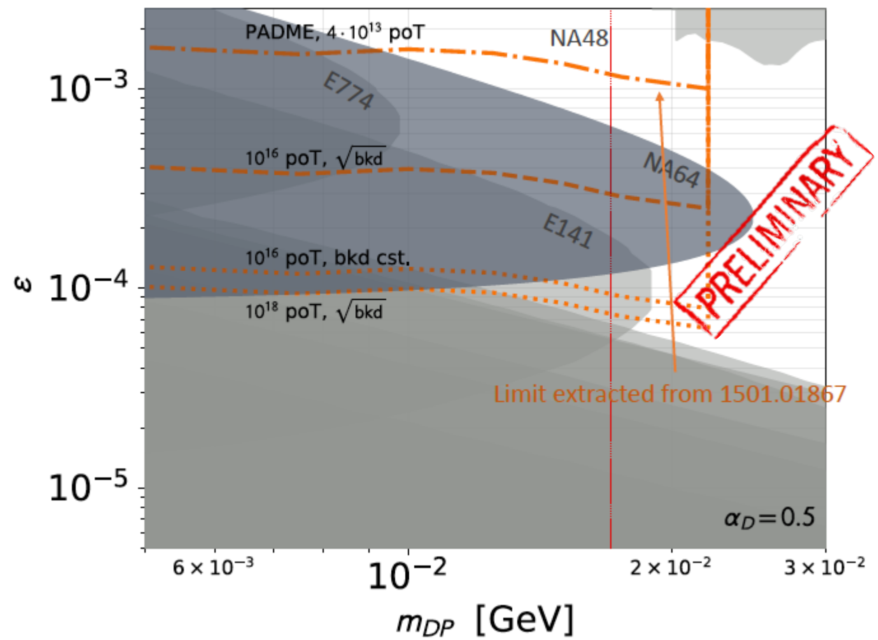

**Dark higgs: $e^+e^- \to h'A'$**

**dark higgs decay:** $h' \to A'A'$, $A' \to ee$

Final State: $A'A'A' \to e^+e^-\ e^+e^-\ e^+e^-$

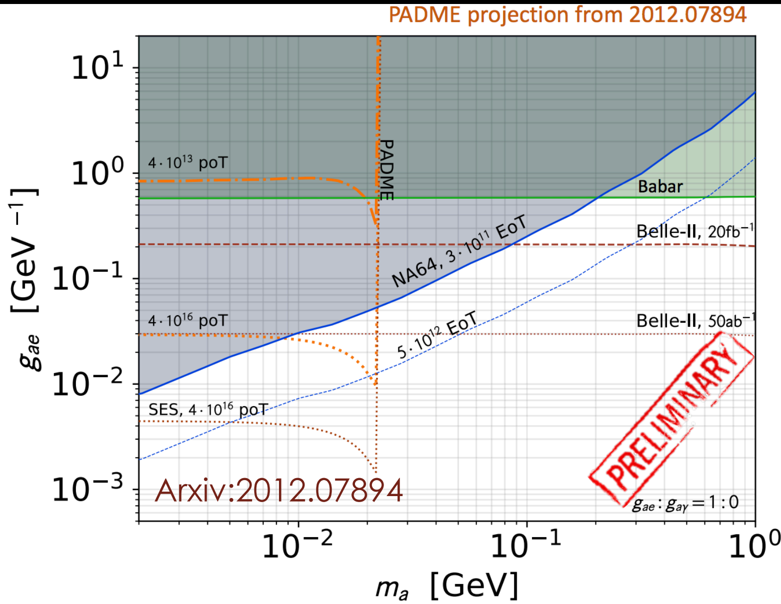
# Visible and invisible A'

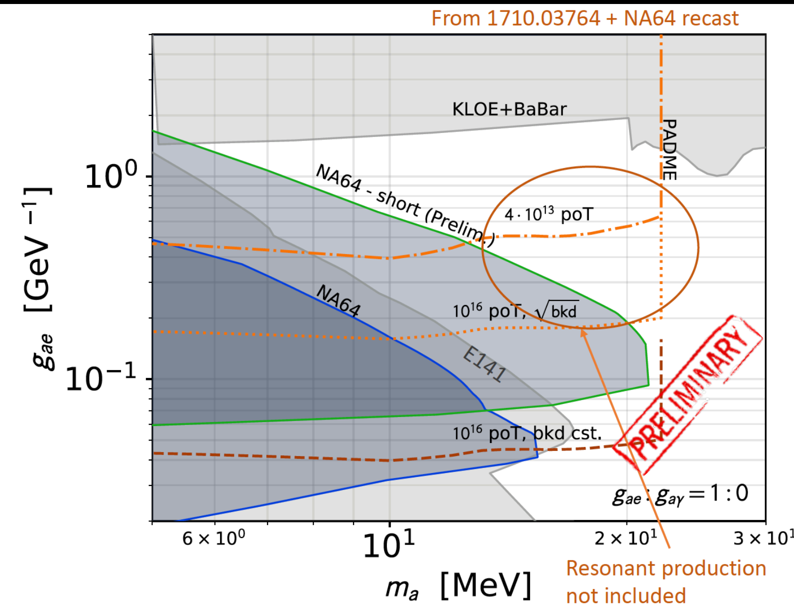



- Invisible searches have just one strong exclusion by NA64
  - PADME can approach the $10^{-4}$ region with $4\times10^{16}$ POT
  - Scaling based on present experiment BG estimate
- In visible decays the constraints from NA64 are less stringent due to the lifetime limitation due to dump technique
  - Limits are based only on associated production
  - NA48/2 limits doesn't hold for leptophilic mediators

# Visible and invisible ALPs

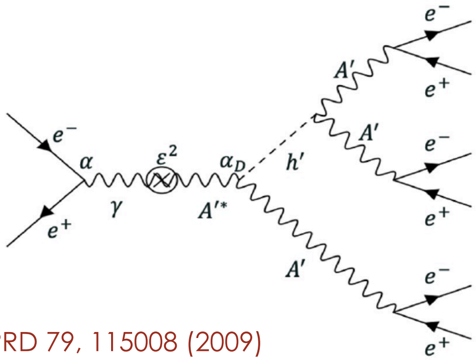



- Invisible searches have just one strong exclusion by NA64
  - PADME can approach the low $10^{-2}$ region with $4\text{x}10^{16}$ POT
  - Scaling based on present experiment BG estimate
- In visible decays the constraints from NA64 are less stringent due to the lifetime limitation due to dump technique
  - good opportunity for PADME sensitivity

# Dark Higgs in 6 leptons final states

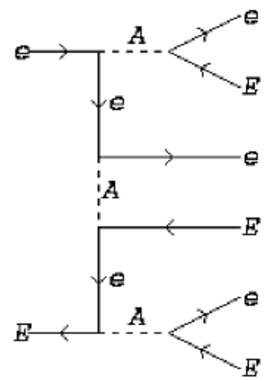
## Dark Higgs in ee collisions




PRD 79, 115008 (2009)

$$\sigma_{e^+e^-\to Vh'} \approx 20\ \text{fb} \times \left(\frac{\alpha'}{\alpha}\right)\left(\frac{\kappa^2}{10^{-4}}\right)\frac{(10\ \text{GeV})^2}{s},$$

## Standard model BG




$$\boxed{\sigma_{e^+e^-\to 3(e^+e^-)} \approx \frac{\alpha^2}{6\pi^2}\sigma_{(\gamma\gamma\to e^+e^-e^+e^-)}\left(\log\frac{s}{m_e^2}\right)^4}$$

$$\sigma_{e^+e^-\to 3(e^+e^-)} \approx \frac{\alpha^6}{\pi^3 m_e^2}\left(\log\frac{s}{m_e^2}\right)^4$$

- At low energy LL-EPA fails due to accidental cancellation

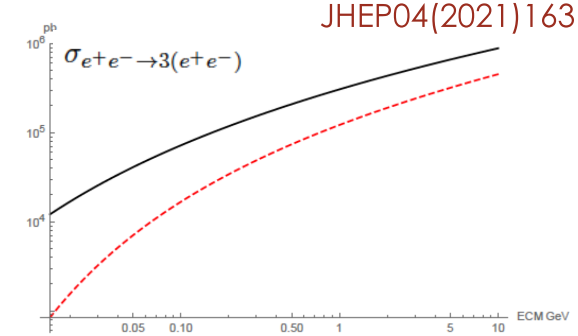
$$A \sim -11.9 \qquad B \sim 22.62 \qquad C \sim 143.5 \qquad D \sim -521.1$$

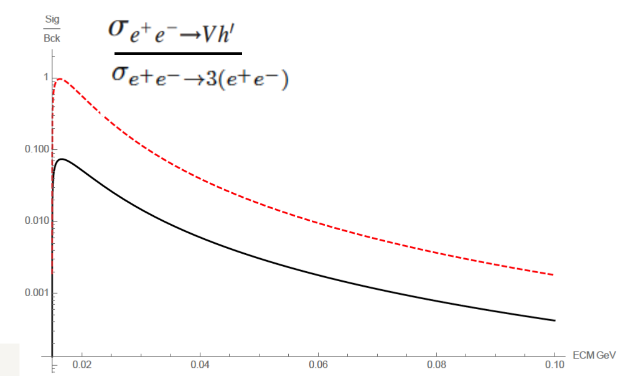
- A new complete Log formula has been developed for PADME

$$\sigma_{\text{EPA full}} = \frac{\alpha^2}{6\pi^2}\sigma_{(\gamma\gamma\to e^+e^-e^+e^-)}\left(\log^4\left(\frac{s}{m^2}\right) + \text{A}\log^3\left(\frac{s}{m^2}\right) + \text{B}\log^2\left(\frac{s}{m^2}\right) + \text{C}\log\left(\frac{s}{m^2}\right) + \text{D}\right)$$

- SM BG reduced by factor of ~10 at $E_{CM}$ ~ 20MeV
- Dark sector cross section close to SM one unique opportunity!!!
  - DH cross section ~1000 pb ($\varepsilon^2$=1E-6 , $\alpha_D$=0.1) **150 ev/1E13 POT**
  - SM 6l ~1500 pb **200 ev/1E13 POT**

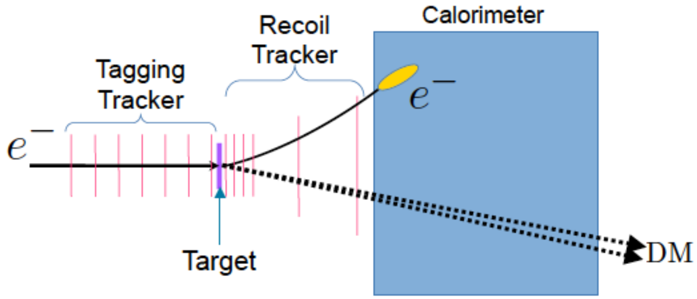
JHEP04(2021)163



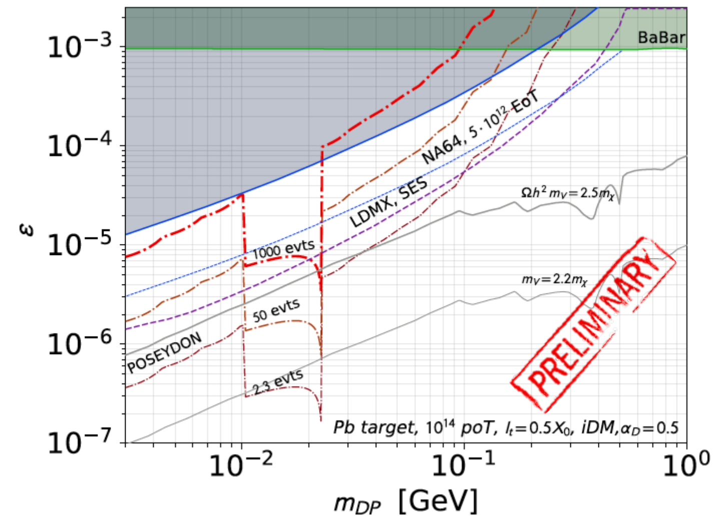
# Different techniques?

- In the hypothesis of single particle beam @$10^{14}$ POT/year
  - Can use different production measurement
  - Can use different technique for DS searches
- Missing momentum experiment can provide interesting reaches for invisible signatures

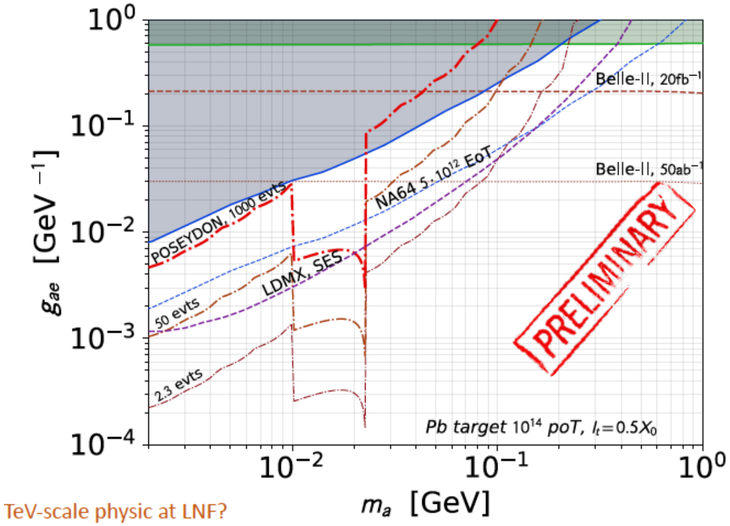



- Challenging techniques from the rate point of view
  - needs very good tracking capability with very high instantaneous rate

## Production rates

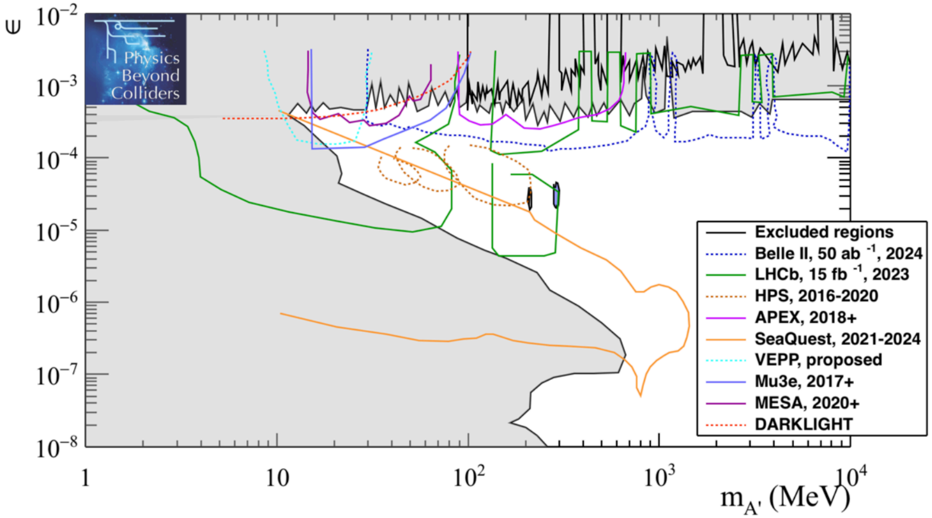



## Production rates

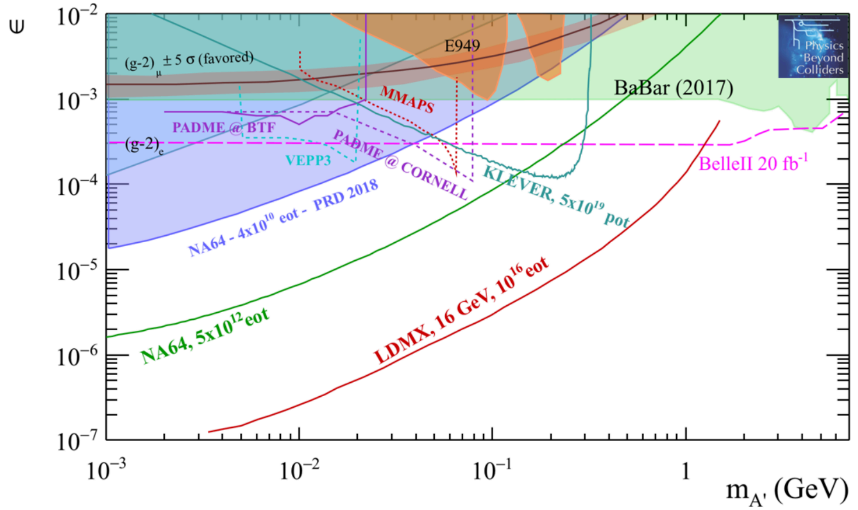


# A'-X17 competitors from CERN PBC

## Visible decays




## Invisible decays




- Visible $e^\pm$ based experiment
  - Belle II >20 MeV
  - VEPP, DarkLight not happening
  - MESA >2024
  - HPS mass to High
- Invisible $e^\pm$ based experiment
  - Belle II projection (need to be confirmed)
  - NA64
  - LDMX far in time if ever happening

# SM measurements at PADME

Mostly based on:

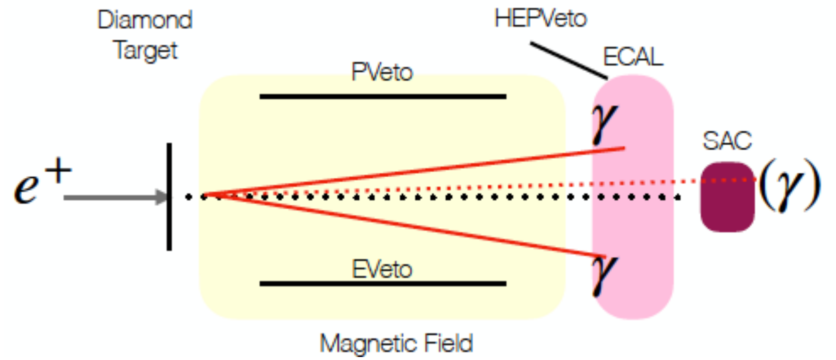
I. Oceano @ FFF 13 Jan 2021:

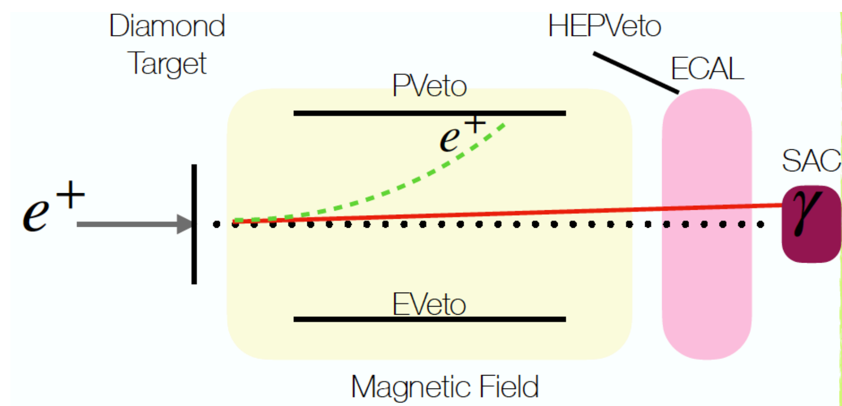
https://agenda.infn.it/event/25299/contributions/127694/attachments/78140/100858/FFF_PadmePhysics.pdf

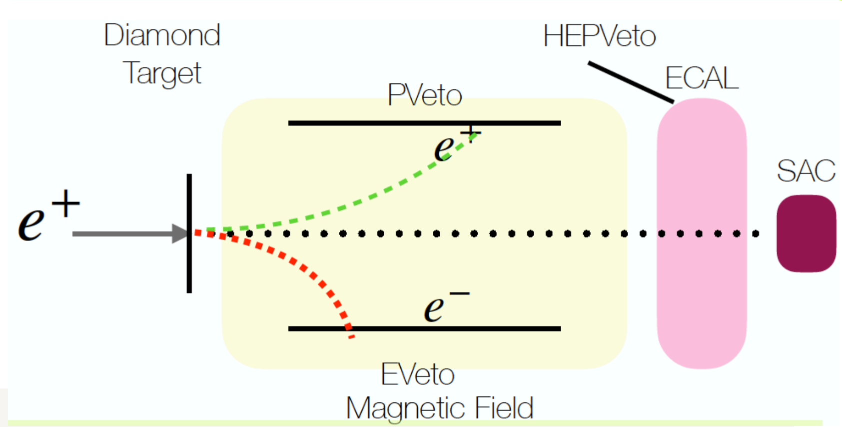
SAPIENZA
UNIVERSITÀ DI ROMA

# SM measurements at PADME

- Photons only
  - **$e^+e^- \to \gamma\gamma$ and $e^+e^- \to \gamma\gamma(\gamma)$**
  - SM NLO checks
  - BG to inv. decaying DS candidates
- Mixed e and $\gamma$
  - **Brems, $e^+e^- \to e^+e^-\gamma$**
  - BG to visible DS in associated prod.
- Only charged particles
  - **$e^+e^- \to e^+e^-$, $2(e^+e^-)$, $3(e^+e^-)$**
  - Non trivial QED $\gamma\gamma$ physics checks
  - BG to visible DS decays
  - Check the EPA cross sections 4e & 6e

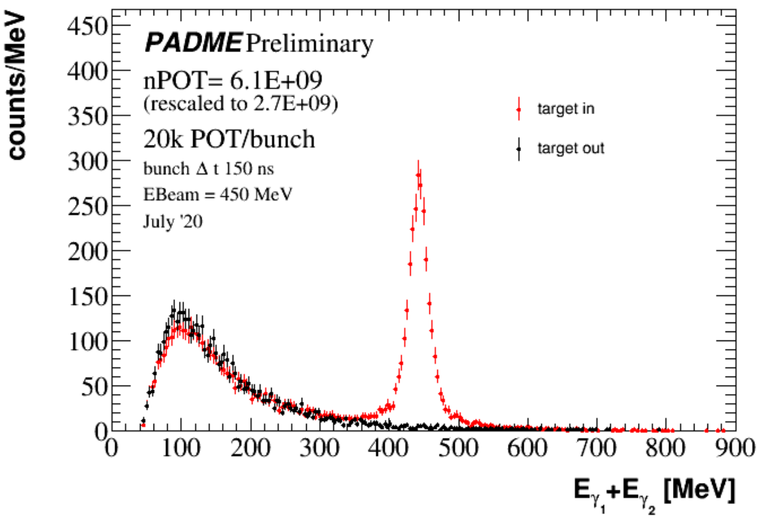


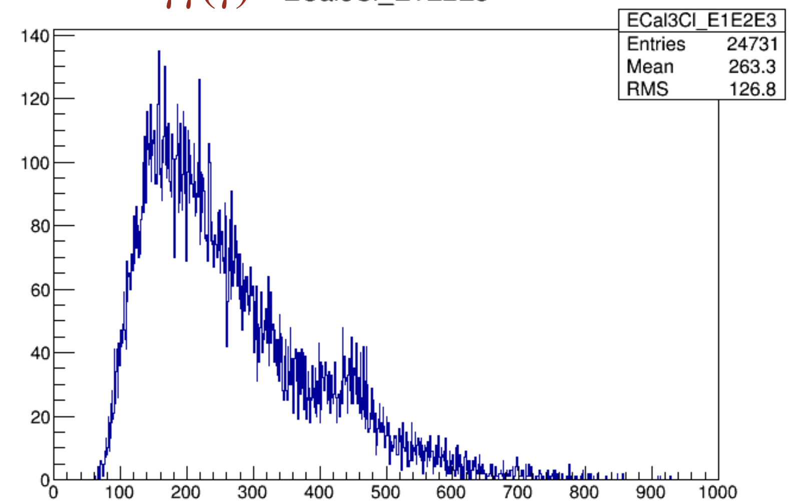



# First plots from the PADME data set

$e^+e^- \to \gamma\gamma$

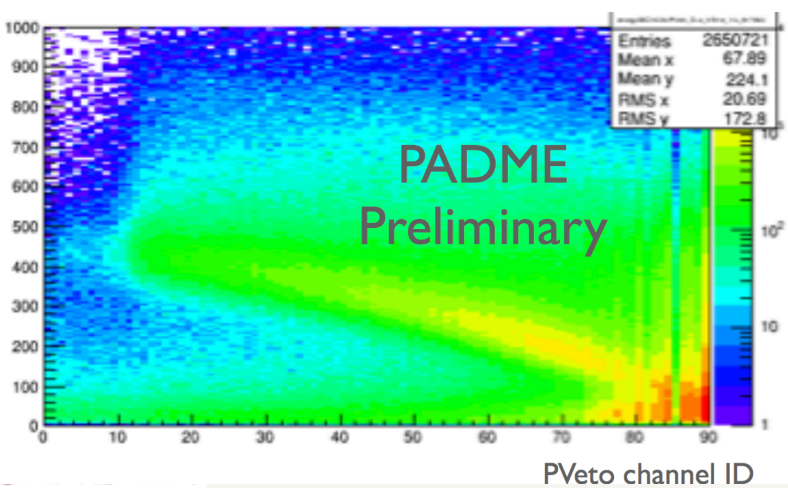



$e^+e^- \to \gamma\gamma(\gamma)$ ECal3Cl_E1E2E3



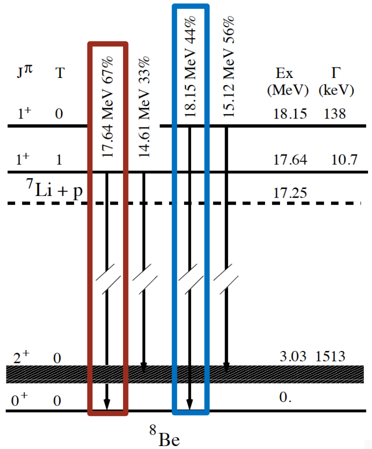

- Precision of ~few-10% in RunII
  - $e^+e^- \to \gamma\gamma$ and $e^+e^- \to \gamma\gamma(\gamma)$
  - $e^+e^- \to \gamma\gamma$
- multi leptons require higher luminostity ($10^{14}$-$10^{15}$

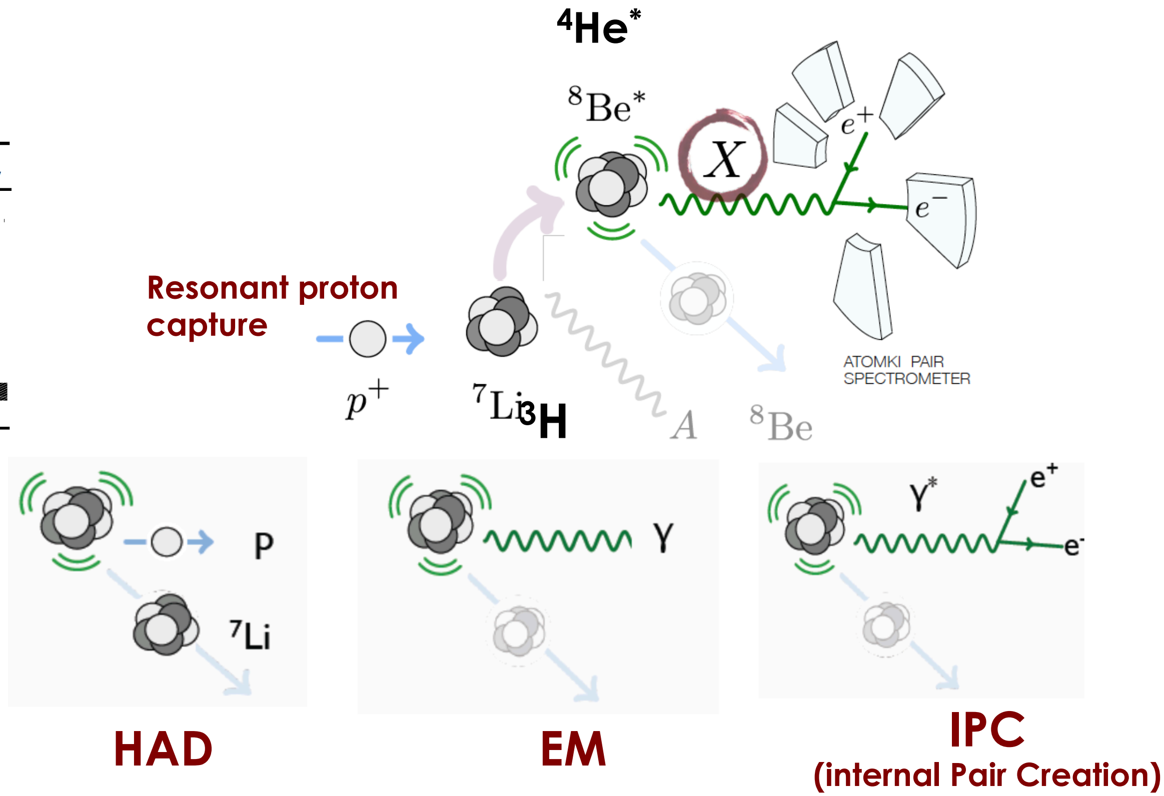
$e^+N \to e^+N\gamma$

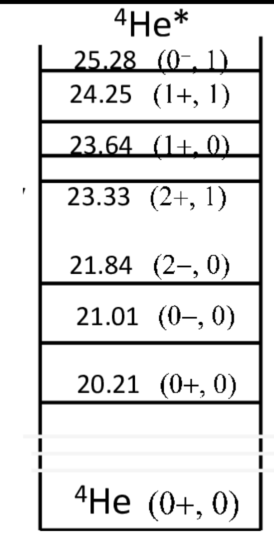


# The case of the 8Be and 4He anomaly

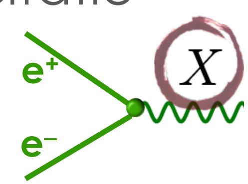
# The $^{8}$Be and $^{4}$He technique



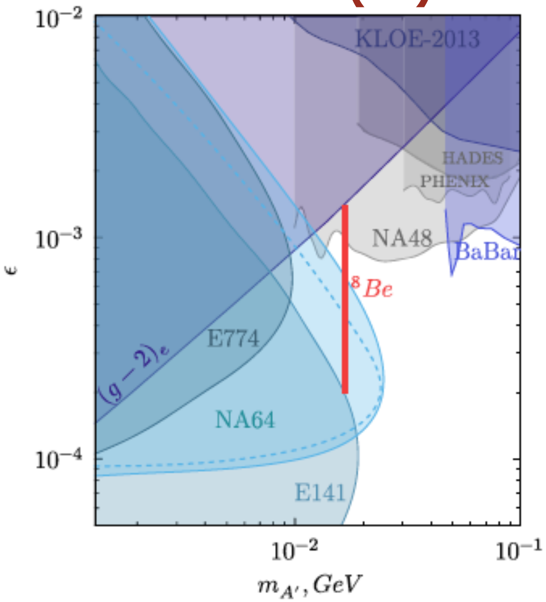




- Atomki Lab studies the angular correlation in IPC deexcitation
  - If X is particle we can reverse the IPC diagram and get
  - e+ energy required is 282MeV! Only LNF can do this!



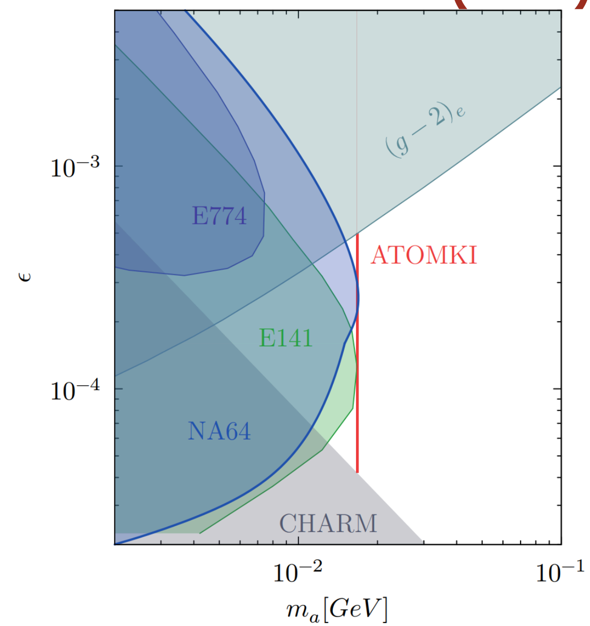
# Current constraints on $^{8}$Be

**Vectors (A')**




Phys. Rev. D 101, 071101(R) (2020)

**Pseudo Scalars (ALPs)**



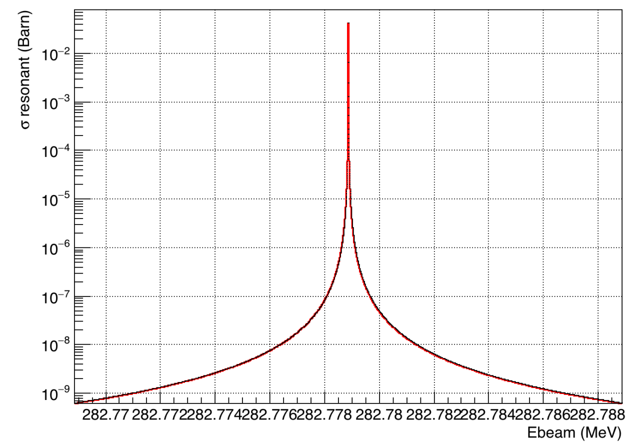

arXiv:2104.13342v1 [hep-ex] 27 Apr 2021

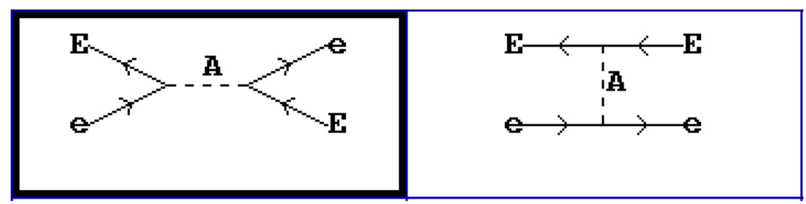
- In both plots there is large room for improvement and the area below 1E-3 is not covered.
  - On pseudoscalars the is basically no solid exclusion
  - On vectors only the region of low $10^{-3}$ is covered by NA64
- The $(g\text{-}2)_e$ constraints has been recently weakened (nature plot)
  - The (g-2)e exclusion is prone to cancellations in more complex DS scenario.

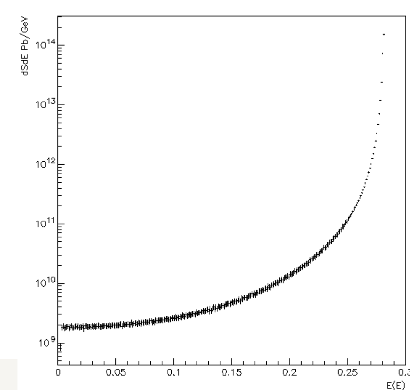
# Opportunity with resonant production

- Resonant annihilation in thin target still provide very high production rates for X17
  - Can scan MeV range with few runs with 1%/0.5% beam energy resolution runs. L. Darme'
  - LNF is the unique Lab. able to profit for
- Main background is BhaBha scattering should be under control
  - T-Channel reasonably small in proper kinematic regions. Investigations ongoing. L. Darme'
- Scanning the resonance we expect very strong enhancement of the number of observed ee pairs due to X17
  - Can obtain very strong exclusions few ($\varepsilon^2 < 10^{-4}$) already with ~$10^{10}$ POT
- PADME can close the 8Be region with few months of running at 282 MeV already in 2022.
- More news and definite plan @ Nov SciCom

**Resonant $e^+e^- \rightarrow$ X17 cross section**



# Summary


- **When?** Next 5-6 years
- **Where?** at the DAΦNE complex
- **What?** an high-lumi extracted beam
- **Why?** Chasing low energy anomalies
- **Who?** Hopefully most part of us ☺
  - A strong and motivated group of accelerator experts
  - A strong and motivated group of experimentalists
  - A strong and committed theoretical division
- **How?** need the help of you all to understand this last point

# Conclusions

- There are different solution to allow the DAFNE complex to provide semi-continuous extracted beams ~ $10^{15}$ -$10^{16}$ POT/s
  - Roughly x1000 with respect to present PADME acquired #POT

- Several dark sector targets can be addressed with this increased luminosity
  - Visible DS decays seem to be the most promising in the next 5-6 years

- in the near future **X17 Be** anomaly boson is a compelling **physics case for future PADME running in 2022**
  - We will ask for dedicated beam time in 2022 with a plan at the next SciCom

- I would like to thank the LNF theory division for working hard on this topic.
  - Invisible decays of axion-like particles: constraints and prospects Arxiv: 2012.07894 (accepted by Jhep)
  - Resonant production of dark photons in positron beam dump experiments, Phys.Rev.D 97 (2018) 9, 095004
  - Novel Way to Search for Light Dark Matter in Lepton Beam-Dump Experiments, Phys.Rev.Lett. 121 (2018) 4, 041802
  - Dark photon production through positron annihilation in beam-dump experiments, Phys.Rev.D 98 (2018) 1, 015031

# Backup slides

# Experiment location

**Extracting from the DR**:

1. Place the experiment in the «alley», parallel to the transfer line:
   - Need a 50 Hz pulsed dipole plus a short dogleg
   - **Very limited space**
   - Almost **impossible** to move there the present PADME dipole
2. Place the experiment in the DAΦNE hall:
   - DHPTT01 and DHPTT02 pulsed dipoles maximum repetition rate is **2 Hz** (100 ms ramp time)
   - Replace the PS to reach few ms ramp time or split the injection line (see spares)

**Extracting from the positron MR**:

3. Place the septum (and the crystal) close to the RCR (opposite to IP1):
   - Plenty of room on the outside of the ring
4. Place the setup close to IP1:
   - The septum would probably need to go in the short arc (in the inside of the machine)
   - Slightly more crowded area (mainly PS)

# To be (better) studied

**Extracting from the MRp or the DR**:

- **Location** of the experiment, i.e. extraction line and available **space** vs. **repetition rate** (pulsed magnets and transfer line). On the basis of this choice:
  - Pulsed magnets modifications/replacement (if needed)
  - Optics (see below)
- Control of extraction time with “RF know-out”

**For MRp option**:

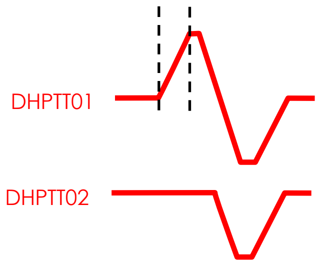
- Crystal and septum location (IP1 vs. RCR) for extraction from MRp
- **Optics modifications** for correct orientation of stable triangle and making room for extraction septum
- Direct injection design (small angle pulsed dipole + DC dipole)
- Extraction line design

**For DR option**:

- **Optics** for **high $\boldsymbol{\beta}$** (offset at crystal) vs. **high energy spread** (longer spill)
- Extraction line design

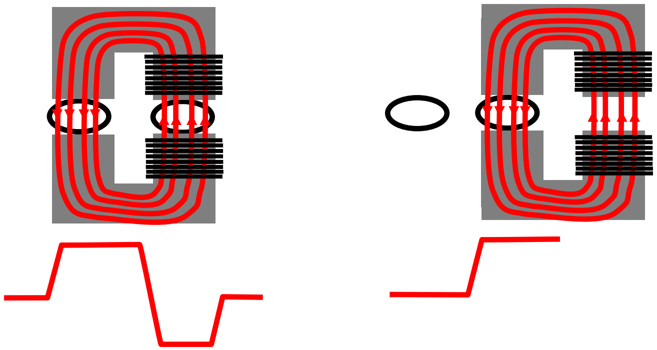
# Pulsed magnets

Limited to 2 Hz due to 100 ms ramping time

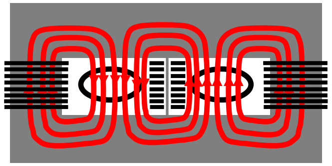



A **new pulsed PS** (four quadrants) **ramping in ~5 ms** seems a challenging project

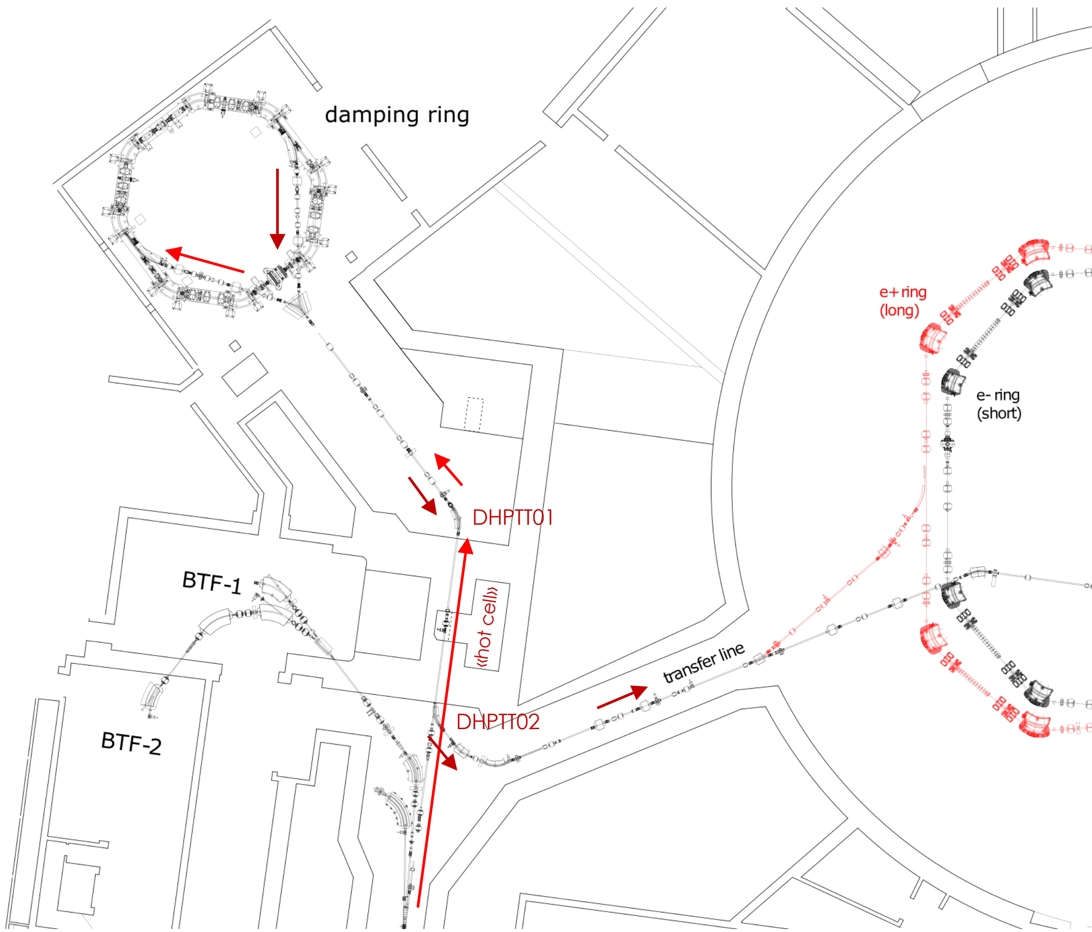
A possible solution (A. Variola, B. Wojtsekhovski): only a small deflection (e.g. by a kicker) plus modified DC dipoles



Similar concept to the (no longer used) DAΦNE splitter magnets



- A **double beam-pipe** is needed
- Not obvious in the «hot cell» segment



# PADME-like experiment requirements

At the Frascati LINAC, the main limitation to the **luminosity** is the **duty-cycle**, i.e. the combination of two factors:

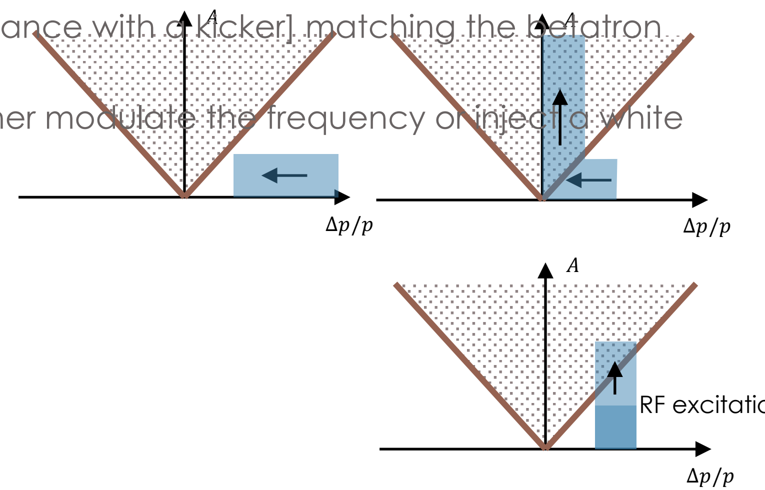
- The limited **repetition rate** of the LINAC (50 Hz, actually 49 usable pulses/s)
- The limited **macro-bunch length**
  - The **pile-up** in the calorimeters and **over-veto** probability (in the calorimeters and in the scintillating bars charged particle veto) limit the maximum tolerable particle density
  - **Assuming the performance of the present PADME detector** this can be expressed by the following rule-of-thumb: $\boldsymbol{n_{e^+}}$ **=100** $\times$ **pulse length[ns]**

The "**dream beam"** would be a **continuous**, low intensity positron beam, making possible to reconstruct each individual interaction in the [thin] target; this would allow a **zero-background** experiment.

However, a significantly long beam pulse structure [i.e. **comparable** to the inter-bunch of 20 ms] would be **very interestingly close** to the ideal beam

# Controlling the extraction rate

- The **uniformity of the extracted beam** is very important: can be controlled modulating the betatron oscillations
- In the so-called "RF knock out" the amplitude is increased for injecting into the separatrix particles with smaller $\Delta p/p$
  - This is done applying an external, transverse electric field [for instance with a kicker] matching the betatron frequency.
  - Due to the tune spread given by not vanishing chromaticity, either modulate the frequency or inject a white




- Also in crystal extraction, a RF excitation could be used to populate the periphery of the beam
- In this way particles with **smaller displacement** could be extracted
- **If a sufficient portion of the beam could be driven to the crystal this could yield a longer beam spill**
  - This deserves a careful experimental study
  - All estimates for crystal extraction use the central orbit
  - For this reason the **same length** as in the **resonant option** is quoted
- In the **SPS crystal extraction studies** the population of the beam halo has been steadily sustained by injecting a properly tuned transverse random noise using a ADT ("Adiabatic Transverse Dumper", a sort of electrostatic capacitor)

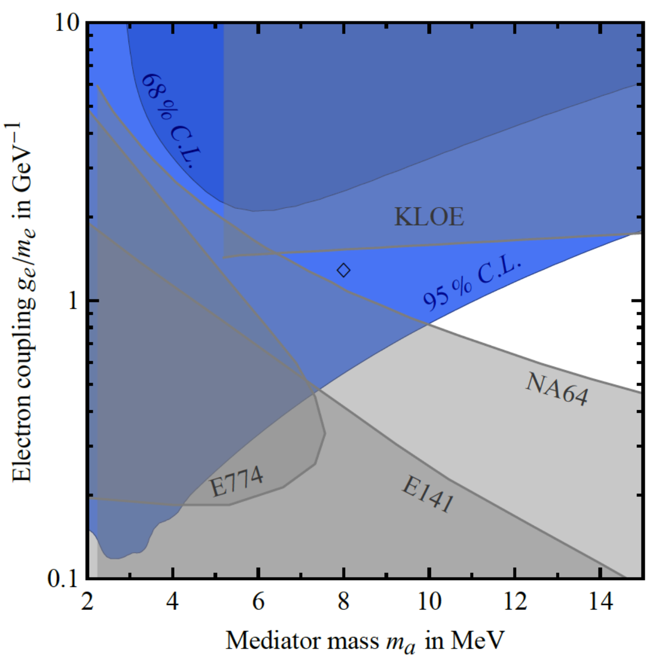
*M. Garattini*

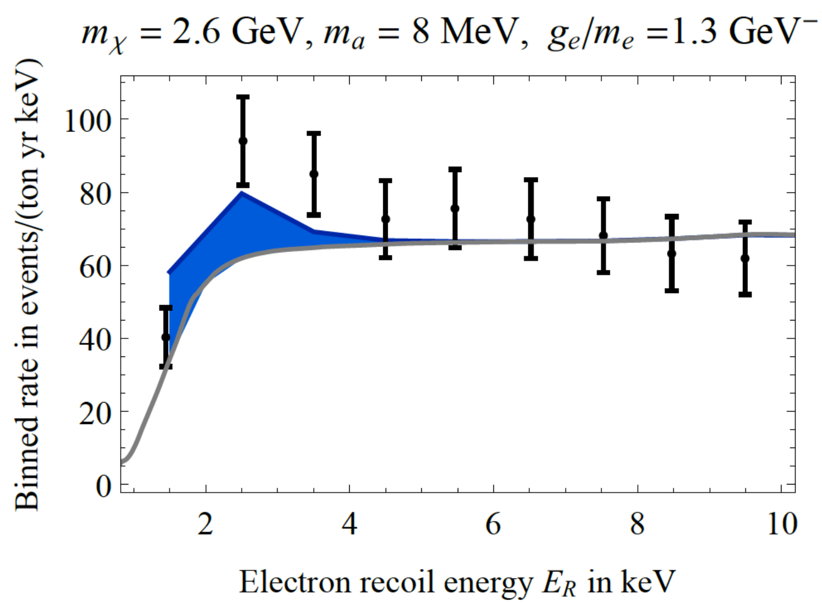
# Xenon 1T anomaly and PADME

CERN-TH-2020-165, TTP20-039, P3H-20-070

XENON1T excess from electron recoils of non-relativistic Dark Matter

Dario Buttazzo,[1] Paolo Panci,[2,1] Daniele Teresi,[3,2] and Robert Ziegler[4]
[1]INFN, Sezione di Pisa, Largo Bruno Pontecorvo 3, I-56127 Pisa, Italy
[2]Dipartimento di Fisica "E. Fermi", Università di Pisa, Largo Bruno Pontecorvo 3, I-56127 Pisa, Italy
[3]CERN, Theoretical Physics Department, 1211 Geneva 23, Switzerland
[4]Institut für Theoretische Teilchenphysik, Karlsruhe Institute of Technology, Karlsruhe, Germany
(Dated: November 19, 2020)

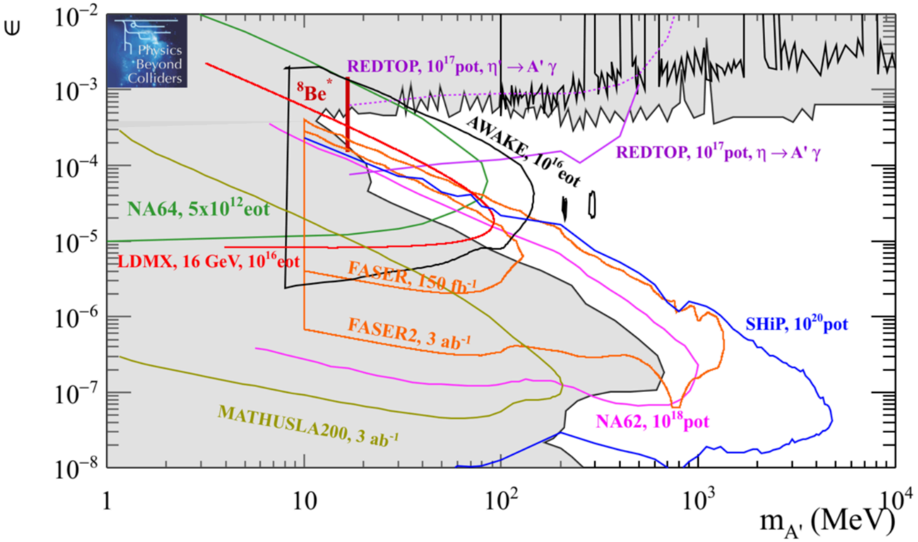



Finally, we stress that, if the excess will be confirmed by future data, the explanation presented here can be investigated at colliders by searching for the ALP mediator $a$ coupled to electrons, since the allowed parameter region is not far from the existing collider limits. Indeed planned

experiments such as PADME [29], VEPP-3 [30, 31] and DarkLight [32, 33] will probe the entire region of interest.

Sapienza Università di Roma



ε
Physics Beyond Colliders
REDTOP, 10^17 pot, η' → A' γ
REDTOP, 10^17 pot, η → A' γ
8Be*
AWAKE, 10^16 eot
NA64, 5x10^12 eot
LDMX, 16 GeV, 10^16 eot
FASER, 150 fb^-1
FASER2, 3 ab^-1
SHiP, 10^20 pot
NA62, 10^18 pot
MATHUSLA200, 3 ab^-1
m_A' (MeV)