The Pool

$\mu^- \rightarrow e^+ (x) \rightarrow \mu^+ (X)$

B.Ohayon MuX for CKM

F.Wauters μ^- and APV

A.Knecht μ^- conversion

L.Gerchow μ^- elem. analysis

A.Antognini e^+ beam

A.Papa dark matter with e^+

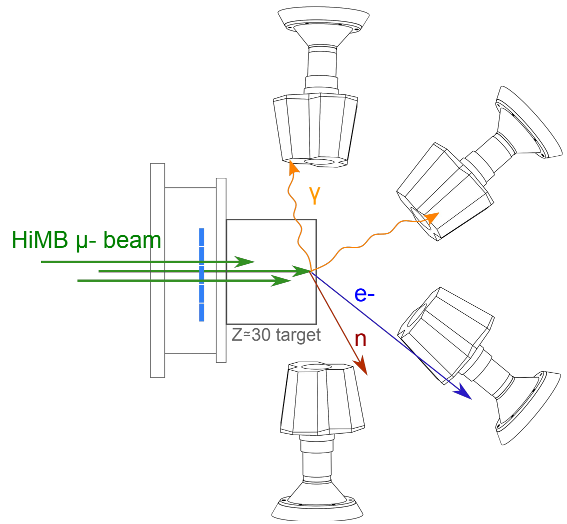
A.Papa μ^+ and ALPS

U.Langenegger M $\leftrightarrow$ Mbar

S.Davidson μ^+ decays

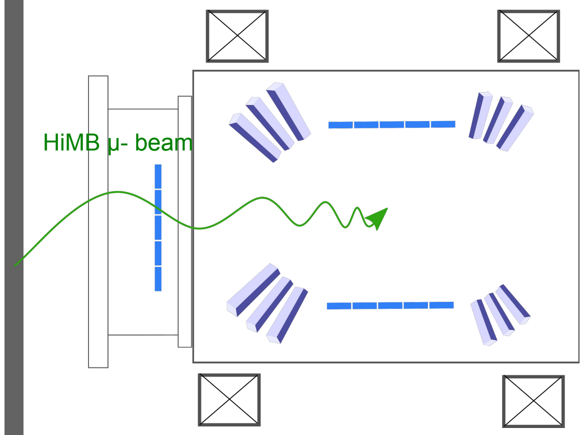
μAPV with HiMB

and other precision muonic atom experiments



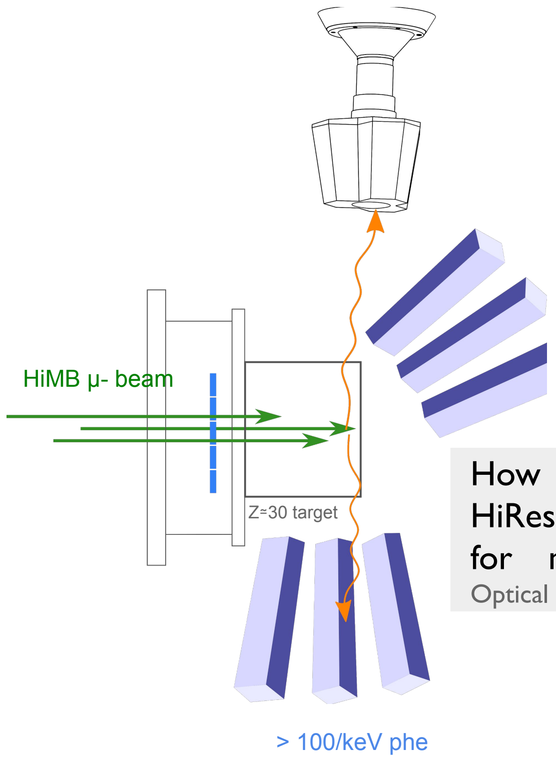
- HPGe detectors have both high resolution and efficiency
- n-dose and rate limited
- > πE1 intensities are beneficial

With a HPGe-array, one can **not** fully exploit HiMB intensities.



- Z = 5-10 APV experiments have a potential < SM reach
- Building on work of L. Simons and Co
- Need to suppress Auger transitions
- Need to develop additional techniques to differentiate 2s1s from 2p1s X-rays, such as K-edge absorption

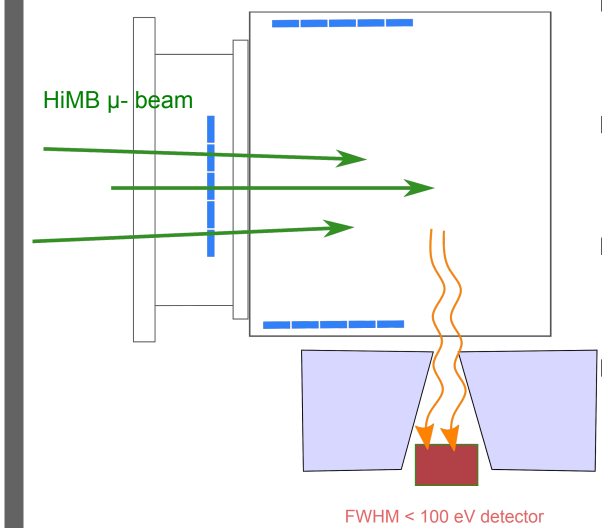
Can we stop a HiMB beam in a low pressure gas target?



- A coincidence experiment with a close scintillator and a HPGe far detector has a 10^{-3} reach
- A pure high-resolution has a potential 10^{-4} reach
- SM μAPV ≤ 10^{-4}

How well can current and future HiRes scintillator detectors perform for muonic X-ray measurements?
Optical Materials: X 1 (2019) 100021

Solid ≥O(SM) amplitude APV experiment motivation?



- < 100 eV resolution can separate in energy most transitions of interest
- For Z≈5, 10^{-3} precision is worth-while (1 cm2 at 1m for 100 days)
- Other high-resolution measurements such as BSQED? arXiv:2011.09715
- Can we efficiently operate new detector technologies such as cryogenic microcalorimeter NIMA **770**, 203-210 (2015)

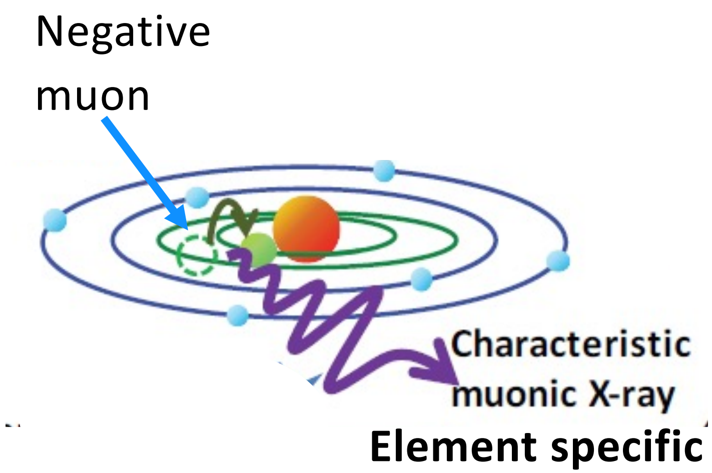
Should we bring high-resolution (<100 eV) X-ray spectroscopy techniques to muonic X-ray studies @ PSI?

Conclusions muon conversion at HIMB

- Mu2e and COMET will perform their measurements with expected muon rates of around 1e10 μ^-/s
- They will improve the sensitivity over SINDRUM II by a factor 10^4 compared to muon conversion at HIMB that could improve the sensitivity at most by a factor 100
- Changes in expected branching ratio as a function of Z are on the level of <4

- Conclusion:
  - It is probably not worthwhile to pursue a muon conversion experiment at HIMB, if Mu2e and COMET reach their targeted sensitivity
  - However, if a signal is observed by either Mu2e or COMET at a relatively high branching ratio such a measurement at PSI might become again attractive

Negative Muons Elemental Analysis

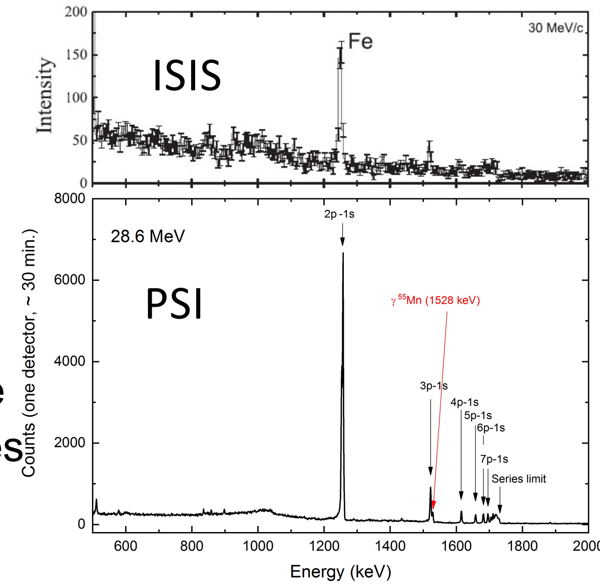


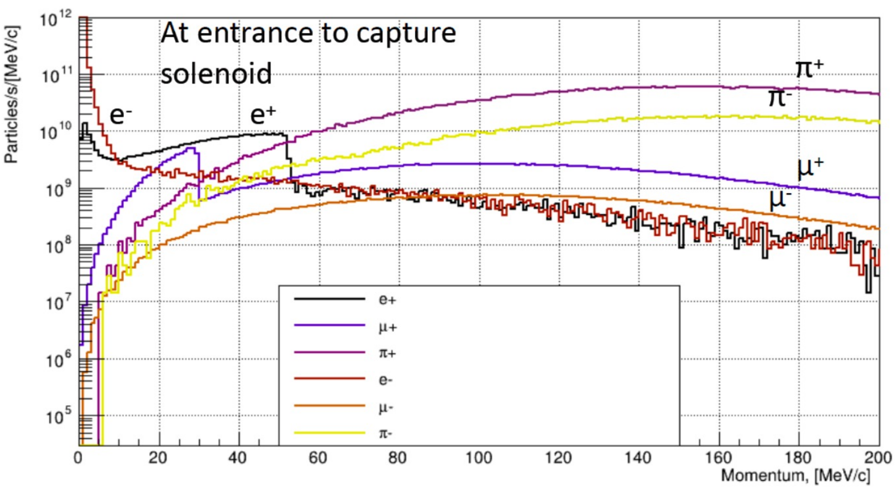
PSI best place in the world for MIXE

CW-beam, high rates

ISIS (pulsed) vs PSI (cw)

Ideal technique to measure very rare / valuable samples





HIMBs offers

- Higher μ- rates for reduced DAQ times

- Moreover, the capture solenoid could allow a **parasitic additional μ- beamline**

Pos.	Menge	Einheit	Sachnummer	Benennung / Merkmale
4	1	Stk	RT81.21.0020	ZUS. STRAHLLINUE MUH3 BERG
3	1	Stk	RT81.21.0010	ZUS. STRAHLLINIE MUH2 BERG
2	1	Stk	06.0.679	3D STRAHLLINIE HIPA LAYOUT
1	1	Stk	01.0.1668	3D BODEN /ABSCHIRMUNG

Fremdnummer:

Aend. a b c d
Aend. e f g h

Gezeichnet	29.10.2020	RAUBER
Geprueft		

Massst. 1:40

Anlage MUH2+MUH3 BERG

Baugruppe
HIMB KONZEPT BERG

Ersetzt durch
Ersatz fuer
Stueckl. Nr.
Zusammenst.Nr.

Blatt Nr. 1/1

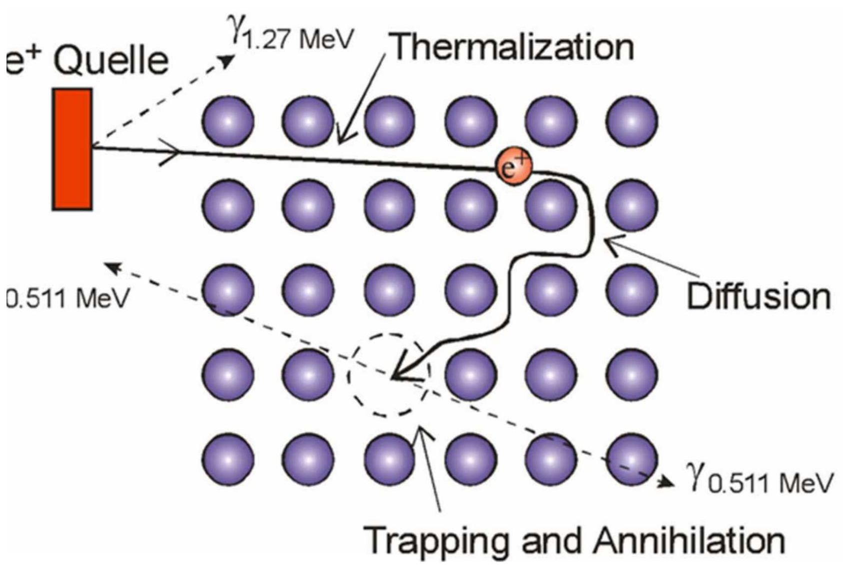
Paul Scherrer Institut

LAY. HIMB TARGET VERTEX 42331

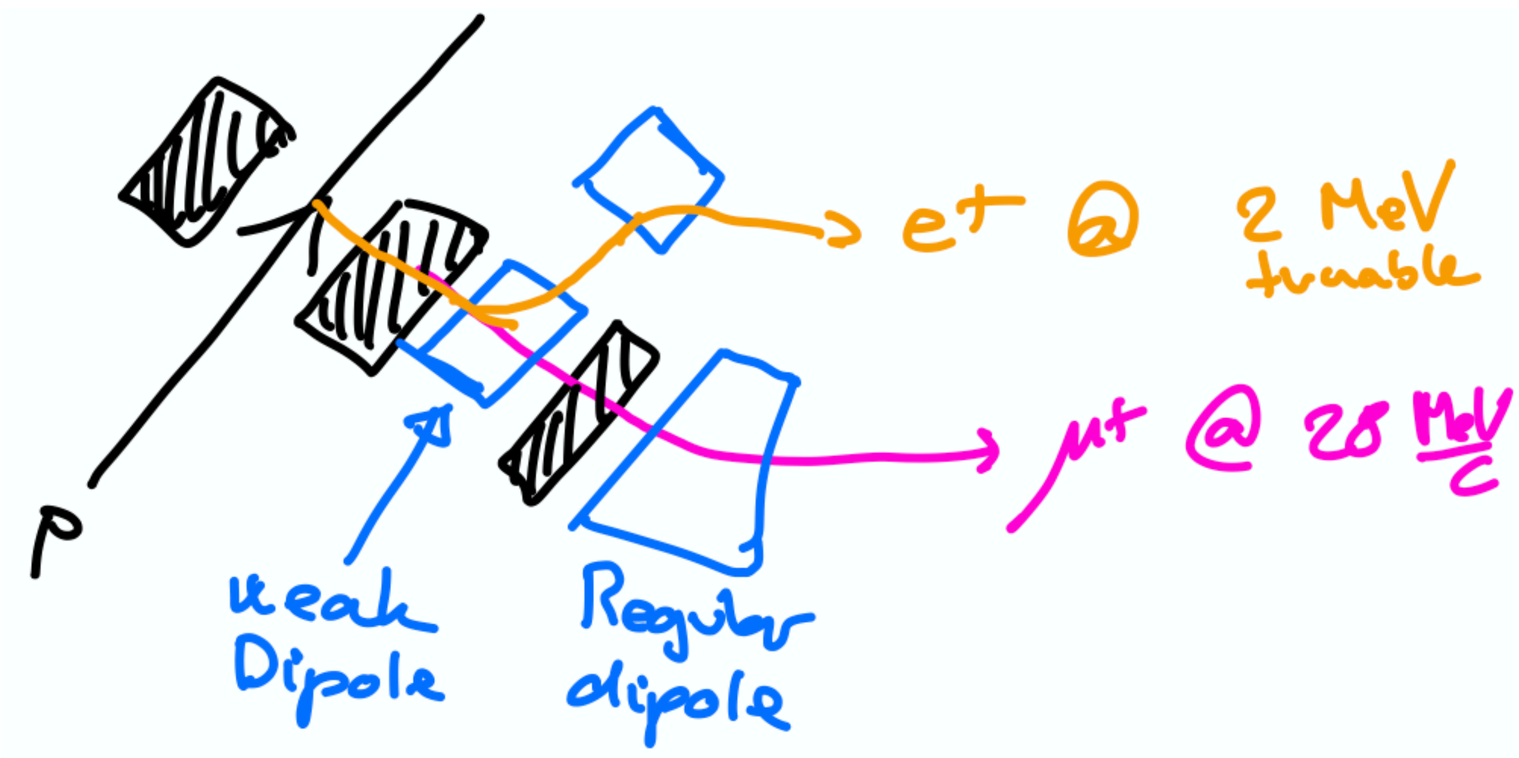
0-RT81.0.0001

CATIA

Positrons for material science?

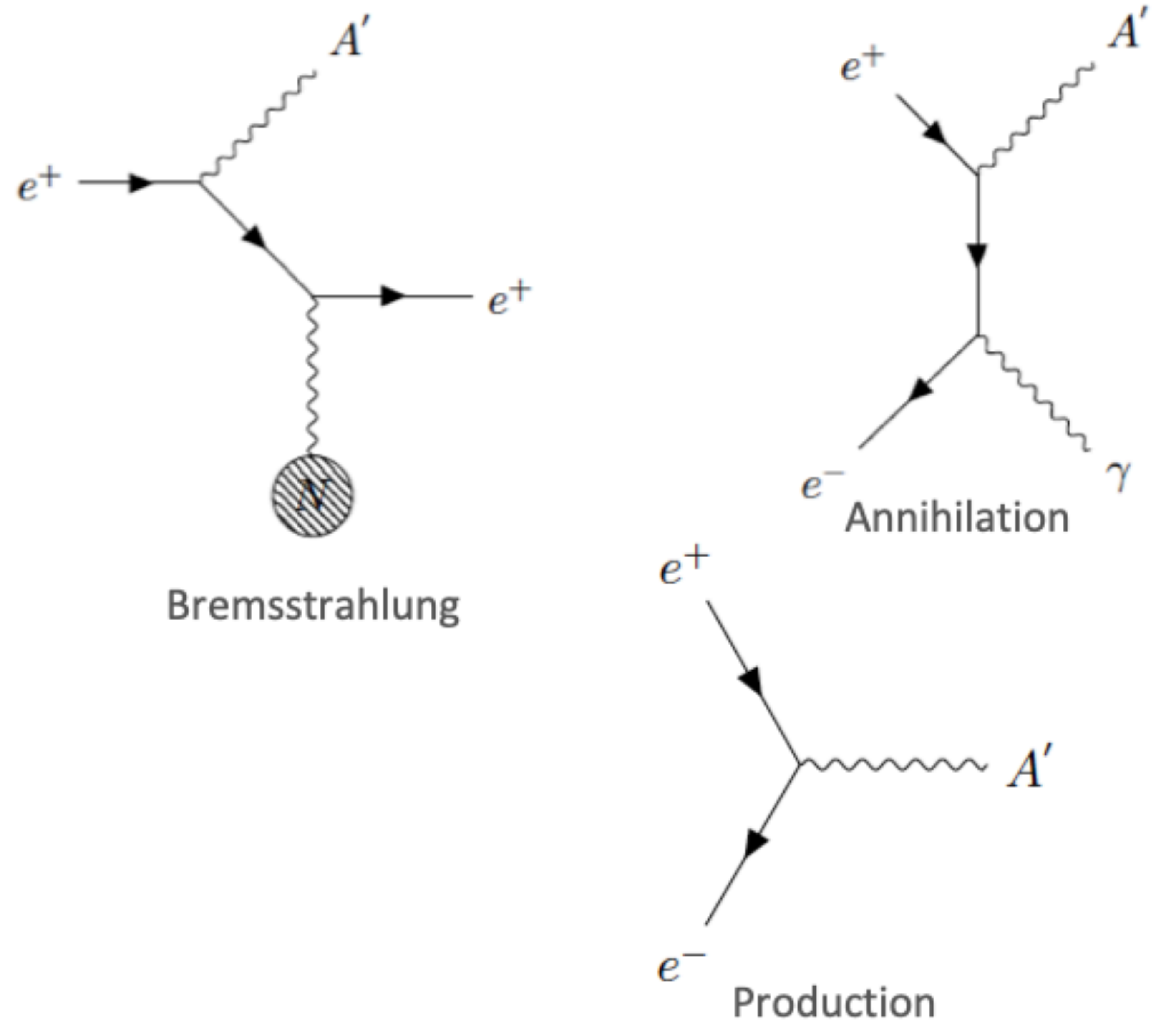


- The positron is a very sensitive probe of nm-sized vacancies
- Can PSI have a competitive MeV-energy beam that can operate parasitically to the muon beamline?
- Very very very probably NOT
- But would be interesting to keep in mind when performing the HiMB simulations

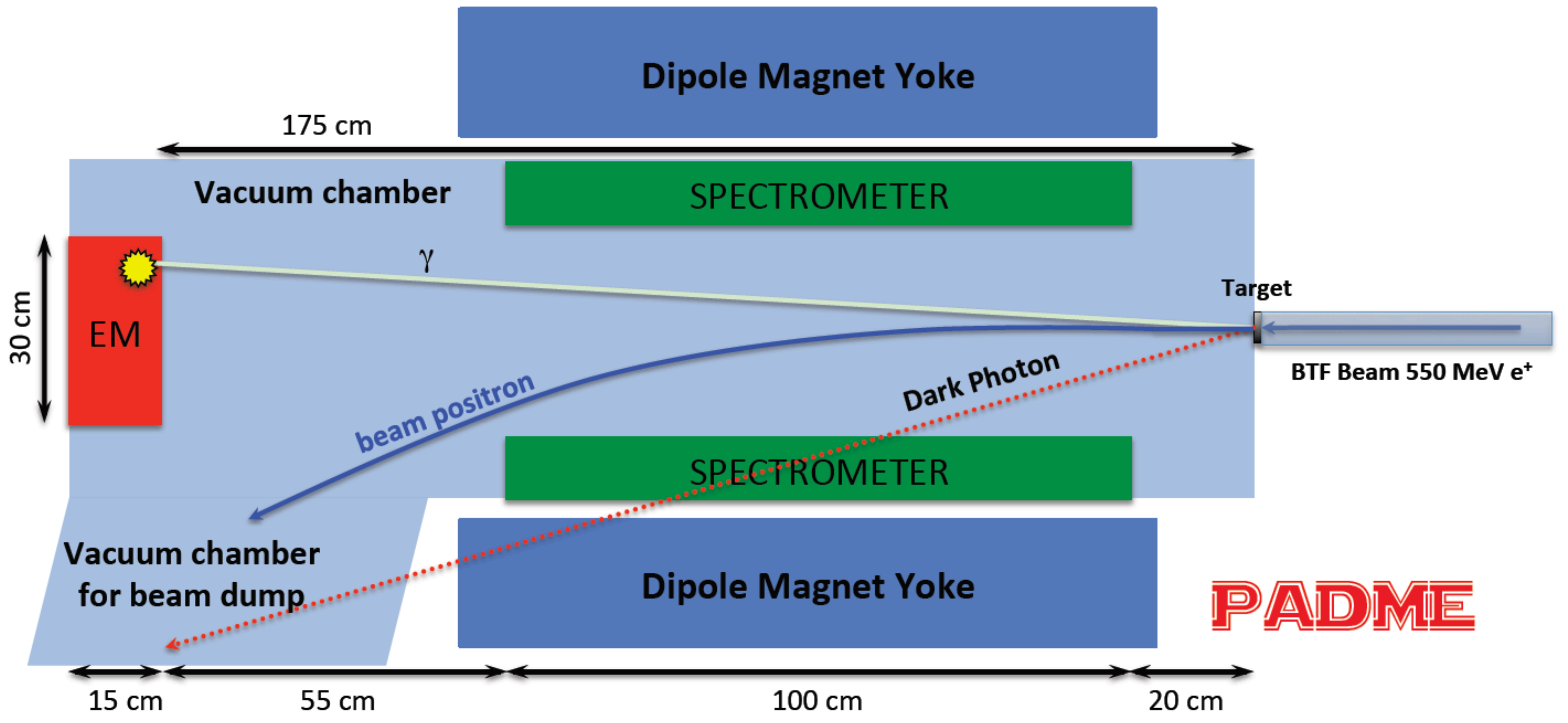


Exploiting positron beam@HiMB for Dark Matter searches

- Low energy and intense positron beams could be attractive for Dark Matter searches to complement the low mass dark matter region (mainly studied via astrophysical searches) to address both invisible (A’ —> X X) and visible (in this case A’ —> e+/e- pair) Dark Matter decay signatures
- Experimental setup based on established technologies looks able to address the experimental requirements
- Dedicated MC simulations (with emphasis also on the beam side) must be performed to assess the final achievable sensitivities with dedicated/complemented experimental setup

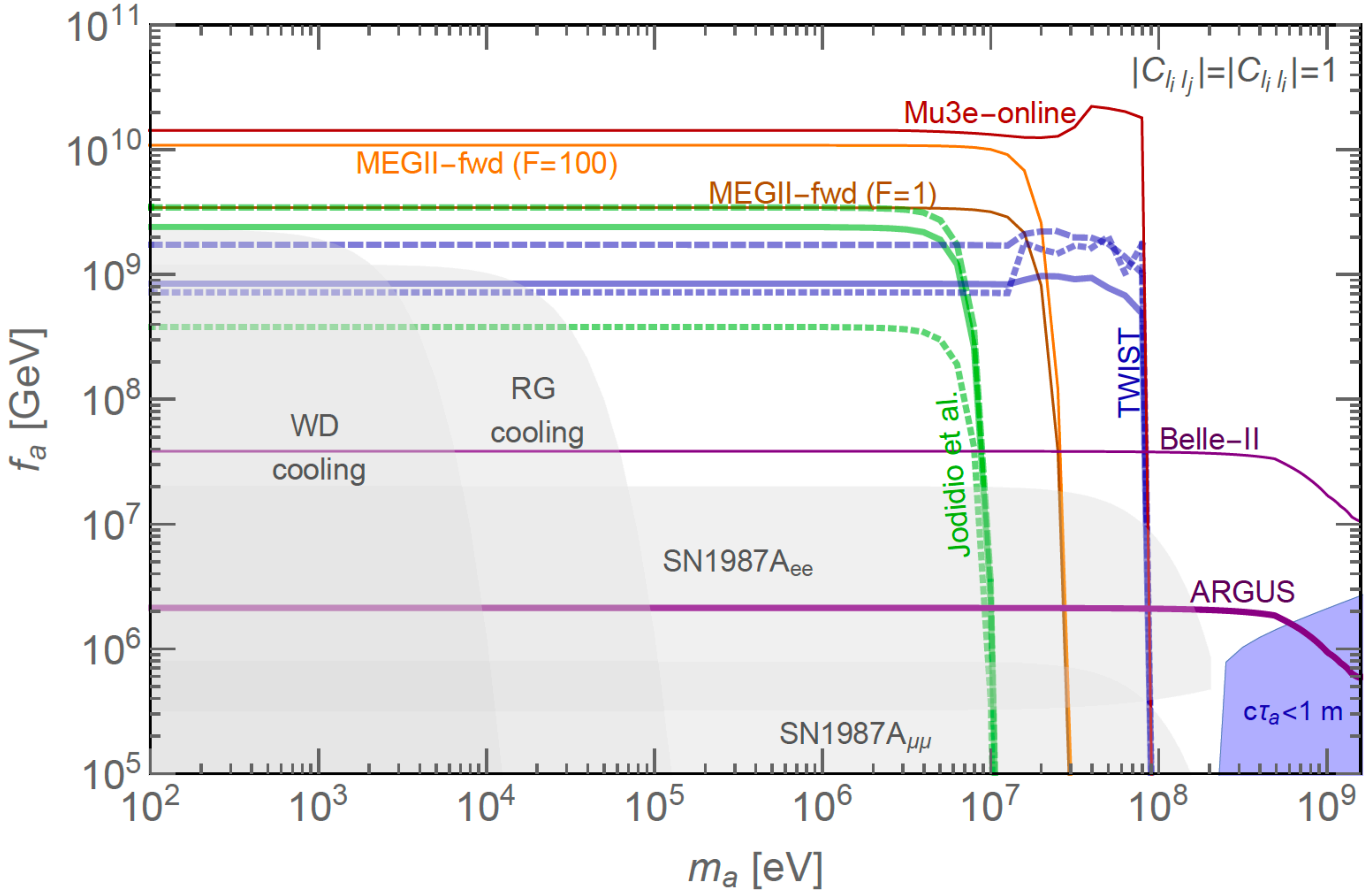


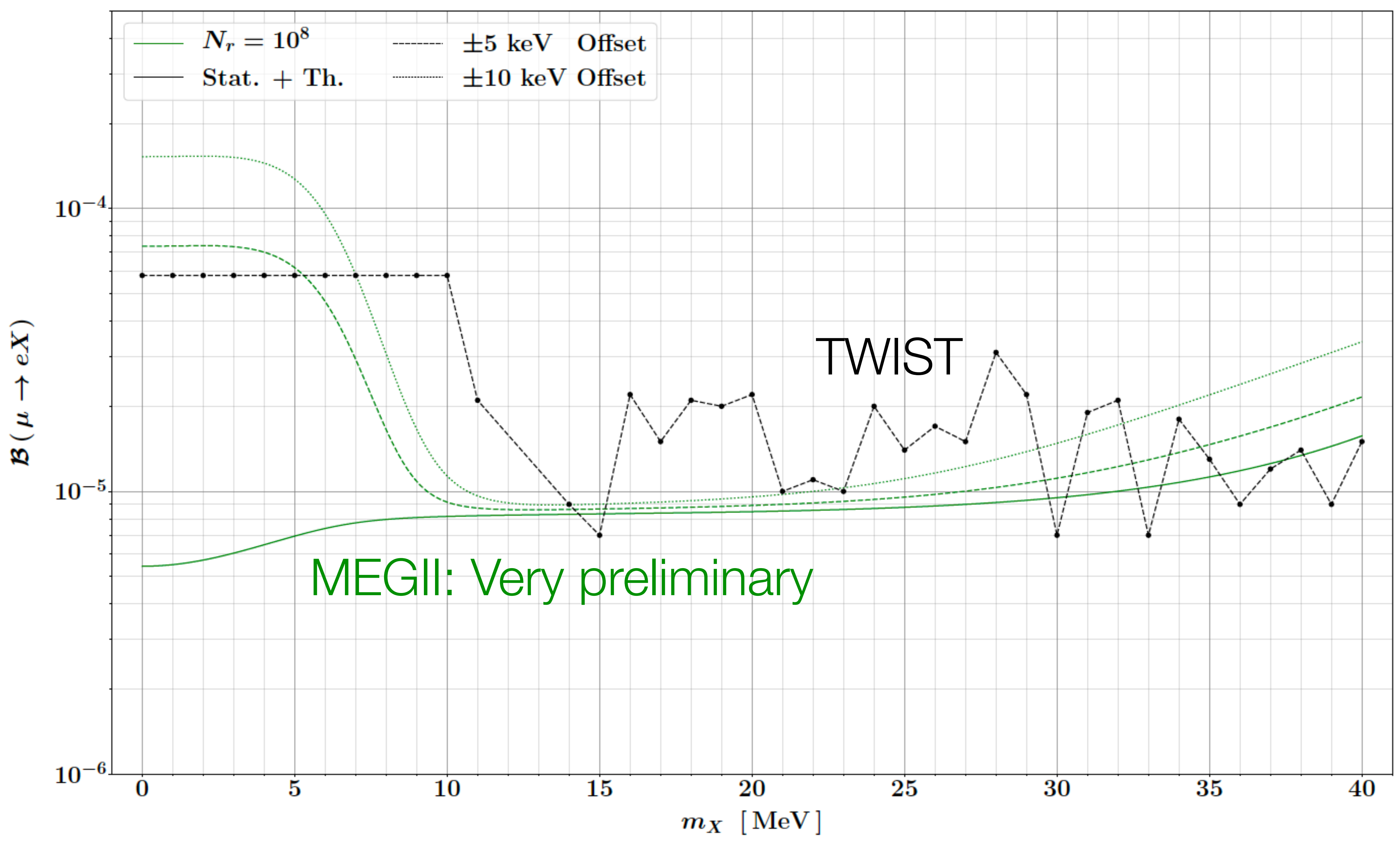
Inspired by the PADME experiment



ALP searches @HiMB

- The search for ALP clearly improves with statistics (and then will benefit from HiMB)
- In order to really take advantage for the high muon beam rates not only more performing detectors are requested (and in principle these will come with the future generation of MEG/Mu3e experiments) but also the systematics must be kept under control increasing the difficulties of such a kind of searches and pointing towards “dedicated” experimental setup
- Precise theoretical inputs of the “SM” backgrounds (i.e. standard muon decay at NNLO+LL) are crucial for the incoming sensitivities
- Detailed MC simulations are foreseen with the incoming MEGII and Mu3e apparatuses as well as with some dedicated/complementary setup

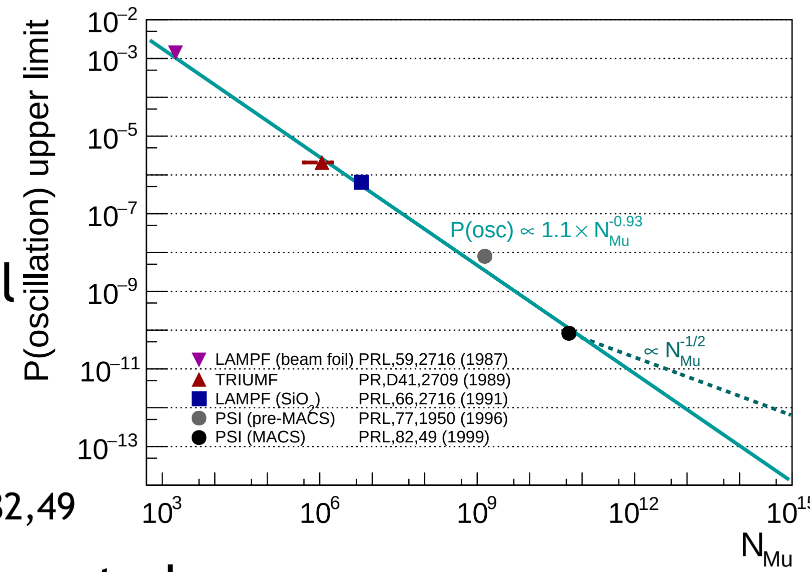




Mu$\overline{\text{Mu}}$ oscillations?

- Best result: MACS/PSI (1998)
  - ▷ πE5 with $8 \times 10^6 \mu^+/\,\text{s}$ at $p = 26\,\text{MeV}$
  - ▷ 280 μm scintillator + 270 μm Mylar degr.
  - ▷ SiO_2 powder target $8\,\text{mg}/\,\text{cm}^2$ on 25 μm Al
    replaced twice/week
  - ▷ $N_{\text{Mu}} = 5.6 \times 10^{10}$ in vacuo

  $\rightarrow$ $\mathcal{P}_{\text{Mu}\overline{\text{Mu}}}(0.1\,\text{T}) < 8.3 \times 10^{-11}$ (90% CL) PRL,82,49
  with 1 event observed/1.7 background expected



- Which HiMB setup?
  - ▷ what minimum efficiency$\times$ acceptance ($\equiv \varepsilon_{\text{total}}$) to improve MACS result by one order of magnitude in a week of beam-time?
    - HIMB-3/5: $10^{10}\mu^+/\,\text{s}$ at $p_{\mu^+} = 28\,\text{MeV}$ $\varepsilon_{\text{total}} > 3 \times 10^{-4}$
    - HIMB-cool: $10^{7}\mu^+/\,\text{s}$ at $p_{\mu^+} = 10\,\text{keV}$ $\varepsilon_{\text{total}} > 3 \times 10^{-1}$ (unrealistic!)

  $\rightarrow$ decay length/volume (enough time for oscillations)?
  $\rightarrow$ background level (Bhabha/rare decays/punch-through)?

$\Rightarrow$ To be studied further with GEANT4 setup

Summary: with $10^{10}\mu$/sec, look for NP in "SM" μ decays?

$\mu \to e(+invisible) \sim 10^{10}$/sec, $\mu \to e\gamma(+inv.) \sim 600$/sec, $\mu \to 3e(+inv) \sim 3 \cdot 10^{-5}$/sec

theorist: opportunity! improve Michel, +look for feebly cpled ALPs, Z', ν_s, etc !!
exptalist: how to cut all that background...

the theory wishlist

- $\mu \to eX$ at MEG forward (BR$\lesssim 2 - 60 \times 10^{-6}$ TRIUMF)
- $\mu \to e\nu\bar{\nu}$ improved Michel parameters (heavy NP,$\mu \to e\nu\bar{\nu} + X$ for cosmo?)
- $\mu \to 3e+$ invisible (new boson cpled to e?) (see eg, Phys Beyond Coll. 1901.09966
- $\mu \to e\gamma+$ invisible : SVP look her too ... (BR$\lesssim 10^{-9}$ CrystalBox)
- ? everything :)

maybe theorists could do some work too:

- where to measure what, to have best sensitivity to which scenario?

(generalised Michel-like parameters for all SM-like decays?)

- (Invisibles who talk to νs (for H_0 tension): what interactions with e, μ?)

random thought: $\mu A \to eA$ will measure the endpt spectrum of their electron; maybe look for massive NP in μ^- decays, and "massless" in μ^+ decays?