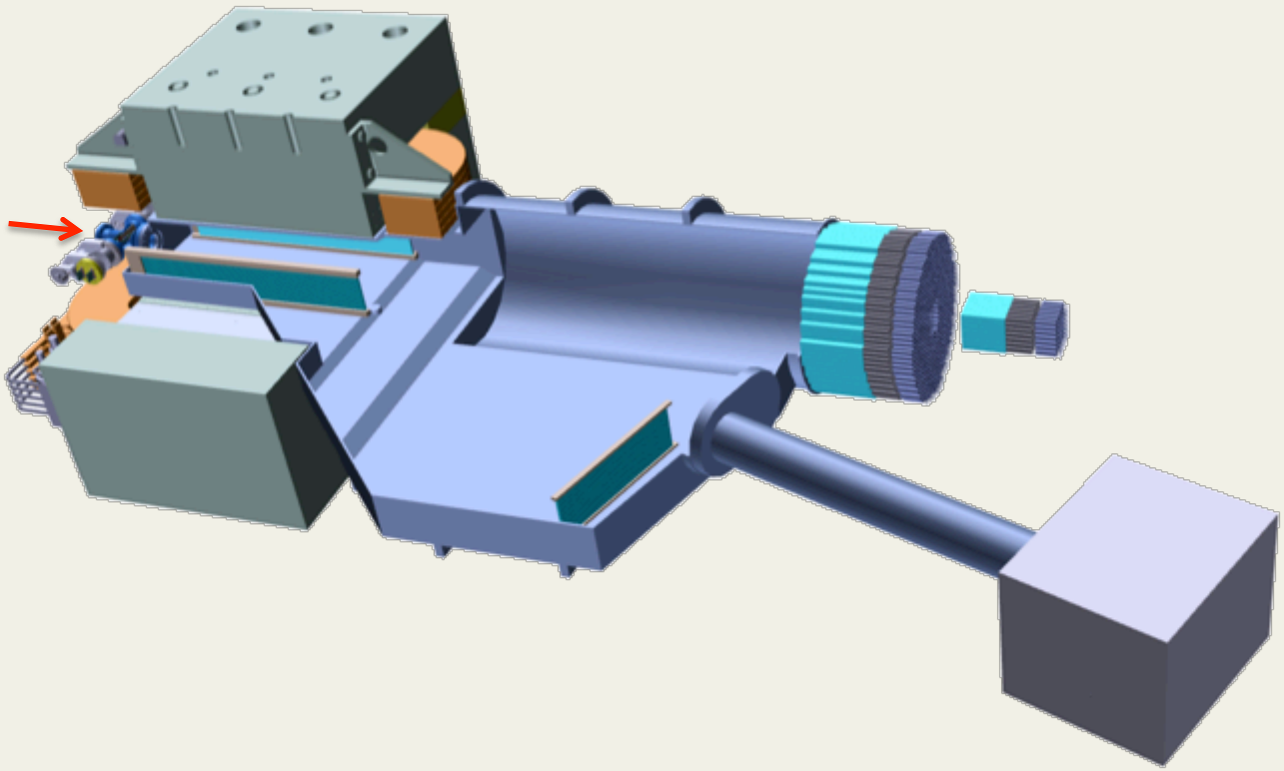
The PADME experiment at DAFNE LINAC

Paolo Valente - INFN Roma



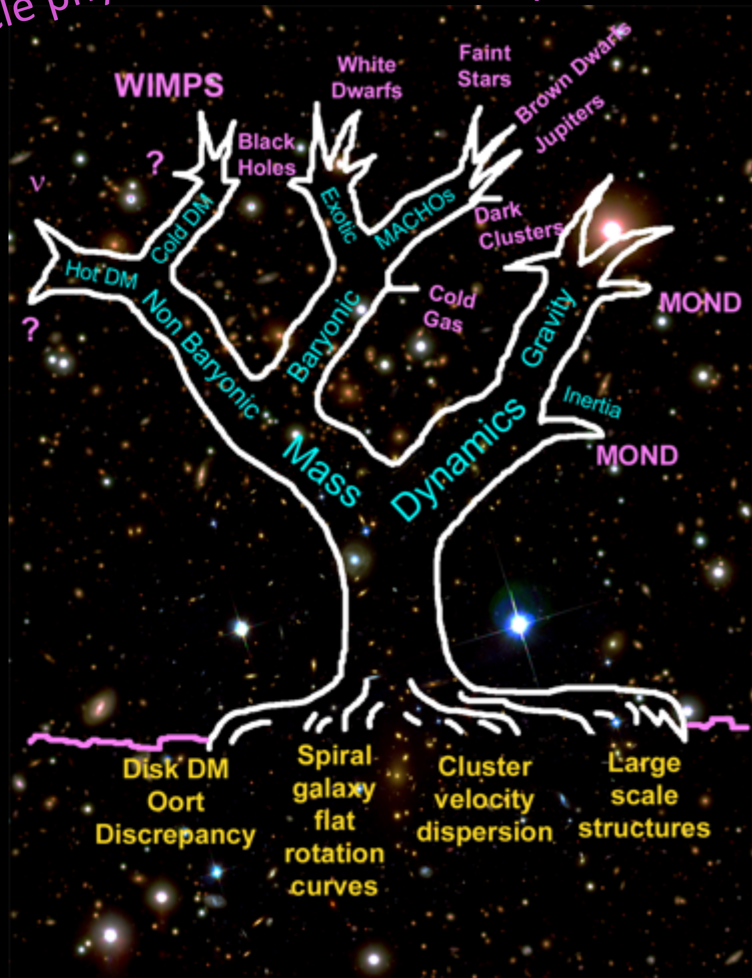
The dark matter problem

Original drawing by
Stacy McGaugh
(1995)

Particle physics

Astrophysics

Modify gravity



Several hypothesized solutions

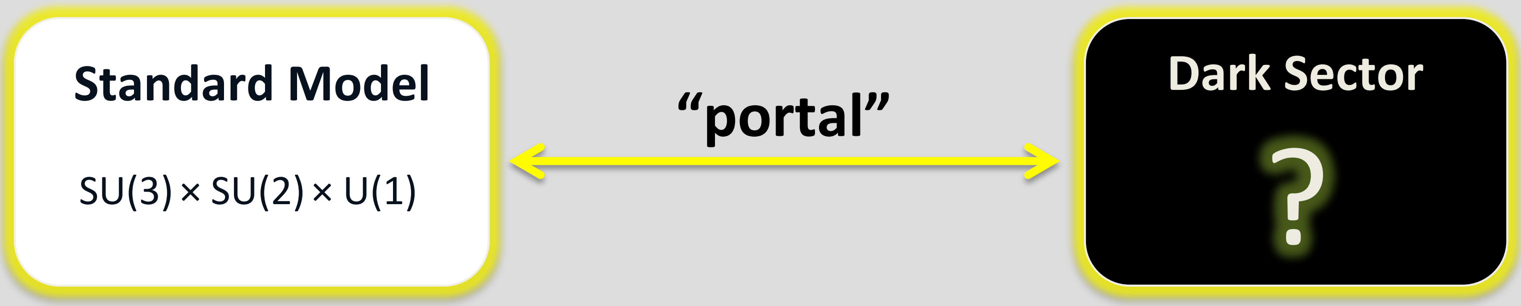
Deep roots in strong empirical observations

Particle physics is **not the only** possible solution

However…

Portals to a hidden sector

A **new, very weak interaction**, connecting the ordinary matter with a (almost) hidden sector (by the smallness of the coupling constant, not by the mass scale)

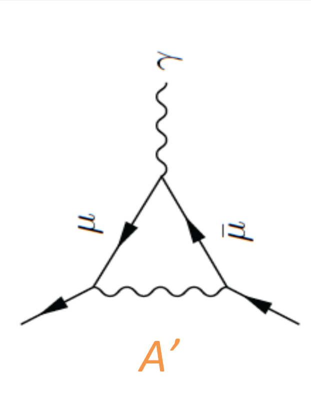


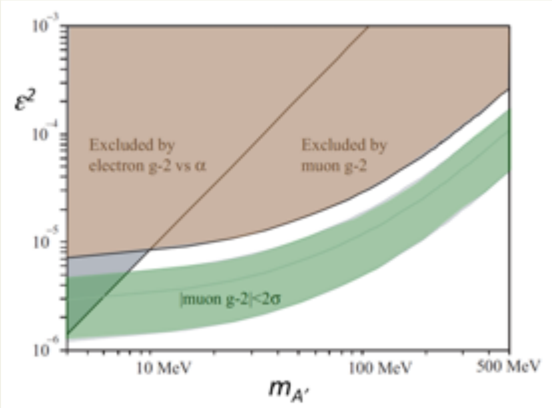
Not so many possibilities:

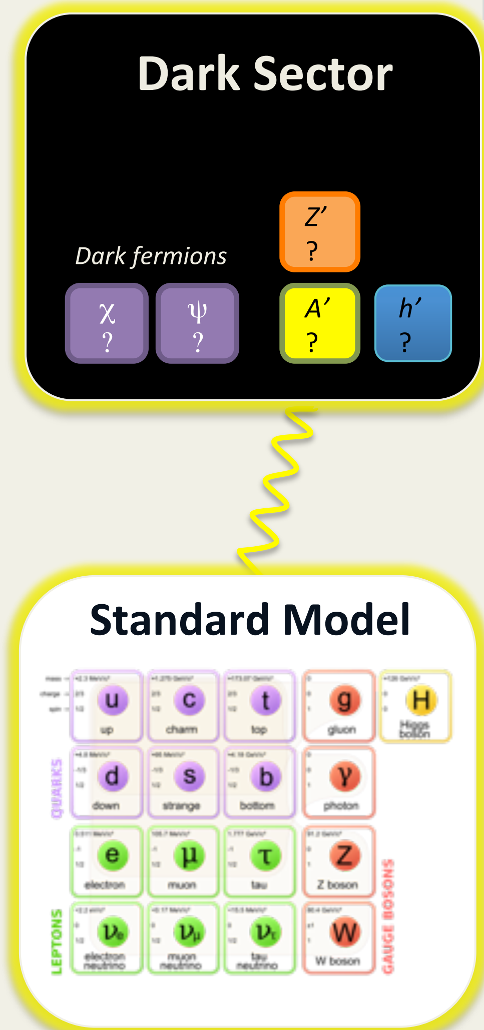
vector	$\frac{1}{2}\epsilon F^{Y}_{\mu\nu}F'^{\mu\nu}$	**dark photon**
Higgs	$\epsilon_h \lvert h\rvert^2 \lvert\phi\rvert^2$	dark scalar
neutrino	$\epsilon_\nu (hL)\psi$	sterile neutrino
axion	$\frac{1}{f_a} a F_{\mu\nu}\tilde{F}^{\mu\nu}$	ALPs

Dark photon

- The simplest hidden sector model just introduces one **extra U(1) gauge symmetry** and a corresponding **gauge boson**: the “dark photon" or U-boson or heavy photon (γ' or $\boldsymbol{A'}$)
- An extra U(1) symmetry is implied in many extensions of the SM, some classes of string theory, etc.
- Appealing explanation of the **muon g-2 discrepancy** in the **1 MeV – 1 GeV** mass range

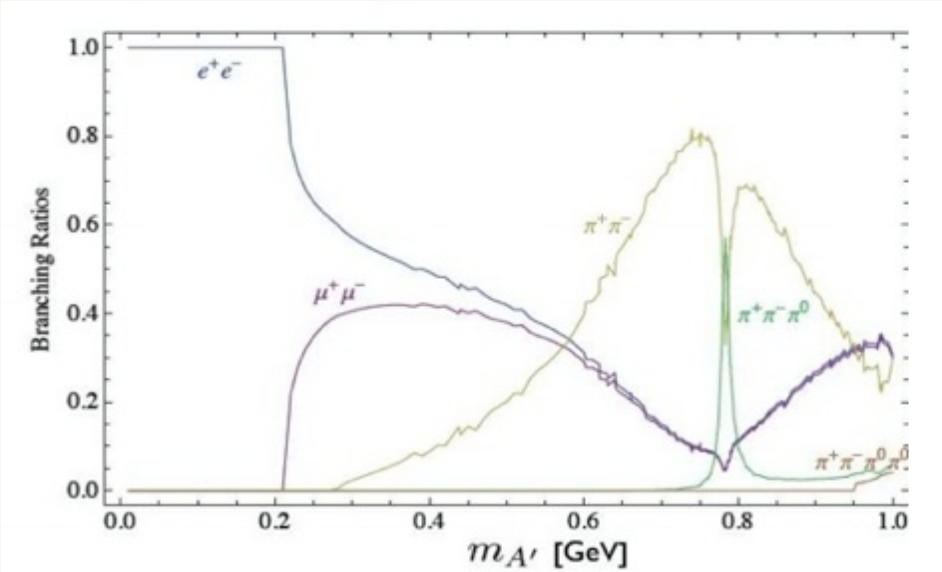






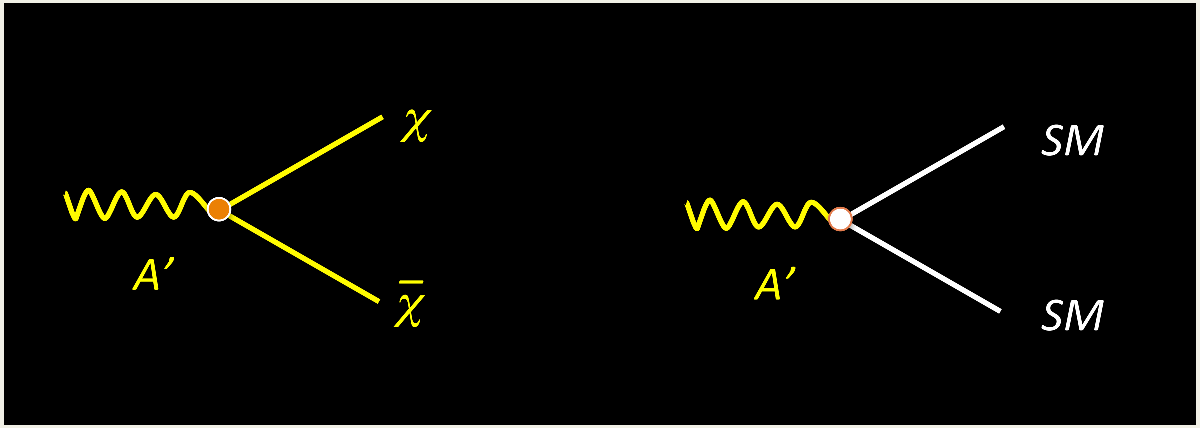
Dark photon decays: "visible"

- Assume that **no additional lighter state** exists in the dark sector with $m_\chi < m_{A'}/2$
- *A'* couples to SM particles **through kinetic mixing only** (with **universal coupling εq**)
- For $m_{A'} < 2\, m_\mu$ only decays to e^+e^-



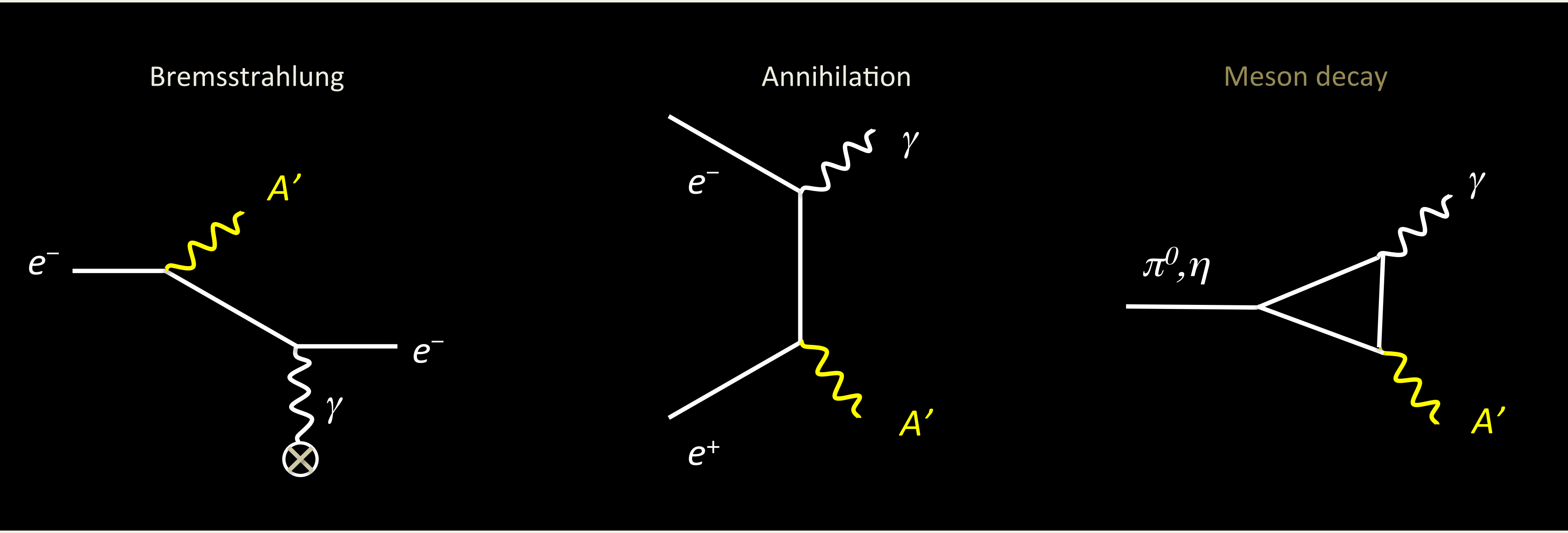
Dark photon decays: "invisible"

- If at least one χ state exists in the dark sector with **U(1) charge q_U** and coupling constant g_U and $m_\chi < m_{A'}/2$, the coupling to the A' will be: $q_U g_U$
- $A' \to \chi\chi$ will be dominant wrt to the visible decays for $\alpha_D > \alpha$, i.e. for $|q_U g_U| > \varepsilon e$



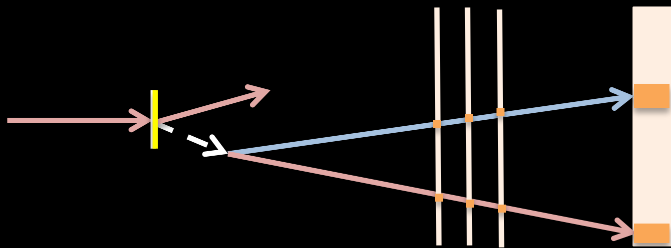
Dark photon production

In any electromagnetic interaction, just replace one γ with *A'*, replacing α with $\varepsilon^2\alpha$



Dark photon experiments/electrons

- We have to add experiments using meson decays: $\eta,\pi^0 \rightarrow \gamma\, \boldsymbol{A'}$ with dark photon “visibile” decay;
- Or A' coming from dark Higgs decays

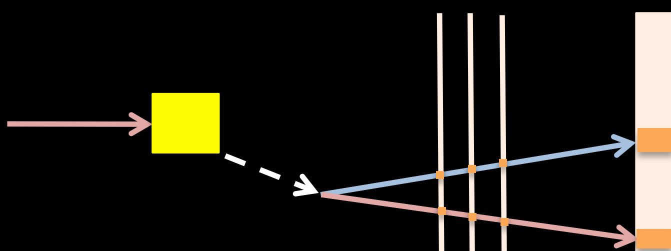


$e^- Z \rightarrow e^- Z A'$

$A' \rightarrow e^+ e^-$

Thin target, visible decays

(APEX, HPS, A1)

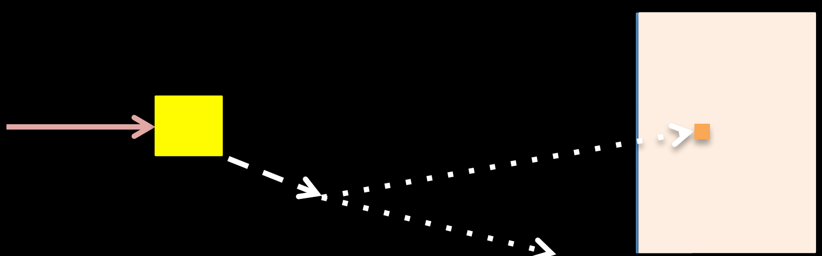


$e^- Z \rightarrow e^- Z A'$

$A' \rightarrow e^+ e^-$

Dump, visible decays

(E-137, E-141, E-774, Orsay, …)



$e^- Z \rightarrow e^- Z A'$

$A' \rightarrow \chi\chi$

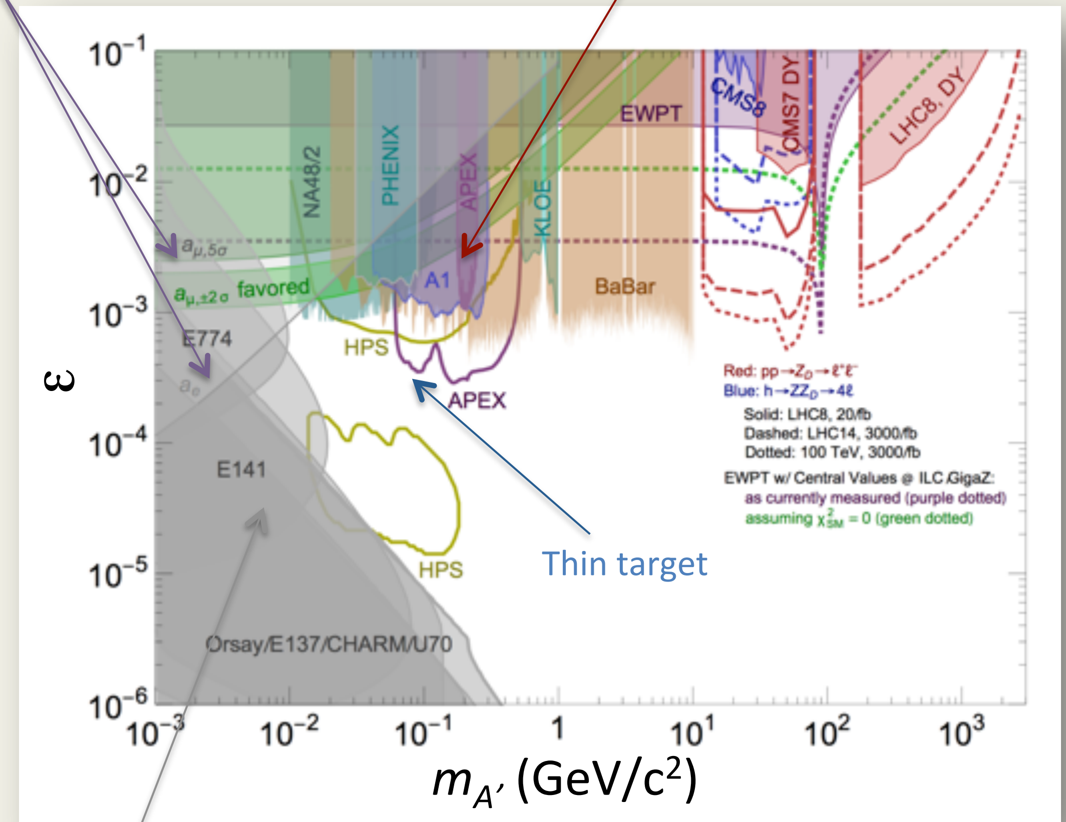
Dump, invisible decays, recoil

(BDX)

Decay to visible states (e^+e^-)

Indirect limits from a_μ and a_e

Thin target or meson decays, $A' \rightarrow$ visible



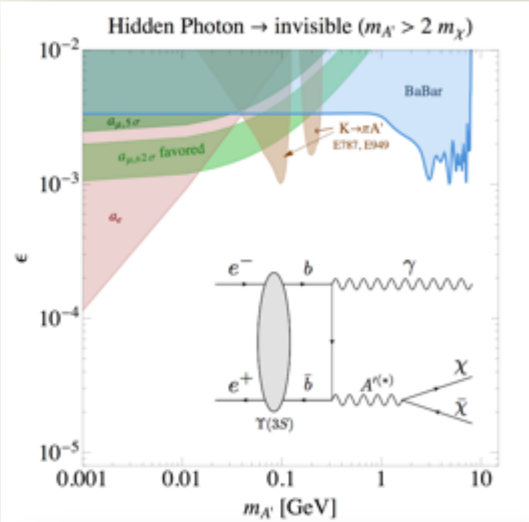
Re-analysis of electron *beam-dump* experiments

- Bremsstrahlung on thick target (dump experiments)
  - Requires the dark photon to decay beyond the dump
- Bremsstrahlung on thin target
  - Look for e^+e^- excess over Standard Model background (**bump hunt**, **displaced vertices**)
  - Requires $m_{A'} > 2m_e$
- Meson decays (collider experiment)
  - Requires coupling to quarks

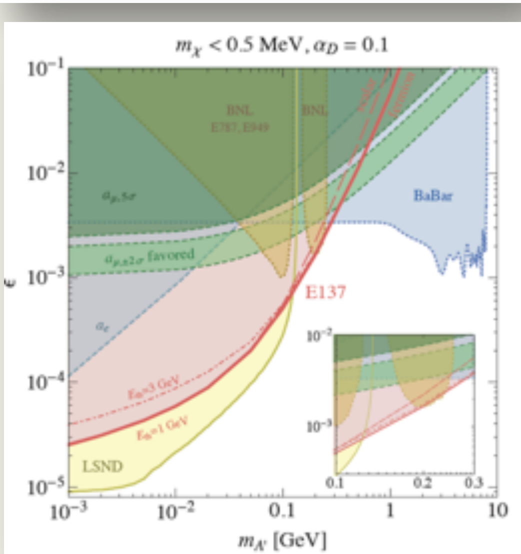
Practically, all the $(g\text{-}2)_\mu$ favored band already excluded

Still large interest for excluding the uncovered parameter space

Decay to invisible states

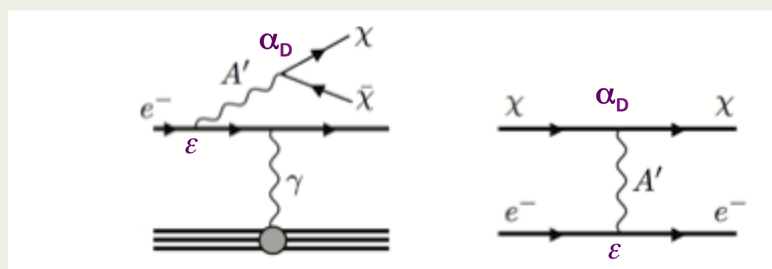


Babar '08 ArXiv 0808.0017
Search for Invisible Decays of a Light Scalar in Radiative Transitions $\Upsilon_{3S} \to \gamma A'$



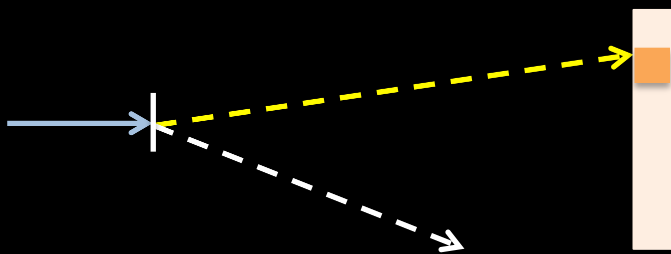
- **Direct searches** for *A'* invisible decays only depend on ε^2 and $m_{A'}$
- **No assumptions on coupling to quarks** (Both Υ_{3S} and $K^\pm$ results rely on that)

- χ **scattering** (indirect) searches instead depend on **4 parameters**: ε^2, $m_{A'}$ and m_χ, α_D

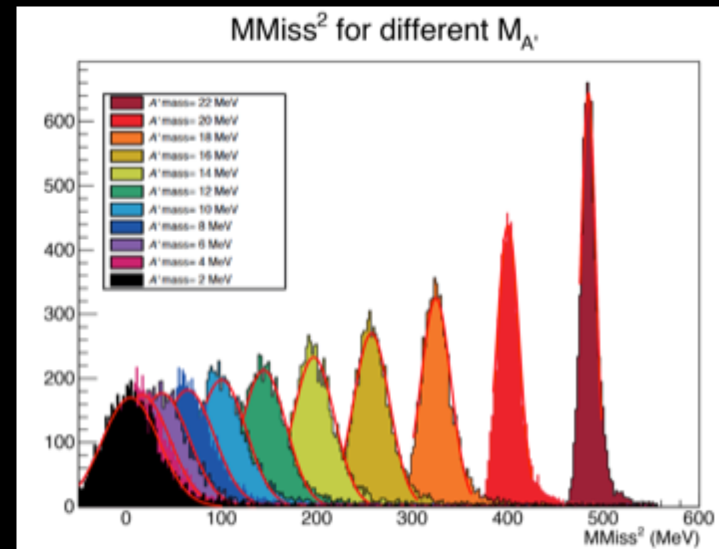


Missing mass approach

Look for **one photon** + **nothing else**
in positron on target electrons annihilations



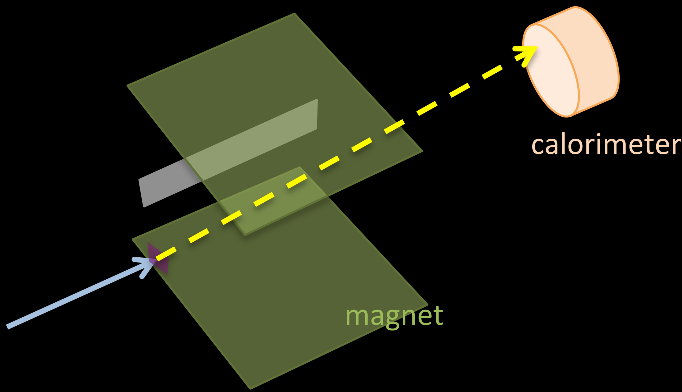
$e^+e^- \rightarrow \gamma\ (E_{miss})$



- Know e^+ beam **momentum and position**
  - Tunable intensity (in order to optimize annihilation vs. pile-up)
- Measure the recoil photon **position** and **energy**
- Calculate $M^2_{\text{miss}} = (\underline{\boldsymbol{P}}_{e+} + \underline{\boldsymbol{P}}_{e+} - \underline{\boldsymbol{P}}_{\gamma})^2$
  - Only minimal assumption: *A'* couples to leptons
  - **PADME** will limit the coupling of **any new light particle** produced in e^+e^- annihilations: scalars (*h'*), vectors (*A'*) or pseudoscalars (ALPs)

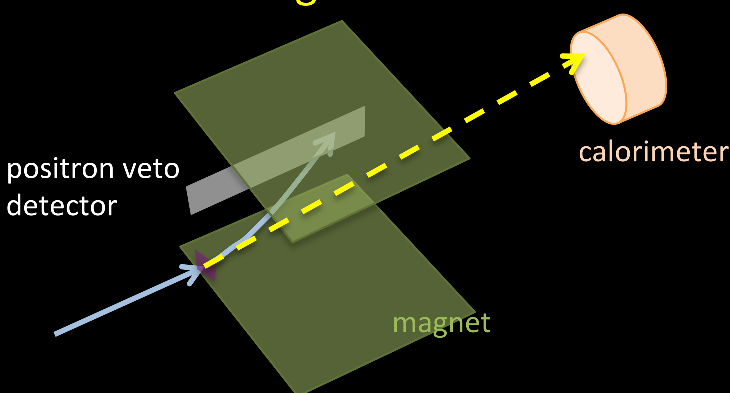
Signal and background

Dark photon event

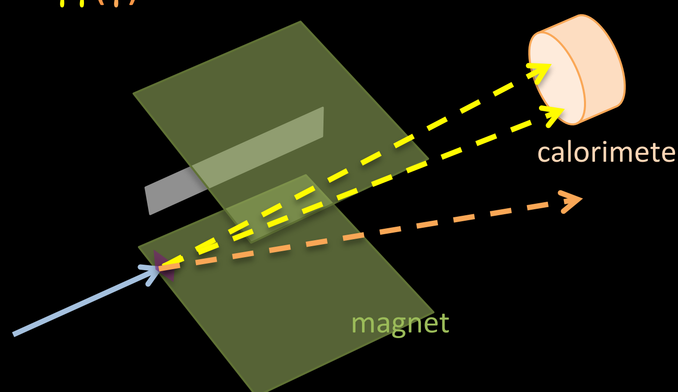


We need to fight the backgrounds:
one photon + something else, typically **one or more photons** going undetected:

Bremsstrahlung



$\gamma\gamma(\gamma)$



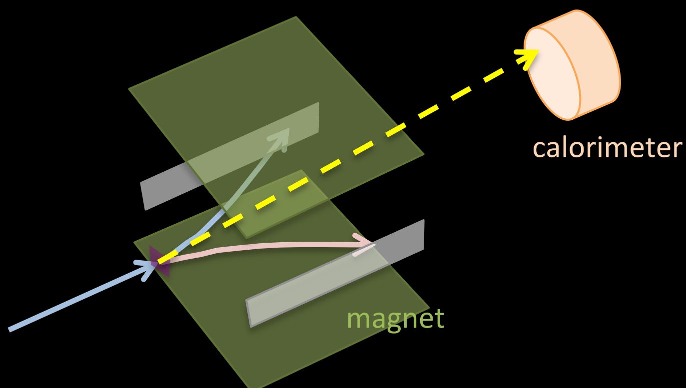
PADME-visible

- Of course, also visible decays can be searched for
- Present **PADME** detector has been optimized for the invisible search
- However, we foresee scintillator detectors both on the "electron" and "positron" side of the analyzing magnet to allow detection of decays to $\ell^+\ell^-$ pairs

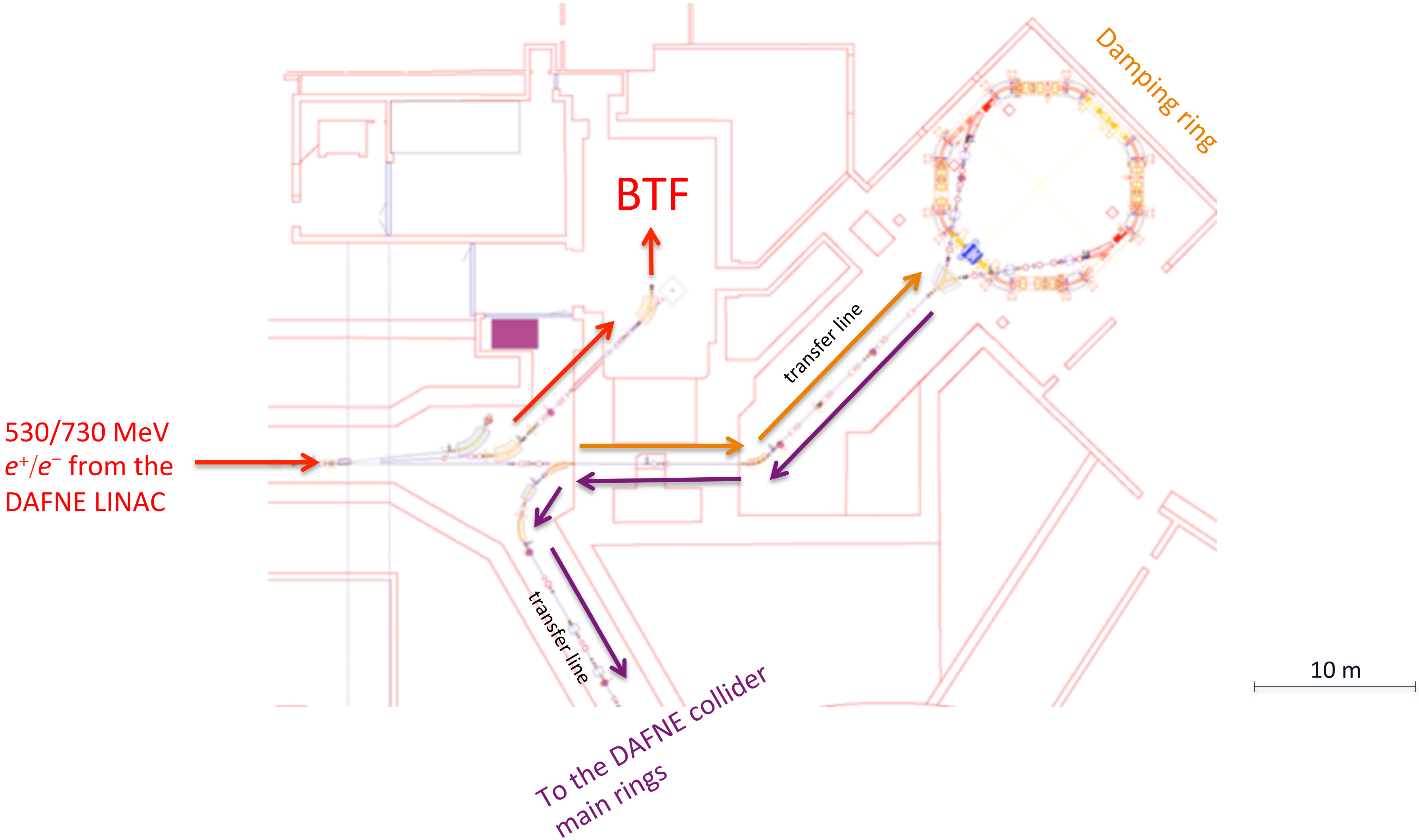
$e^+e^- \to \gamma A'$

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

Annihilation, visible decays



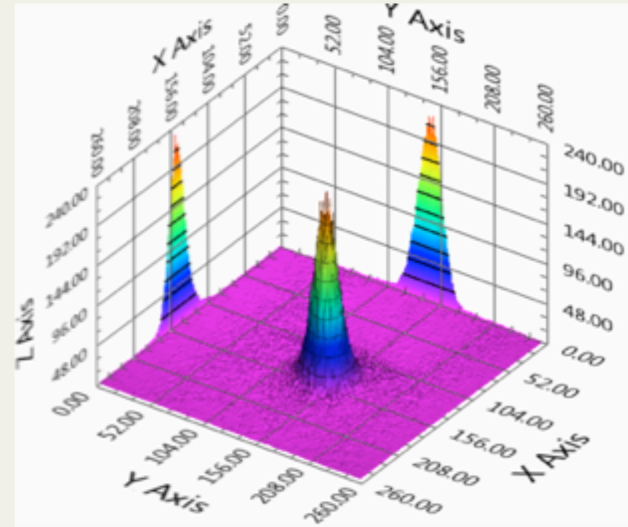
The beam test facility



BTF positron beam

- Energy spread **Δp/p ~1%**
- Beam spot: <**1 mm RMS**
- Divergence: **1 – 1.5 mrad**
- Beam position: **0.25 mm RMS**
- Pulse duration: **1.5 – 40 ns**
  - 10 ns during collider operations
- Two intensity ranges (with and without attenuation target)
  - **PADME will be limited by the pile-up anyhow**

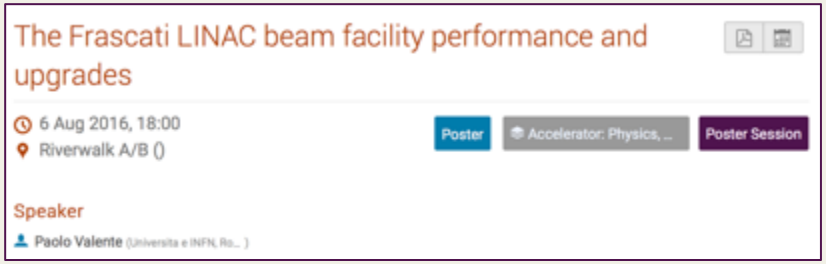
Beam spot after Be window



Beam parameters

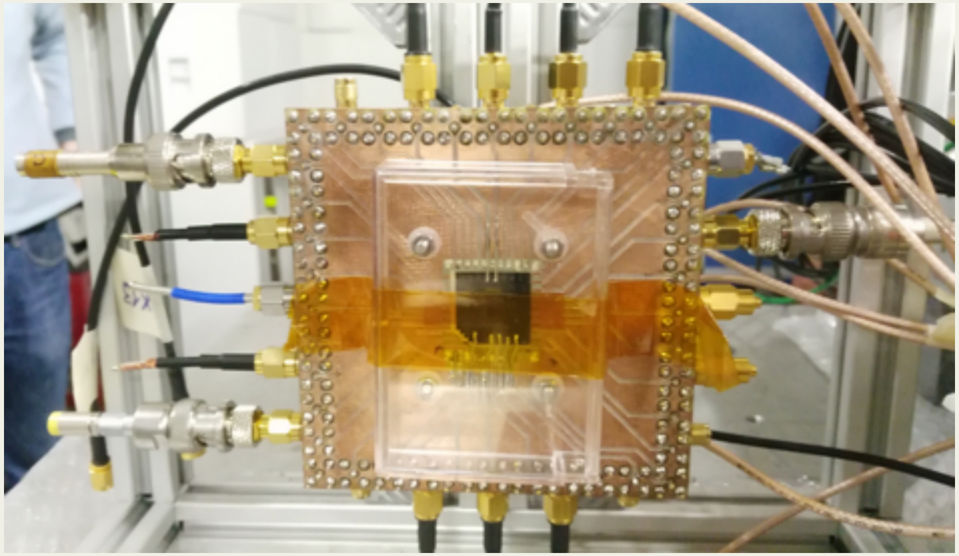
	Parasitic mode		Dedicated mode	
	With target	Without target	With target	Without target
Particle species	e⁺ or e⁻ Selectable by user	e⁺ or e⁻ Depending on DAFNE mode	e⁺ or e⁻ Selectable by user	
Energy (MeV)	25–500	510	25–700 (e⁻) 25–500 (e⁺)	250–730 (e⁻) 250–530 (e⁺)
Energy spread	1% at 500 MeV	0.5%	0.5%	
Rep. rate (Hz)	Variable between 10 and 49 Depending on DAFNE mode		1–49 Selectable by user	
Pulse duration (ns)	10		1.5–40 Selectable by user	
Intensity (particles/bunch)	$1–10^5$ Depending on the energy	$10^7–1.5\ 10^{10}$	$1–10^5$ Depending on the energy	$10^3–3\ 10^{10}$
Max. average flux	$3.125\ 10^{10}$ particles/s			
Spot size (mm)	0.5–25 (y) × 0.6–55 (x)			
Divergence (mrad)	1–1.5			

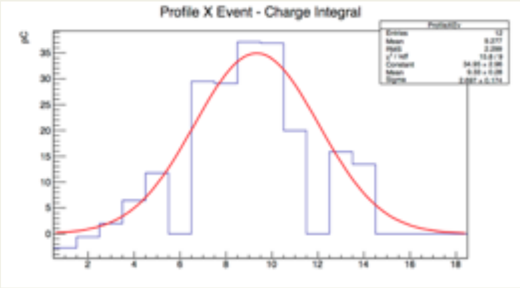
See poster on Saturday:

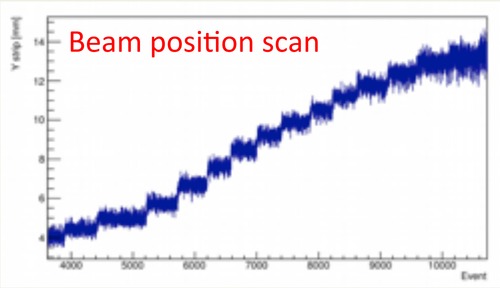


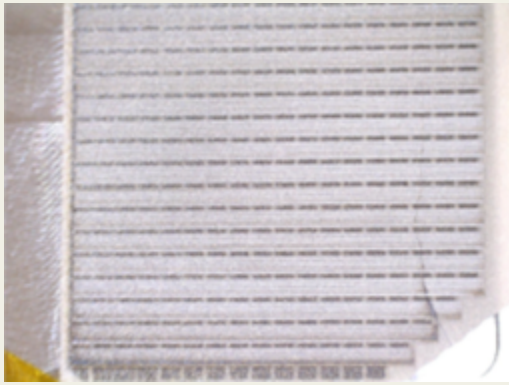
Thin, segmented, full Carbon target

Monitor beam **intensity** and **spot** position/size

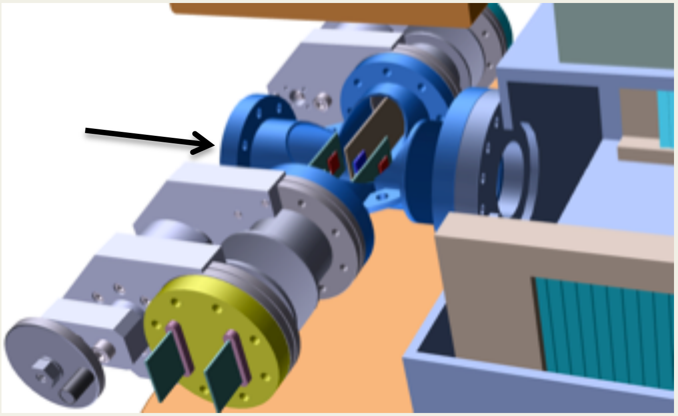




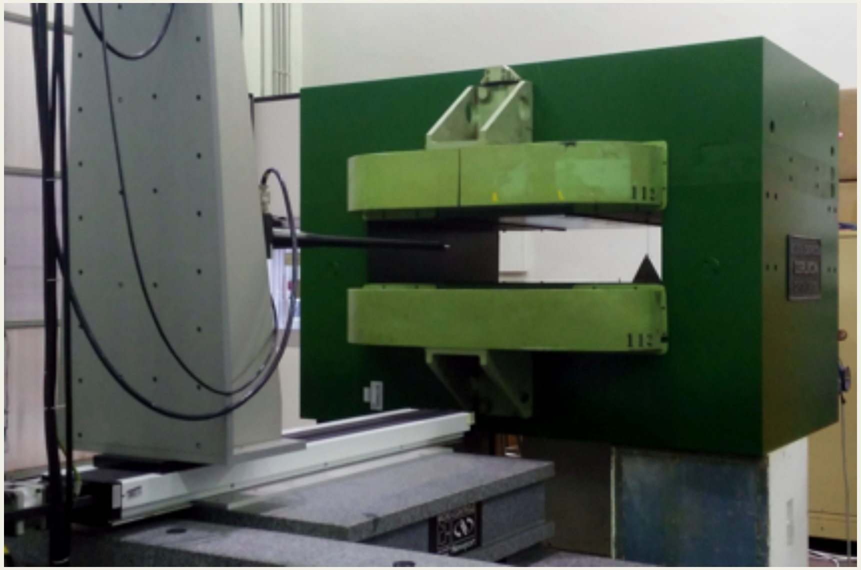


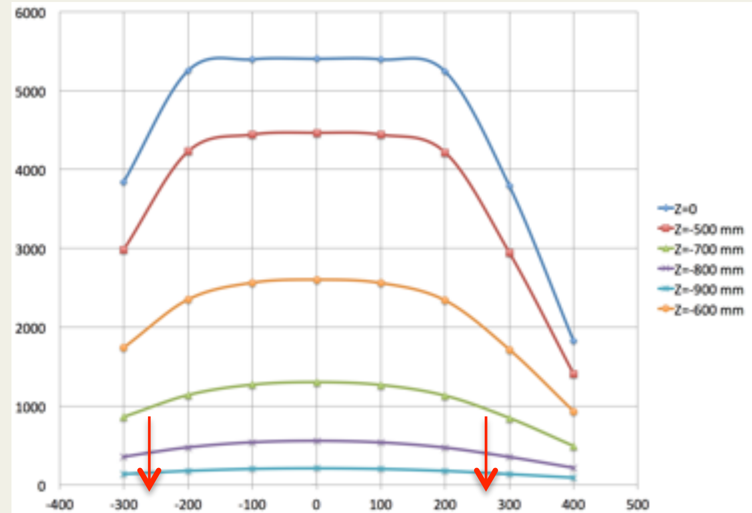


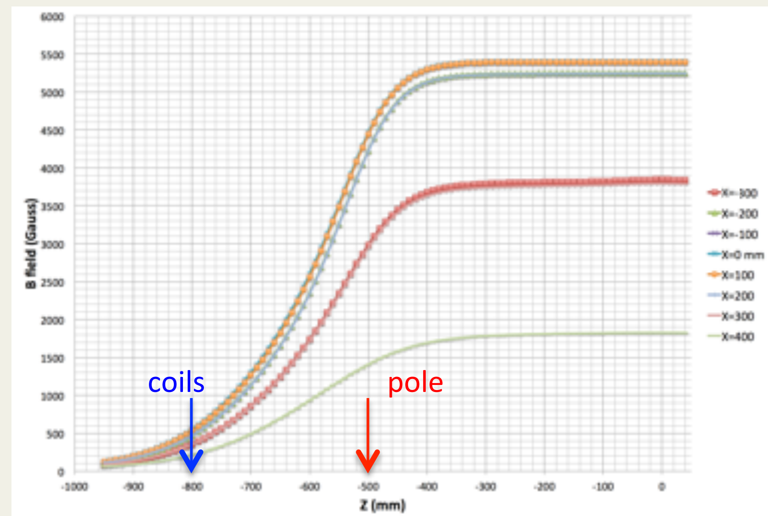
- **20×20×0.050 mm^3** sensor
- **1 mm** pitch *x-y* graphitic strips produced by UV laser
- Moveable inside vacuum



Sweeping/analysing magnet







- MBP-S series, **on loan from CERN**
    - Many thanks to TE-MSC-MNC, R. Lopez, D. Tommasini
- Poles: 100 cm length, 52 cm width
- Variable gap 11 to 20 cm, **further extended to 23 cm**
- Detailed field mapping
    - Good B field quality
    - **Fringe field** not negligible, even outside the coils, relevant for the precise beam steering onto the active target

Measuring the recoil photon

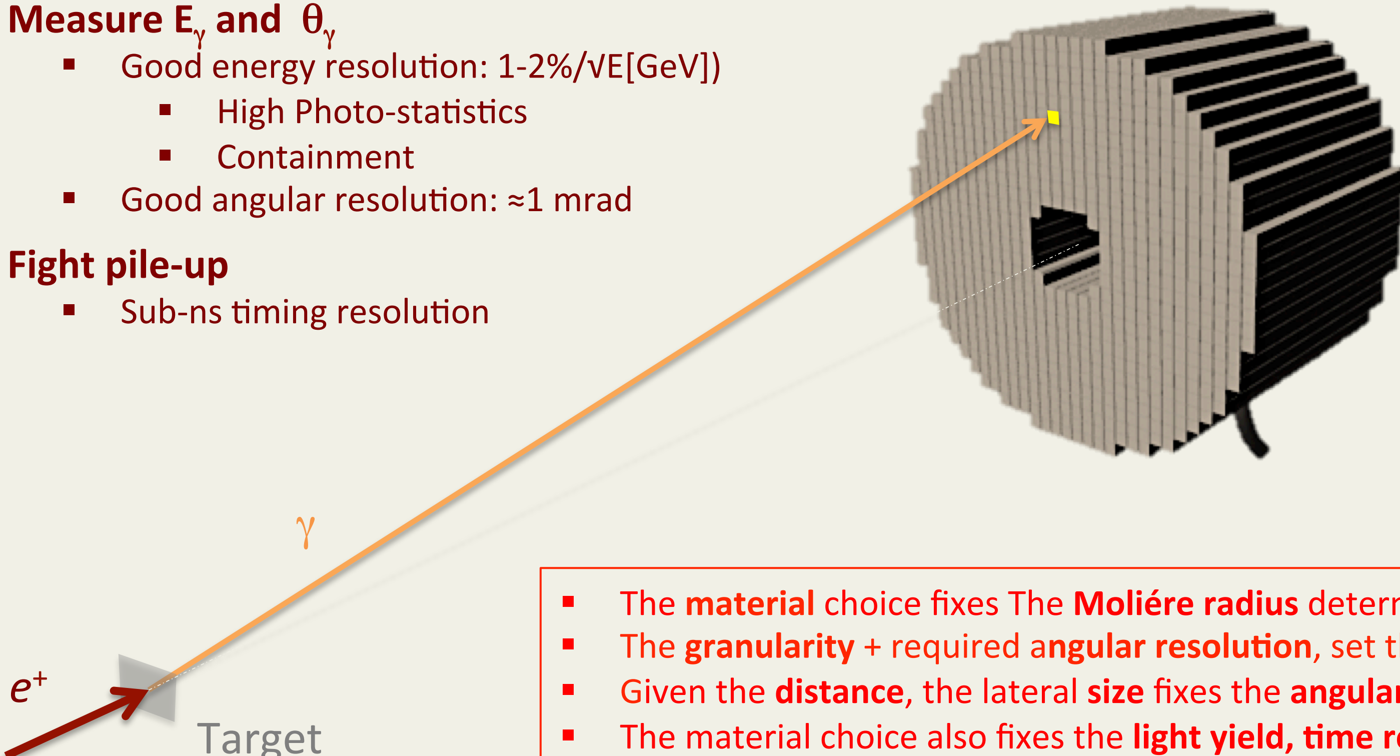
Our main detector is of course a calorimeter, with two basic requirements:

1. Measure E_γ and θ_γ

- Good energy resolution: 1-2%/√E[GeV])
  - High Photo-statistics
  - Containment
- Good angular resolution: ≈1 mrad

2. Fight pile-up

- Sub-ns timing resolution



- The **material** choice fixes The **Moliére radius** determines **granularity**
- The **granularity** + required a**ngular resolution**, set the **distance** from the target
- Given the **distance**, the lateral **size** fixes the **angular coverage** (i.e. **acceptance**)
- The material choice also fixes the **light yield, time resolution**, and $\boldsymbol{X_0}$

Moreover:

- The **overall size** of the experiment is limited by the hall length (<5 m)
- **Cost, complexity, time schedule, man-power**

Crystal choice

Parameter:	ρ	MP	X_0^*	R_M^*	dE^*/dx	λ_I^*	τ_{decay}	λ_{max}	$n^\natural$	Relative output[†]	Hygro-scopic?	$d(LY)/dT$
Units:	g/cm^3	°C	cm	cm	MeV/cm	cm	ns	nm				%/°C[‡]
NaI(Tl)	3.67	651	2.59	4.13	4.8	42.9	245	410	1.85	100	yes	−0.2
BGO	7.13	1050	1.12	2.23	9.0	22.8	300	480	2.15	21	no	−0.9
BaF_2	4.89	1280	2.03	3.10	6.5	30.7	650[s]	300[s]	1.50	36[s]	no	−1.9[s]
							0.9[f]	220[f]		4.1[f]		0.1[f]
CsI(Tl)	4.51	621	1.86	3.57	5.6	39.3	1220	550	1.79	165	slight	0.4
CsI(pure)	4.51	621	1.86	3.57	5.6	39.3	30[s]	420[s]	1.95	3.6[s]	slight	−1.4
							6[f]	310[f]		1.1[f]		
$PbWO_4$	8.3	1123	0.89	2.00	10.1	20.7	30[s]	425[s]	2.20	0.3[s]	no	−2.5
							10[f]	420[f]		0.077[f]		
LSO(Ce)	7.40	2050	1.14	2.07	9.6	20.9	40	402	1.82	85	no	−0.2
$LaBr_3$(Ce)	5.29	788	1.88	2.85	6.9	30.4	20	356	1.9	130	yes	0.2

Small Moliére radius and high light yield: **BGO** and **LYSO**

- **BGO**: high LY, high ρ, small X_0 and small R_M, long τ_{decay}
  - $\sigma(E)/E$ in 1-2%/$\sqrt{E}$ range
- **LYSO(Ce)**: high LY, high ρ, small X_0 and small R_M, short τ_{decay}
  - $\sigma(E)/E = 1.1\%/\sqrt{E} \oplus 0.4\%/E \oplus 1.2\%$

Granularity ≈R_M → 2 cm

- σ_{point}=6 mm → 2 mrad at 3 m **distance** (too much!)

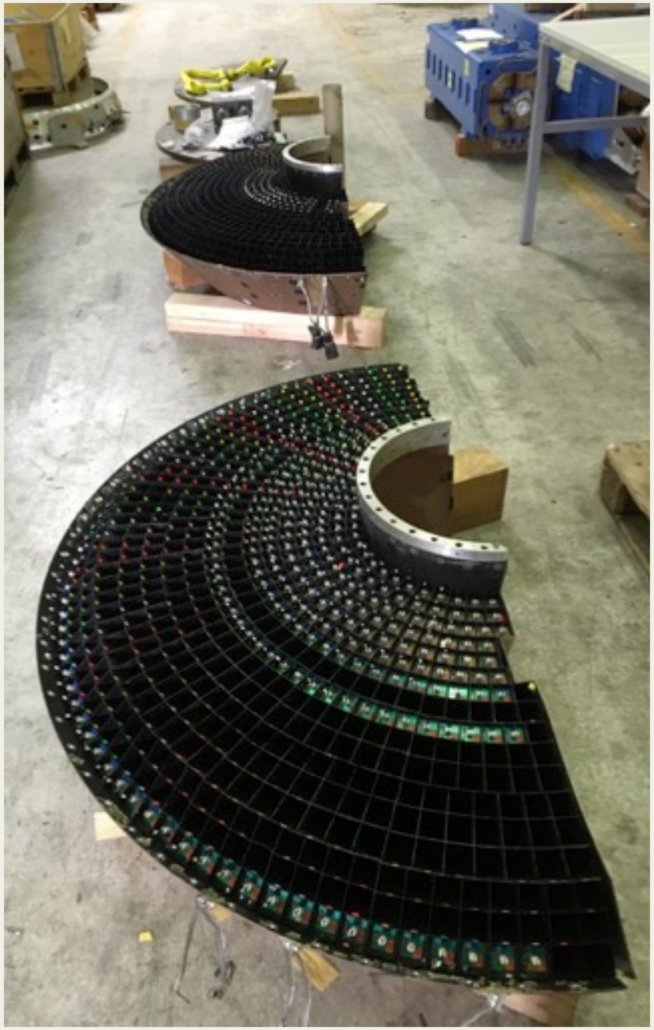
But we have **clusters**:

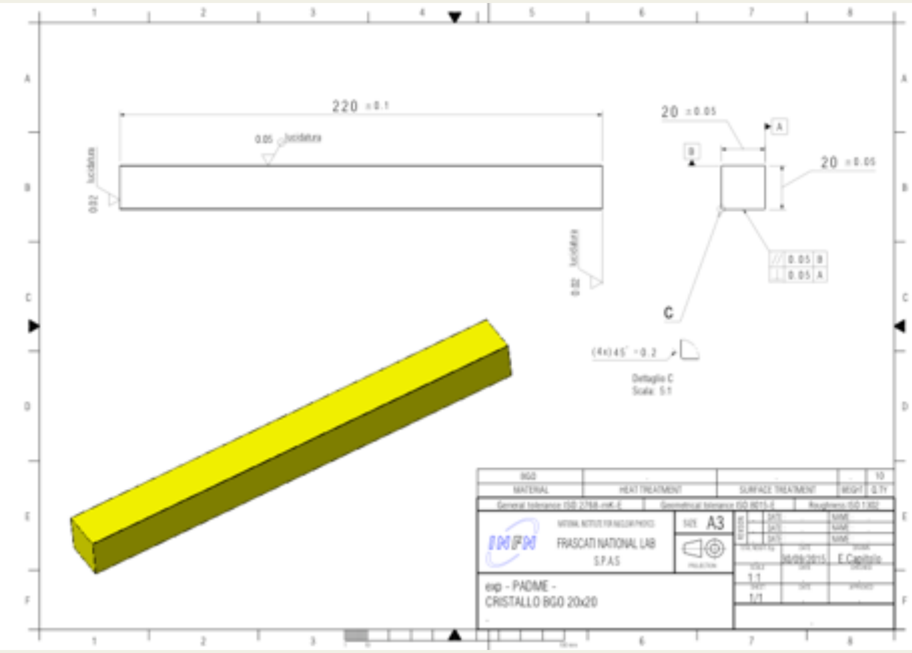
- Center of gravity should have a better resolution
- Most of the energy will be in a single crystal, pulling the **cog** towards the center of the most energetic one)

LYSO would be **faster** and with **higher light yield**

but…

L3 BGO crystals

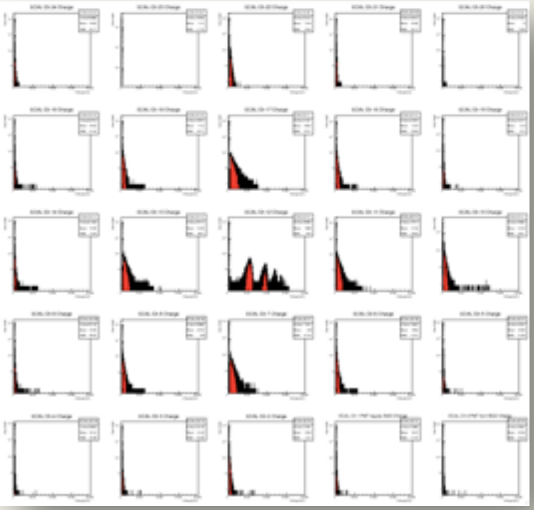


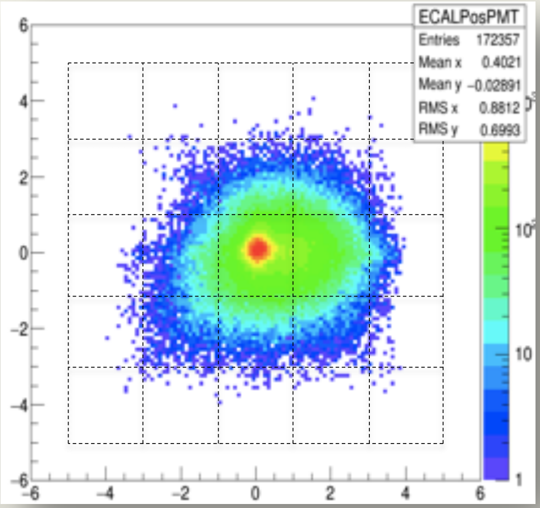


- BGO crystals **available** from the electromagnetic calorimeter of the former L3 experiment at LEP
- Reshape to square section **21×21 mm²**, **220 mm** long

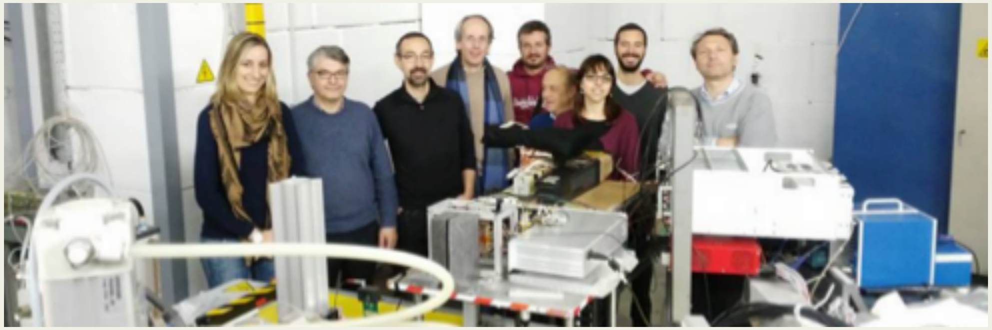
Beam tests

HZC and Hamamatsu PMT's under test

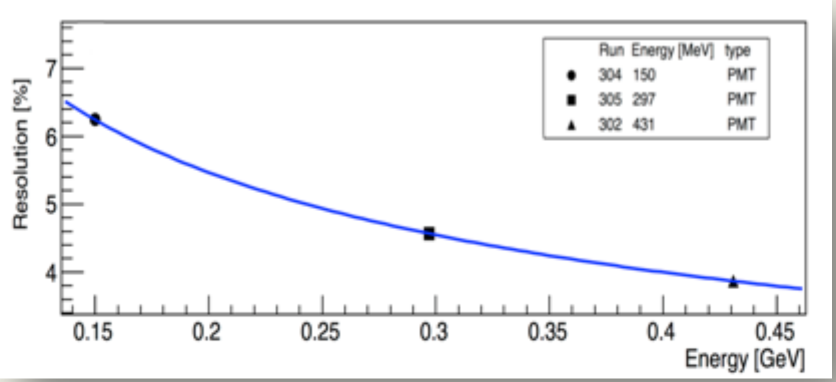




- First tests of **diamond** target and of **5×5 crystals matrix**
- DAQ based on 1 GS/s digitizer (DRS-4)

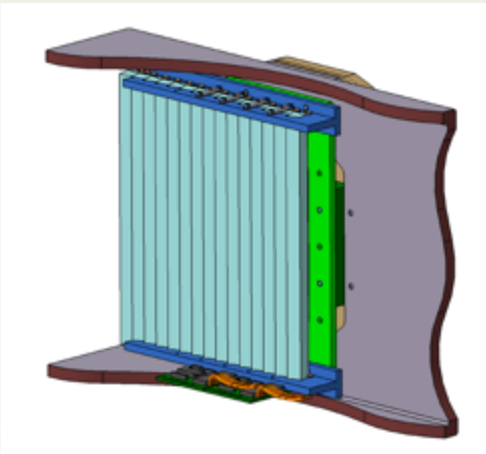


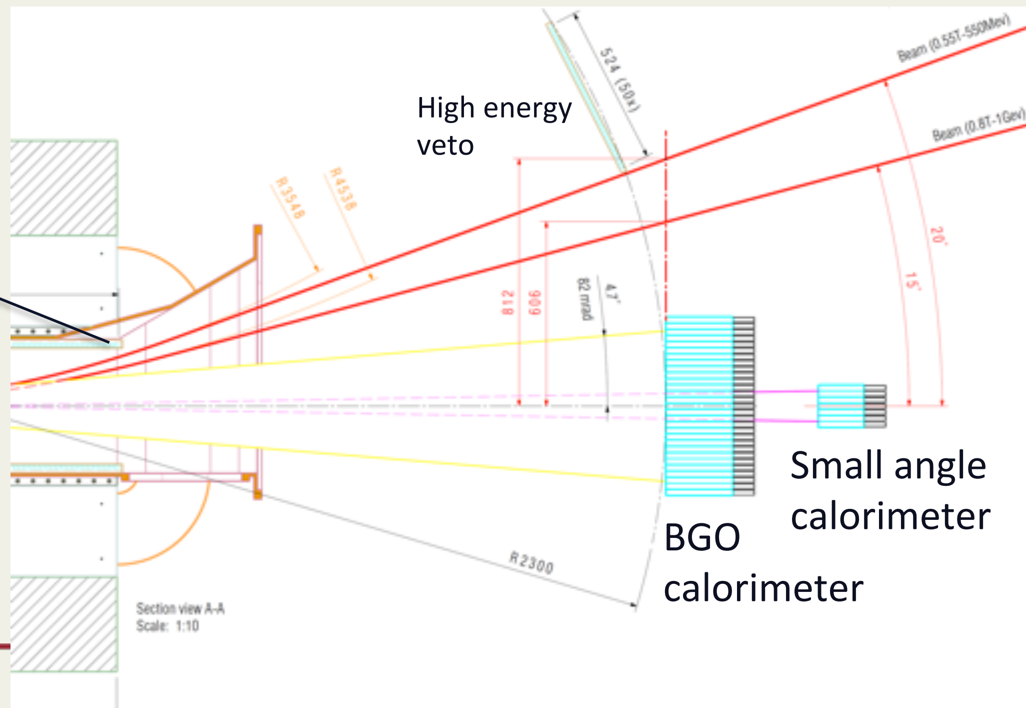
2.3%/√*E* already achieved without inter-calibration



Small angle calorimeter/Positron veto

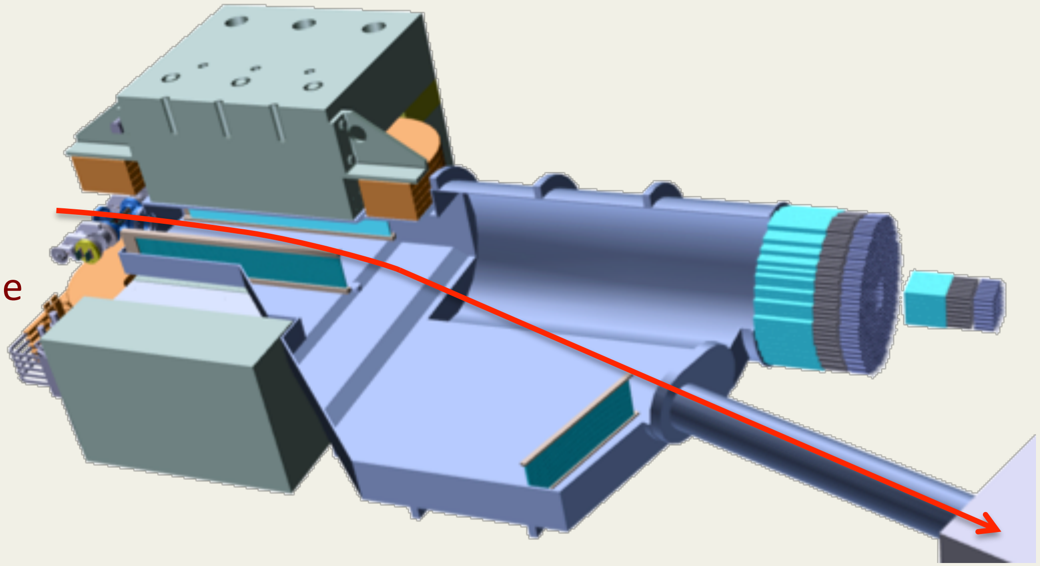
- BGO calorimeter cannot tolerate the Bremsstrahlung rate in the very central crystals
  - Inner hole 5×5 crystals
  - Small angle calorimeter: sustain a rate of O(10) clusters (40 ns pulses)
  - The only fast enough inorganic crystal is BaF_2 with a fast PMT readout
  - A possible alternative: Cherenkov detector
- Scintillating bars for detecting irradiating positrons in the magnetic field region (low energy e^+) and close to beam path (high energy e^+)





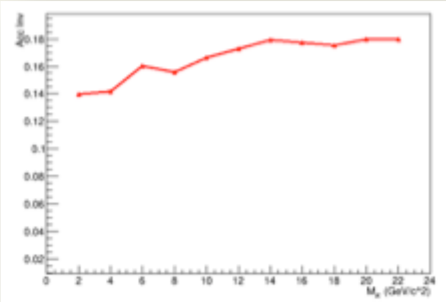
PADME experiment in summary

- **10^3-10^4 e^+ on target per bunch**, at 50 bunches/s (10^{13}-10^{14} e^+/year), **limited by pile-up**, mainly due to Bremsstrahlung events
- Positron **annihilations** on target: **thin and active** (50-100 μm) diamond with graphite strips
- Magnetic spectrometer ~ 1m length × 0.5 T for sweeping away the 550 MeV beam
  - Conventional magnet with **large gap** for gaining **acceptance**
  - Possibility to increase field for LINAC upgrade to ~ 1 GeV
- Positron veto (from Bremsstrahlung events)
- **Cylindrical crystal calorimeter**
- Optimized radius vs. distance by looking at the **background rejection vs. acceptance**
- In order to have an acceptable rate, central hole
- **Small angle detector for Bremsstrahlung veto**
- Vacuum decay volume
- **Positron veto detectors**
- Compute **missing mass** from the momenta of the incoming **positron** and of the recoil **photon**



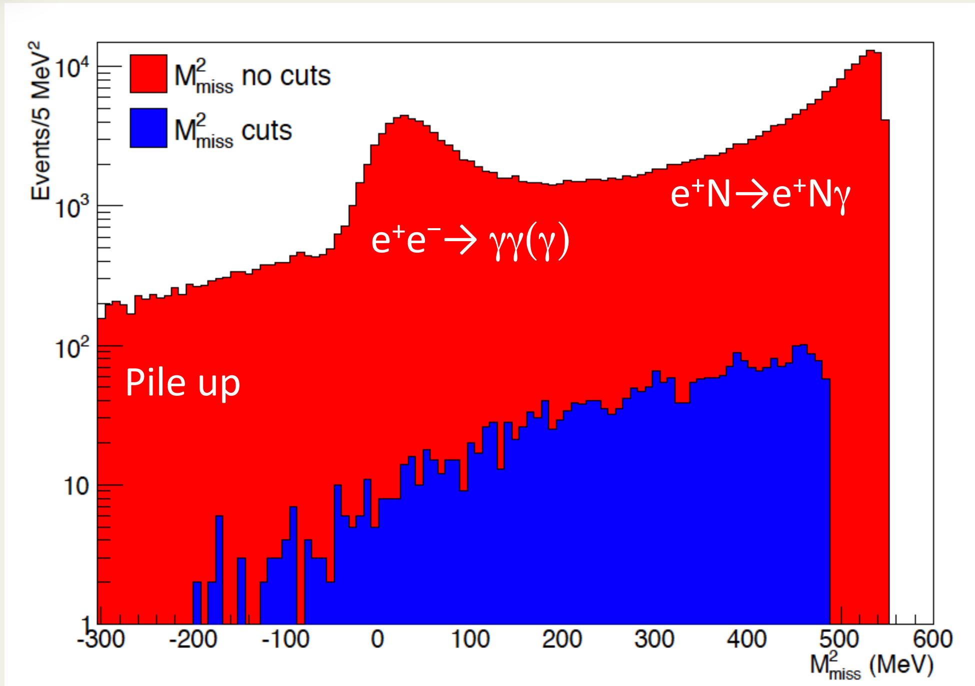
Signal vs. background

Signal acceptance



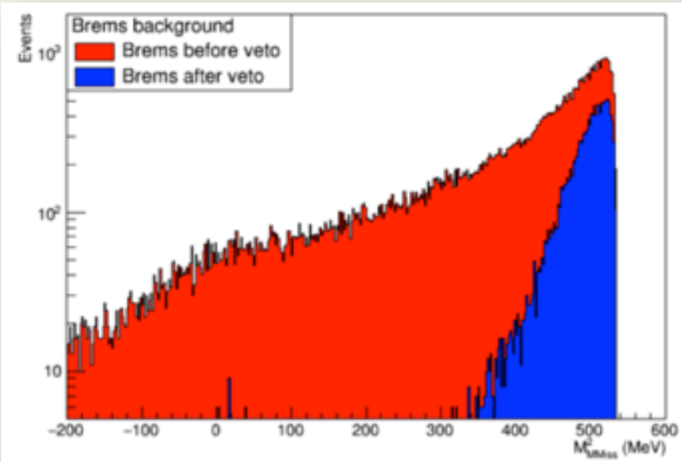
Simple cuts:

- 1 cluster in fiducial region (angle and momentum)
- no hit in positron veto in ±2ns
- <50 MeV in small angle
- 2-σ missing mass cut

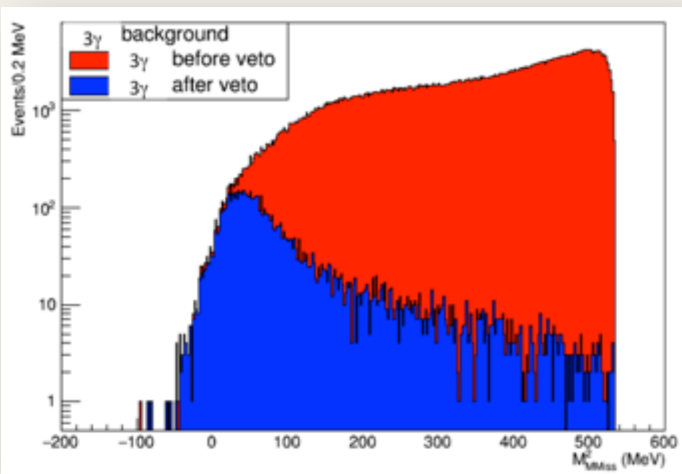


Residual background

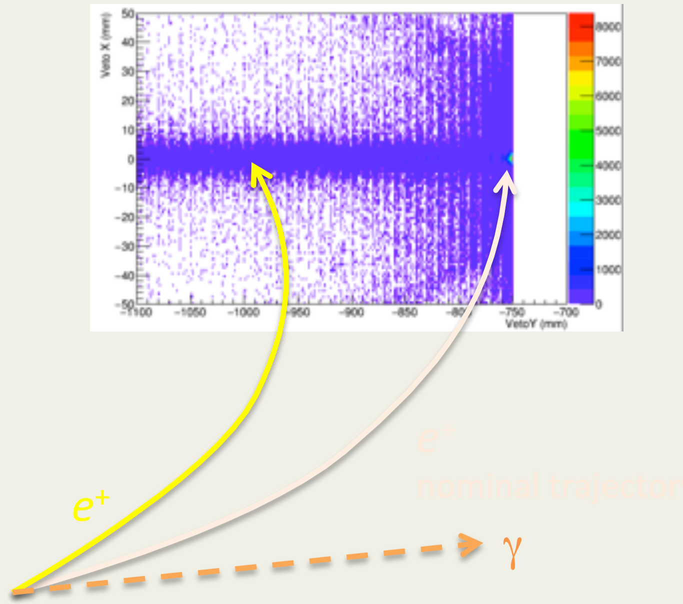
Bremsstrahlung

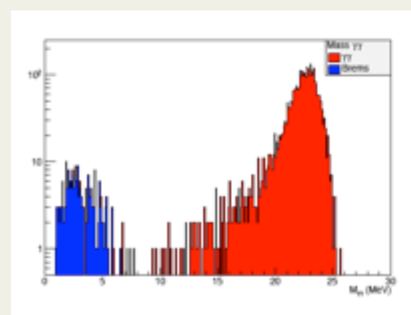


3 photons decay



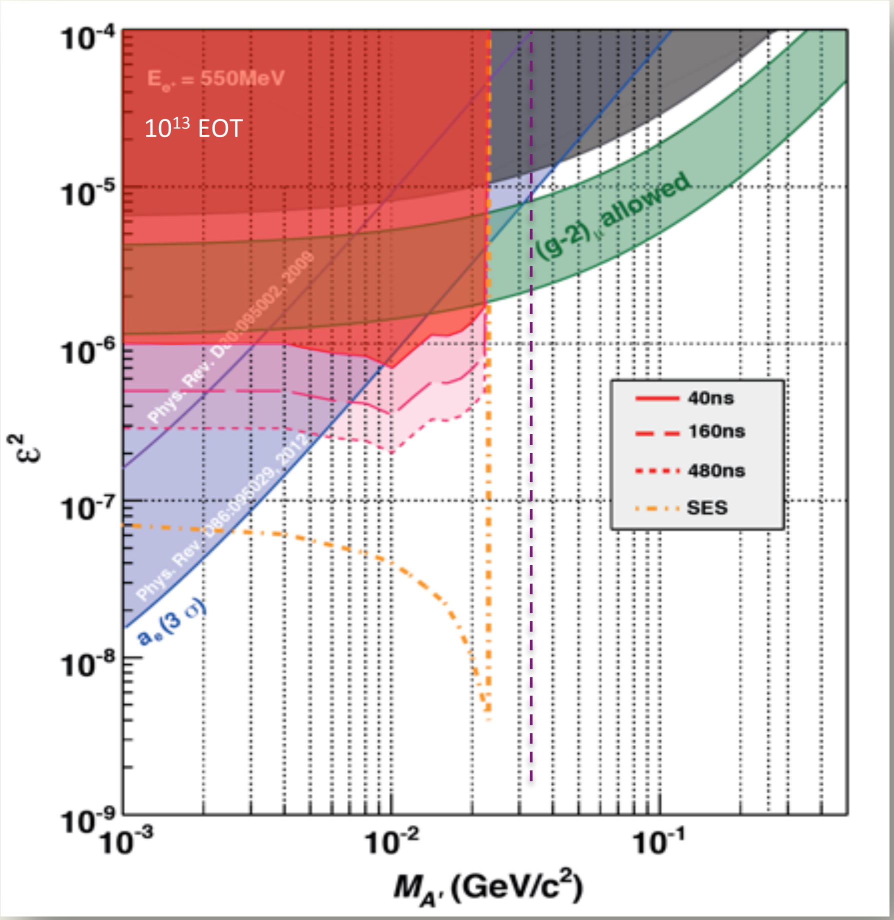
A high-resolution imaging veto could help rejecting $E \approx E_{beam}$ events





γγ events can be cleanly selected for measuring the **beam flux**, in addition to the diamond

PADME sensitivity



Based on 2.5×10^{10} fully GEANT4 simulated 550 MeV e^+ on target events

- Number of background events is extrapolated to 1×10^{13} electrons on target
- Room for improvement by looking at the **single event sensitivity** (zero-background)

PADME 10^{13} EOT

- Bunch length of 40 ns:
  5000 e^+/bunch × $2 \cdot 10^7$ s × 49 Hz

Lengthening the beam pulse would **LINEARLY**:

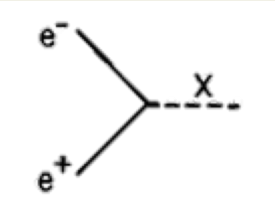
- Either **reduce** the run time for reaching **10^{13} EOT**
- Or **increase the sensitivity** for the same running time of **$2 \cdot 10^7$ s**

E_{e+}=550 MeV: $M_{A'}$ < **23.7 MeV/c^2**

E_{e+}=1 GeV: $M_{A'}$ < **32 MeV/c^2**

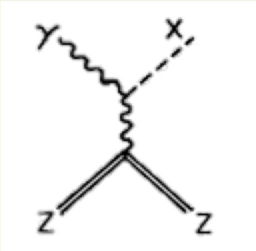
ALPs at PADME

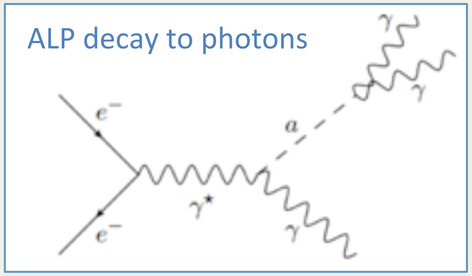
Annihilation



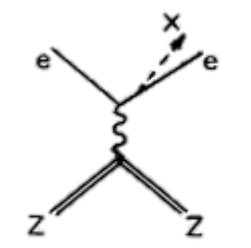
PADME can search for **invisible** decaying or long-lived ALPs looking at **$1\gamma + M^2_{miss}$ final states**

Primakoff





Bremsstrahlung

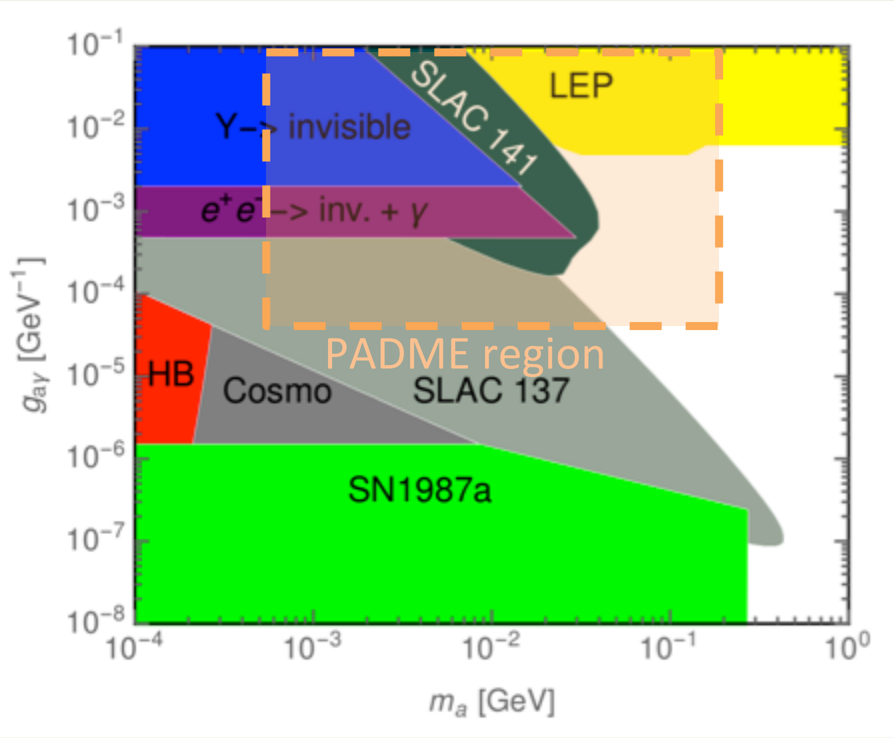


In the **visible** final state $a \rightarrow \gamma\gamma$ **all** production mechanisms can be explored, extending the mass range in the region of ~100MeV

The observables at PADME will be:

***e*γγ or γγγ**

Limits on ALPs coupling to photons



Dark Higgs at PADME

Dark Higgs production at PADME

$$e^+ + e^- \to A'h', \ \textbf{with}\ h' \to A'A',$$

Depending on dark Higgs and dark photon masses:

a) $2M_{A'} < M_{h'}$

Dominant *A'h'* → *A'A'A'* → 6 leptons

b) $2M_{A'} > M_{h'}$

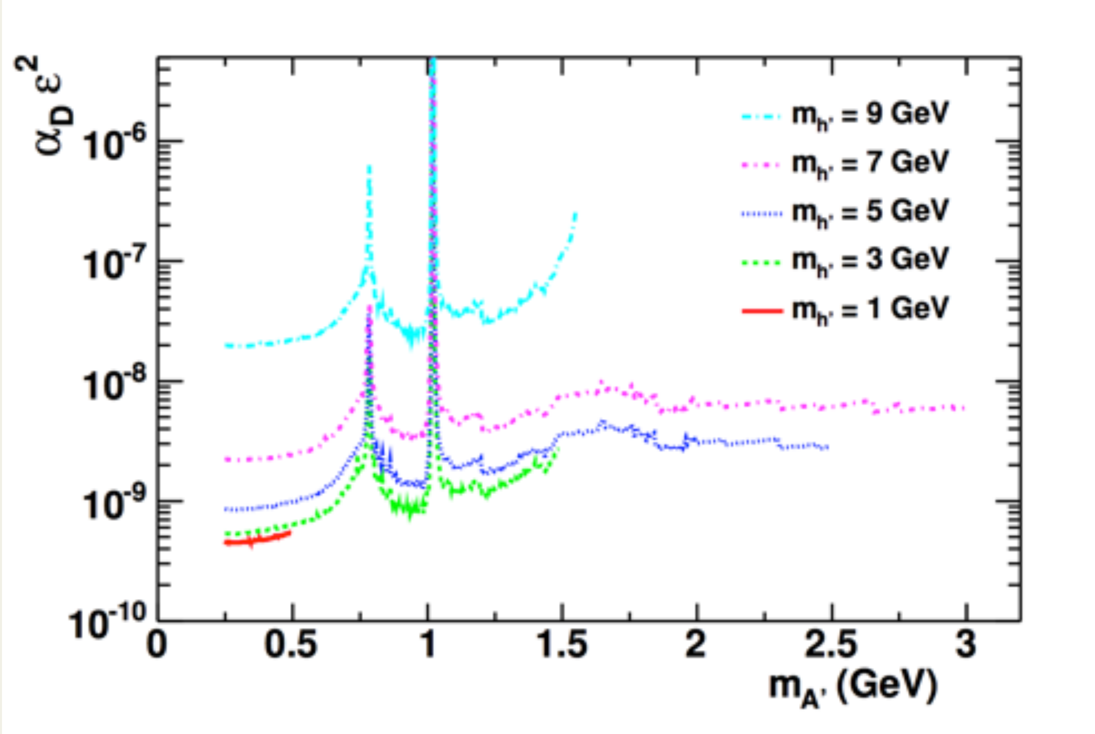
Dominant *A'h'* → *A'* Invisible → 2 leptons

In PADME just count the number of events with:

- 6 leptons in time
- With zero total charge
- And sum of the momenta < E_{beam}

No data below $m_{A'}$ = 250 MeV

Limits on Dark Higgs



Outlook

- **PADME** detector construction fully funded by INFN
- Aim at a first **physics run in 2018**, immediately after the KLOE-2 run
- Construction schedule tight but still respected
  - Mainly dominated by BGO calorimeter construction
  - Well advanced R&D activities on diamond thin target
  - Finalizing the design for vacuum vessel, positron veto, small angle calorimeter

Even though the sensitivity we have estimated is for the **presently available beam** parameters and energy, there is still **room for improvement**:

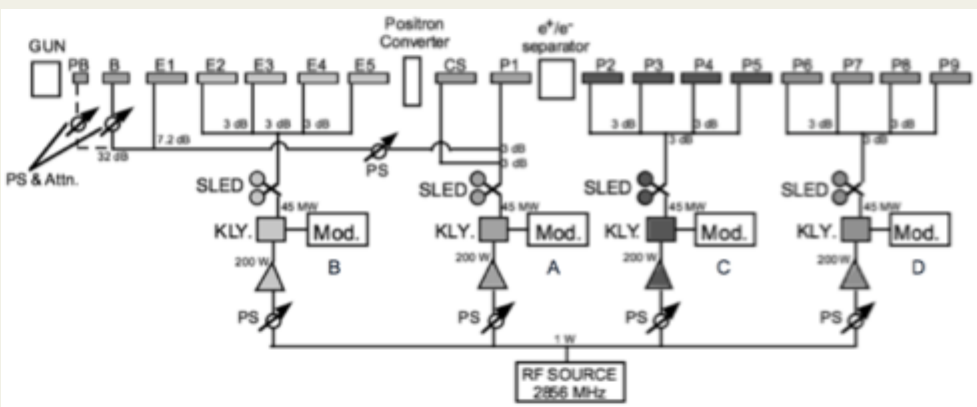
- **Beam**:
  - New gun pulser installation due in September for **extending the beam pulse** from 40 ns to hopefully 100-150 ns (linear increase of sensitivity)
  - **LINAC consolidation** and **energy upgrade** proposed (increase *A'* mass accessible range)
  - **BTF beam-line splitting** (increase the availability of the beam, i.e. the data-taking efficiency)

- **Detector**:
  - PADME is being designed in order to be capable of searching also **visible decays** of the dark photon
  - And also to replace the target with a thicker one in order to perform a "classical" **dump experiment**

PADME is looking forward to new ~~jedi~~ collaborators

http://www.lnf.infn.it/acceleratori/padme

The Frascati LINAC



LINAC parameters

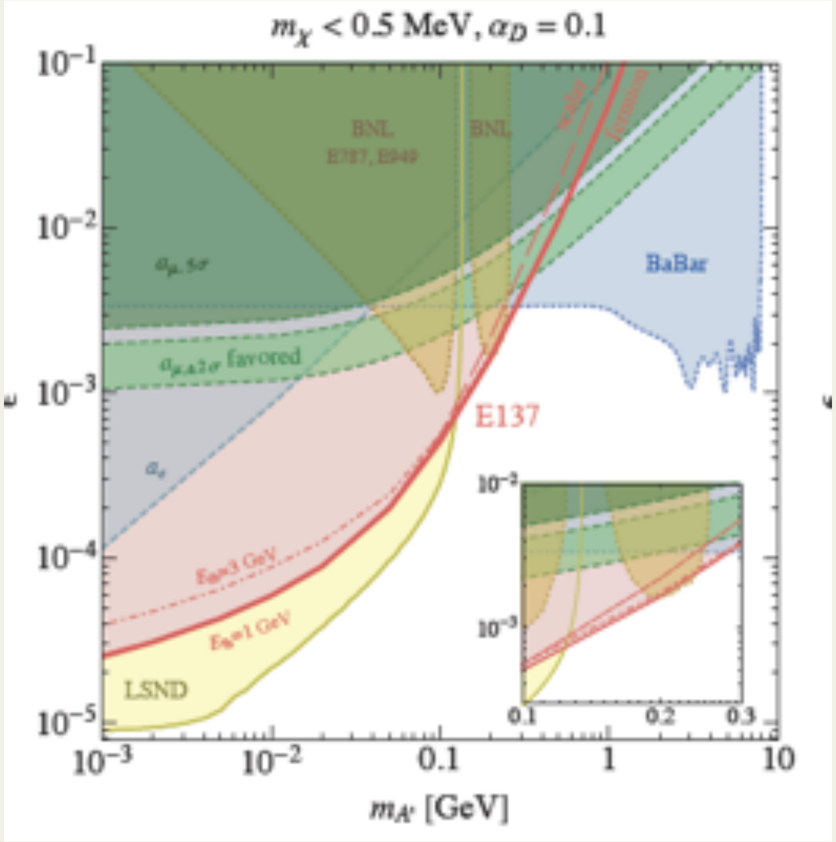
	Design	Operational
Electron beam final energy	800 MeV	510 MeV (750)
Positron beam final energy	550 MeV	510 MeV (550)
RF frequency	2856 MHz	
Positron conversion energy	250 MeV	220 MeV
Beam pulse rep. rate	1 to 50 Hz	1 to 50 Hz
Beam pulse length	10 nsec	1.4 to 40 nsec
Gun current	8 A	8 A
Beam spot at converter	1 mm	1 mm
Normalized Emittance (mm mrad)	1 (electron) 10 (positron)	<1.5
rms Energy spread	0.5% (electron) 1.0% (positron)	0.5% (electron) 1.0% (positron)
electron current on converter	5 A	5.2 A
Max. electron current (10 ns)	>150 mA	200 mA
Max. positron current (10 ns)	36 mA	85 mA
Trasport efficiency	90%	90%
Accelerating structure	SLAC-type, CG, 2π/3	
RF source	4x45 MWp SLED-ed klystrons	

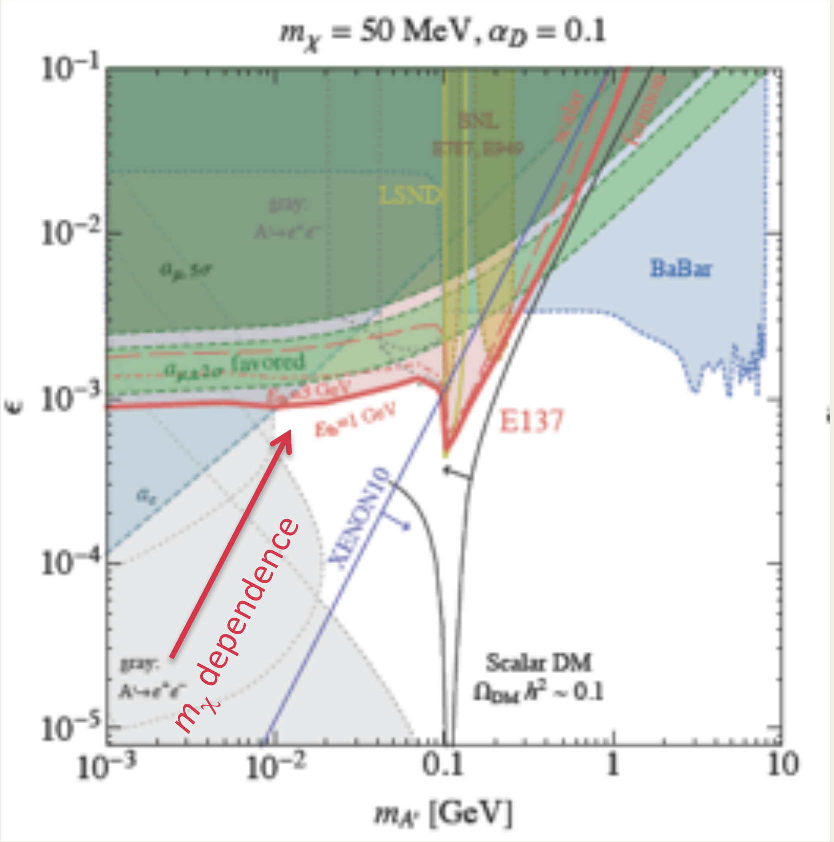
50 Hz repetition rate

BTF experimental hall

Approximately **<5.5 m total** length
(<3 m lateral width)

Decay to invisible states, scattering searches





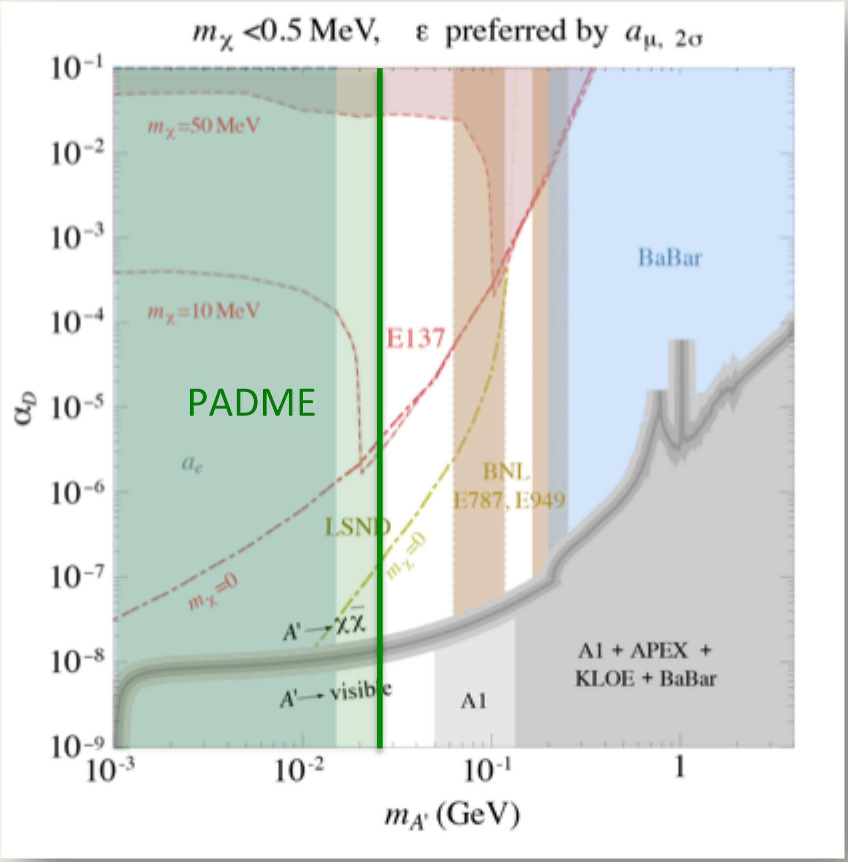
Visible and invisible decays exclusion

Fix ε to the preferred value from a_μ (±2σ), limits are represented in the plane α_D versus $m_{A'}$

Still different curves due to the **mass dependence of the dark sector particles m_χ**

N.B. ε is fixed to the minimum value of the a_μ band

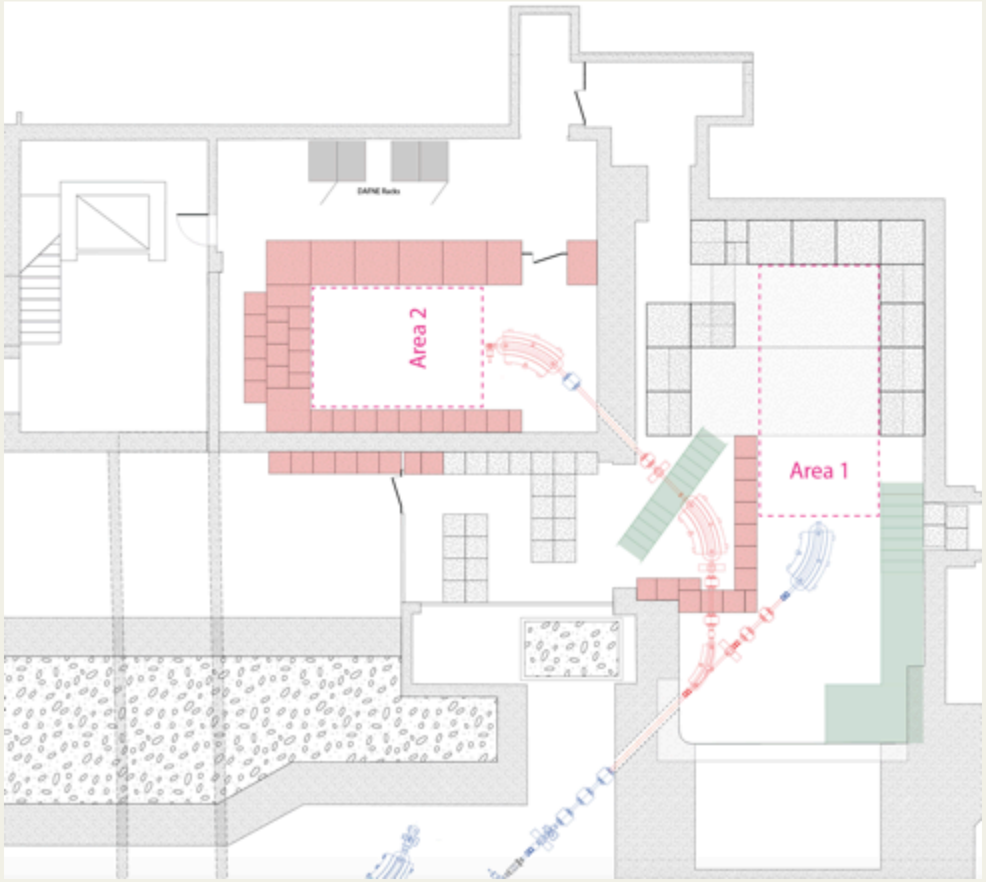
Adapted from arXiv:1406.2698v1



DAΦNE complex in Frascati

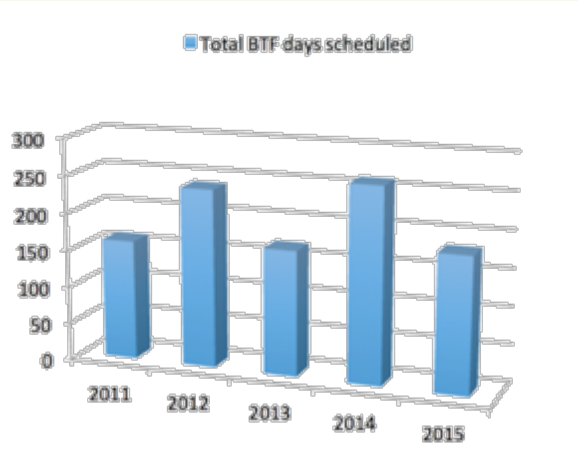
- DAΦNE, replacing ADONE (operational until 1993), has been running as e^+e^- collider at 1,02 GeV since 1999, for KLOE, DEAR, FINUDA, Siddharta, and now KLOE/2 …
- Synchrotron light source operational with 3 lines (X, UV, IR)
- **H**

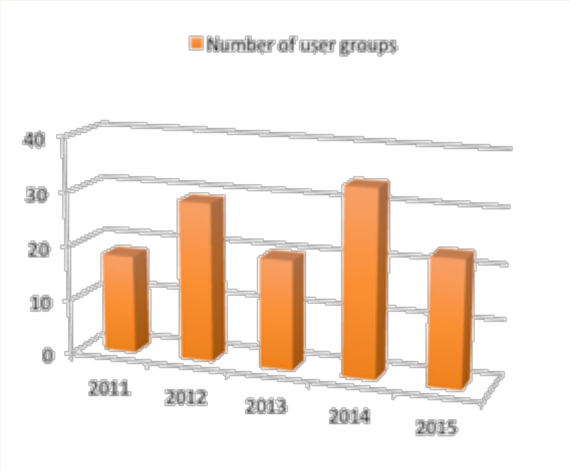
BTF beam-line upgrade

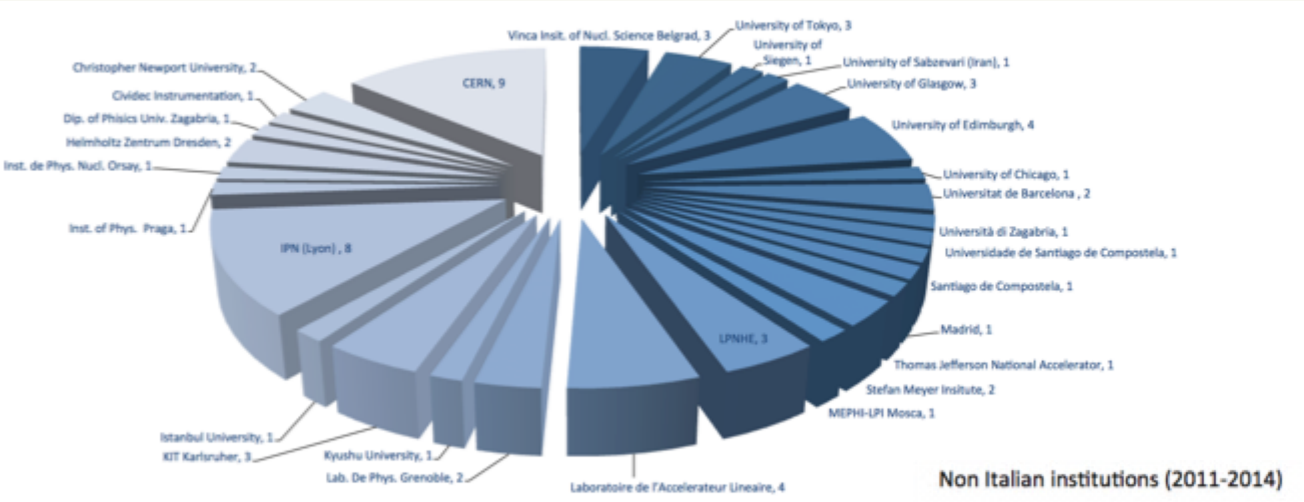


BTF users

[Luckily] BTF is already extensively used by many experimental groups in HEP and astro-particles…

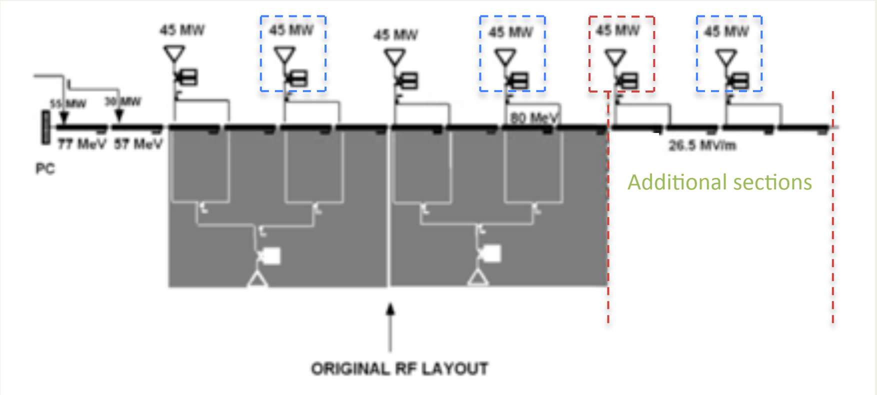






Linac energy upgrade

Linac layout downstream the positron converter:



Proposal of exploiting drift space at the end of accelerating structures put forward

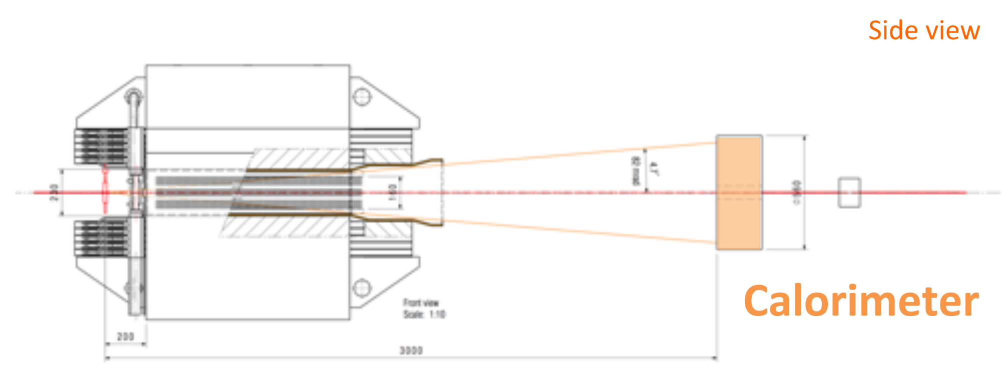
Adding **four** more SLAC-type **accelerating sections** (3 m length)

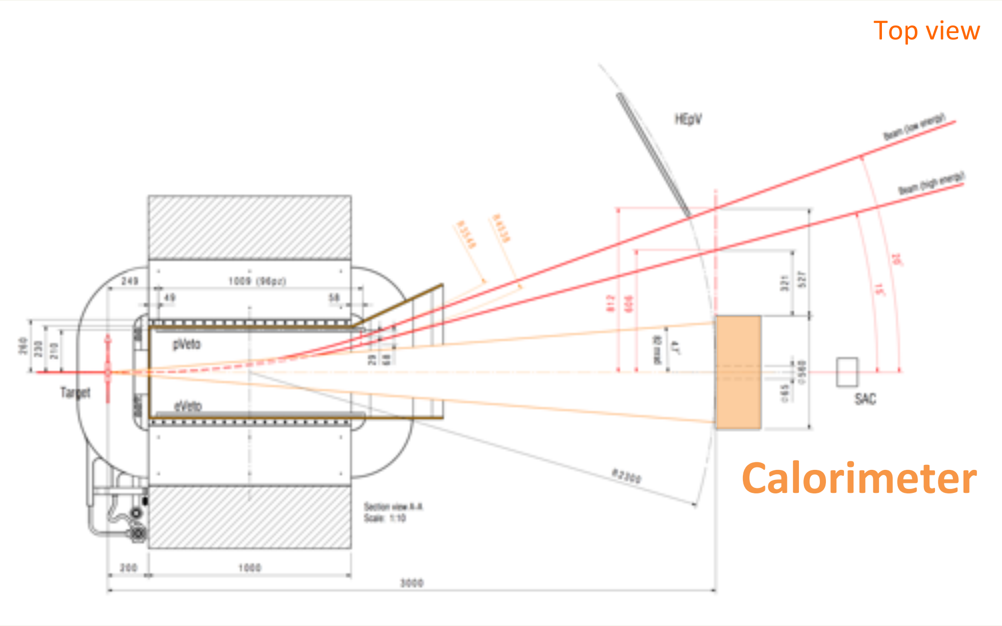
- Fed by a 5th RF station: 45 MWp klystron + SLED: 17.5 MV/m × 12 m = **+210 MeV**

Or/And

– Increasing the accelerating gradient splitting the RF power of one station /2 instead that /4 sections
  - Assuming 27 MV/m: **+110 MeV** (4 accelerating sections)
  - **1 to 3 more RF stations** for the last 4 to 12 sections

Acceptance vs. magnet



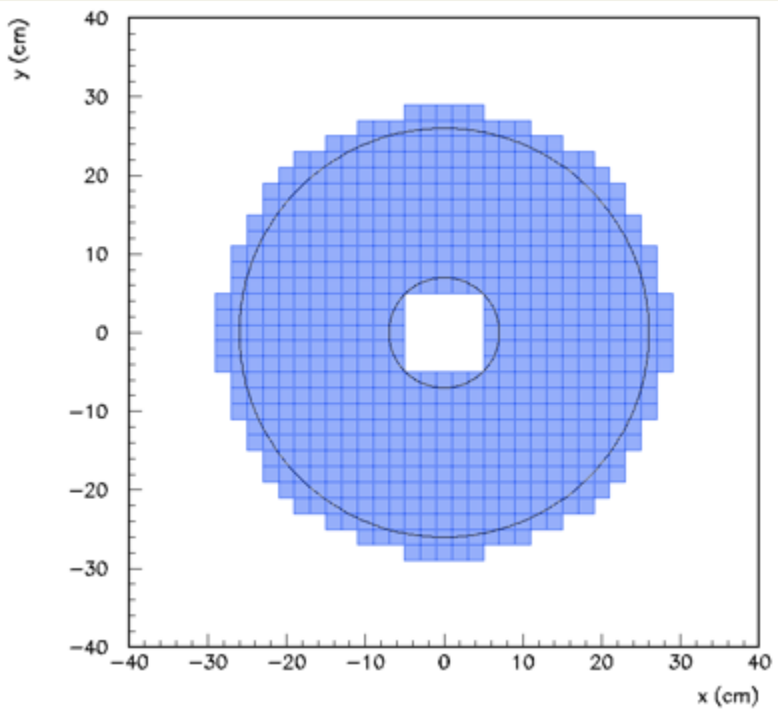


Magnet **gap** (– vacuum pipe depth): fixes the maximum (vertical) **acceptance together with the target position**

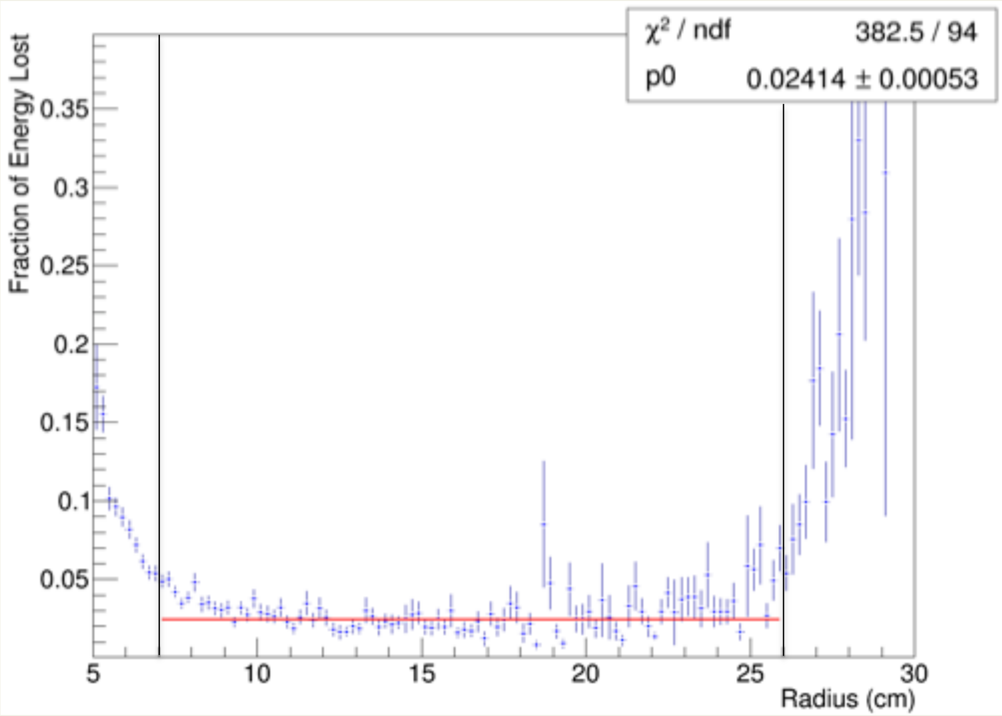
Given the gap, the minimum magnetic field is given by **beam momentum** and needed **sweeping angle**, depending on the calorimeter angular acceptance (in the bending, horizontal, plane)

Calorimeter: signal acceptance

N=616 crystals, 2×2 cm² size

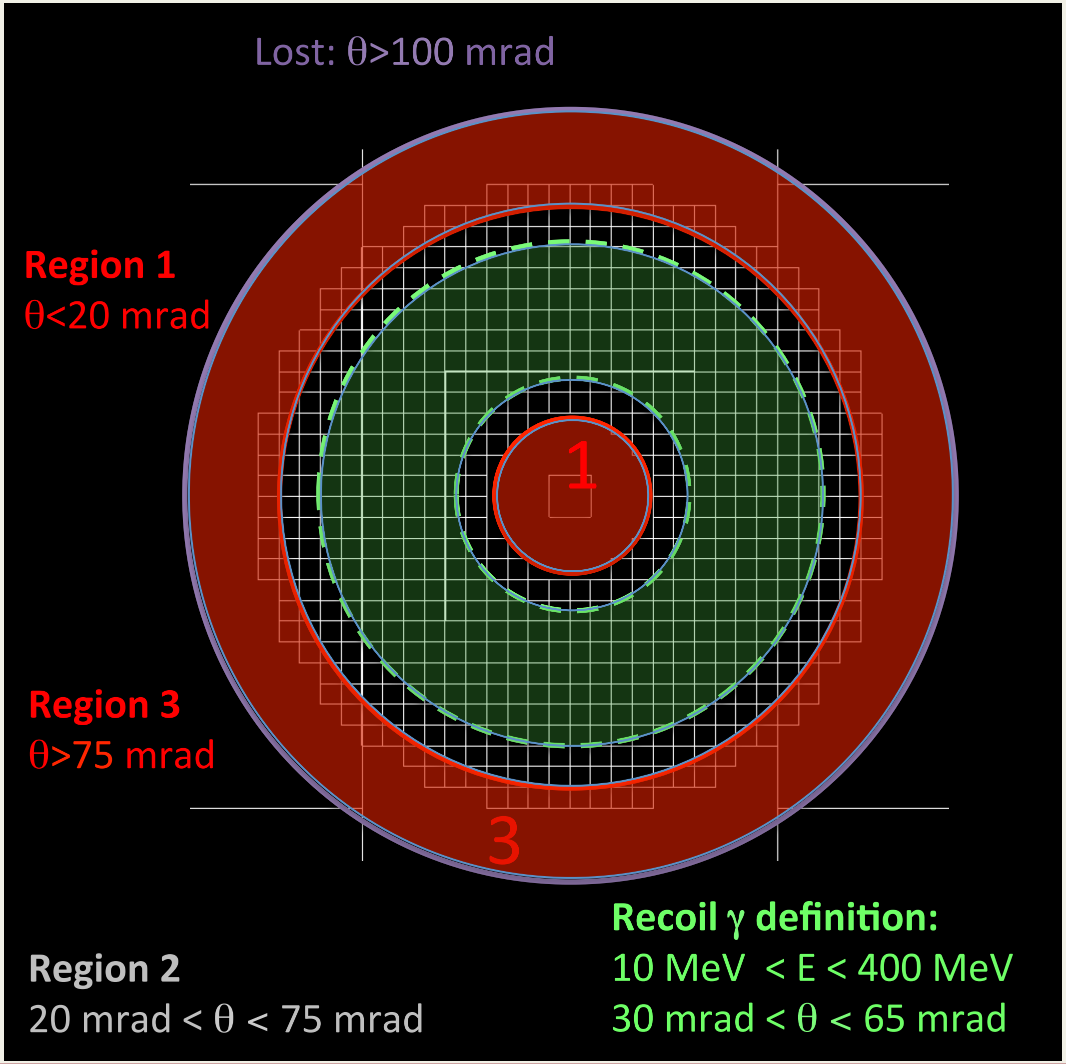


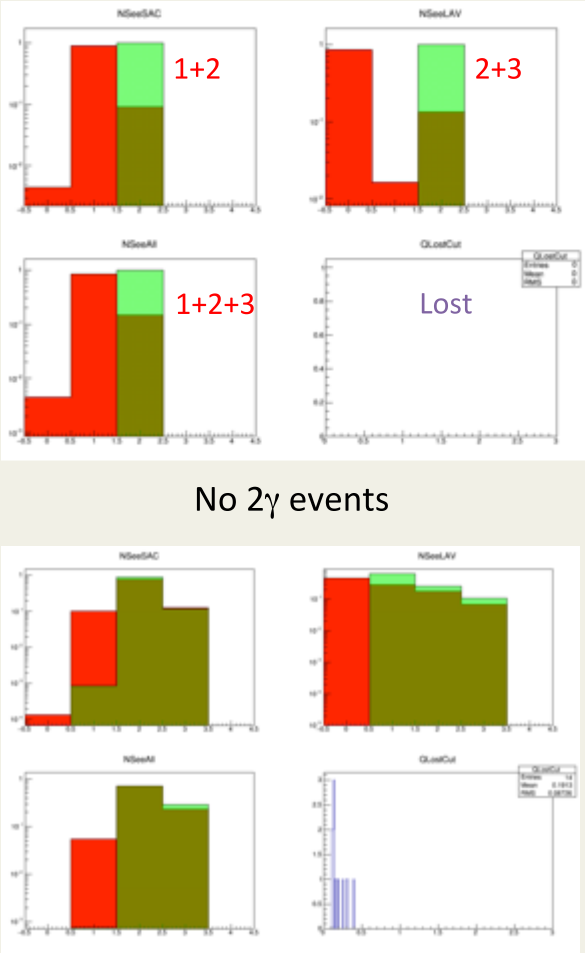
Fraction of energy loss, leaving at least 1.5 cells for lateral containment



Central hole to keep under control pile-up, mainly due to Bremsstrahlung events

Calorimeter 2γ and 3γ backgrounds



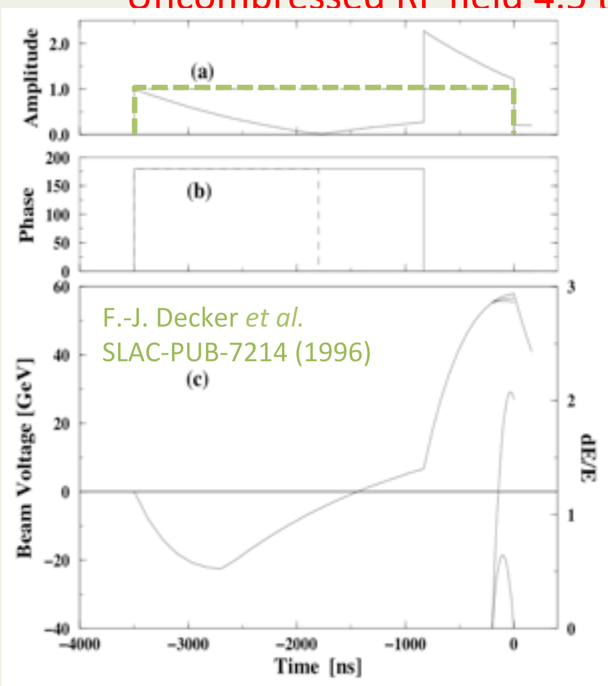


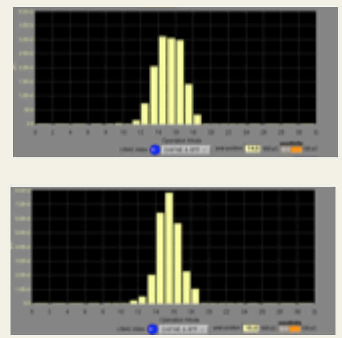
No 2γ events

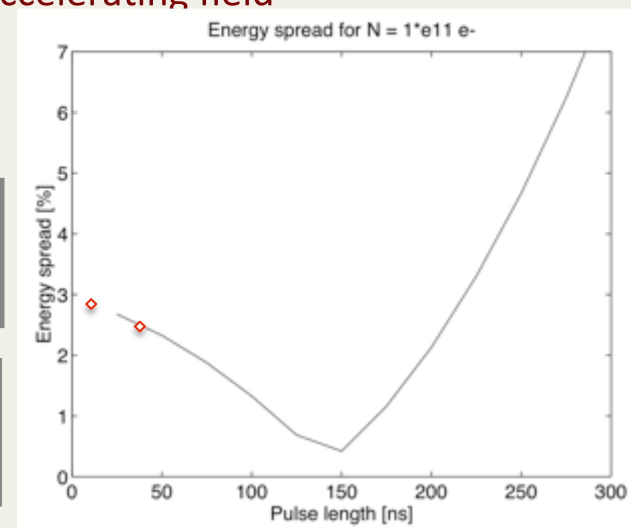
Per-mil 3γ background

Increasing linac beam pulse length

- Diluting the same number of positrons in a longer pulse is a plus from the point of view of pile-up
- Main limitation coming from the **SL**ac **E**nergy **D**oubling system (SLED) used to reach higher energy in our linac
- Uncompressed RF field 4.5 μs long, but with a 1/9 lower accelerating field
- ts the energy spread

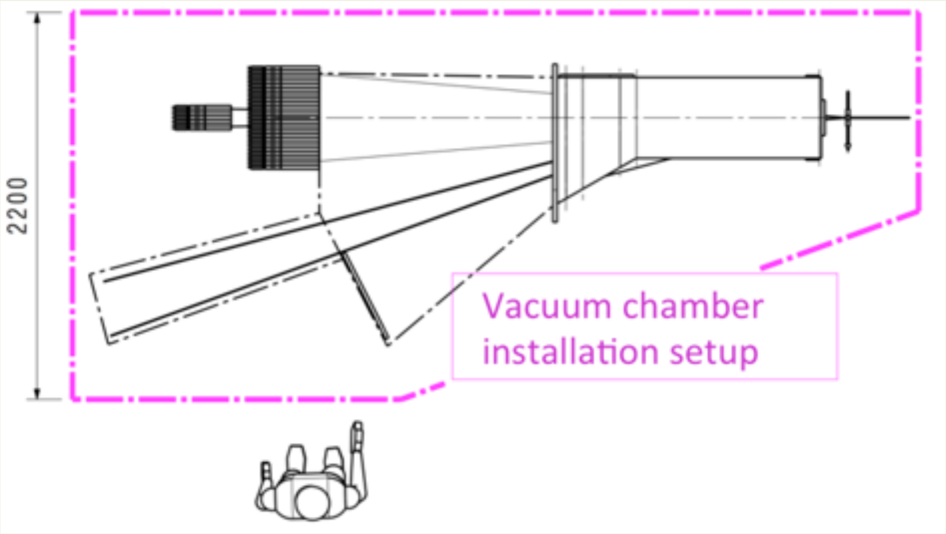






- New pulser capable of up to 4.5 μs pulses will be installed during next shutdown (summer 2016)
- 500 ns pulses with 0.5% energy spread achieved at SLAC

Vacuum vessel



Al 2219 T851 or AL6082 T6
2 mm side walls
4 mm ribs

Vacuum mandatory for **three purposes**:

1. Not to spoil **beam quality** before hitting the target
2. To minimize **photon interactions** before reaching the calorimeter
3. To minimize **positron interactions** before hitting the veto detector (in particular showers!)

Different possibilities under study to minimize the material thickness, i.e. increase acceptance (given the magnet gap) for the vessel, with the following requirements:

- Hold the vacuum
- Host the scintillating bars for positron veto detectors
- Interface to target box (upstream) and straight section before calorimeter (downstream)

Positron veto

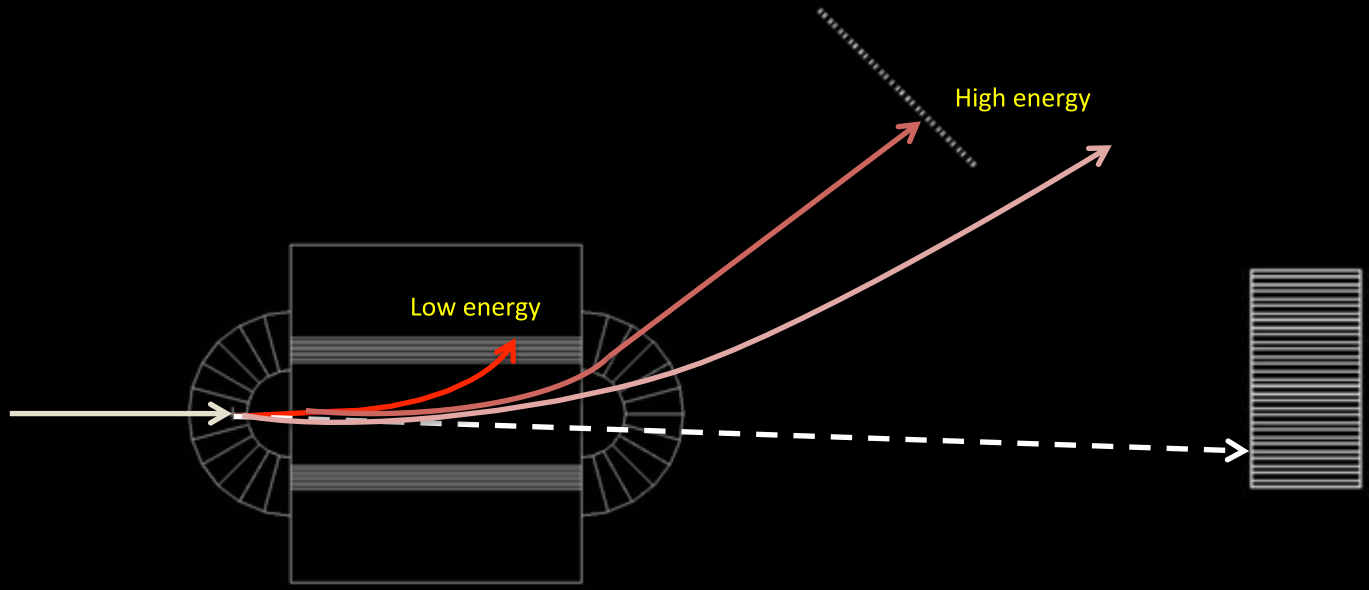
Time resolution better than 500ps

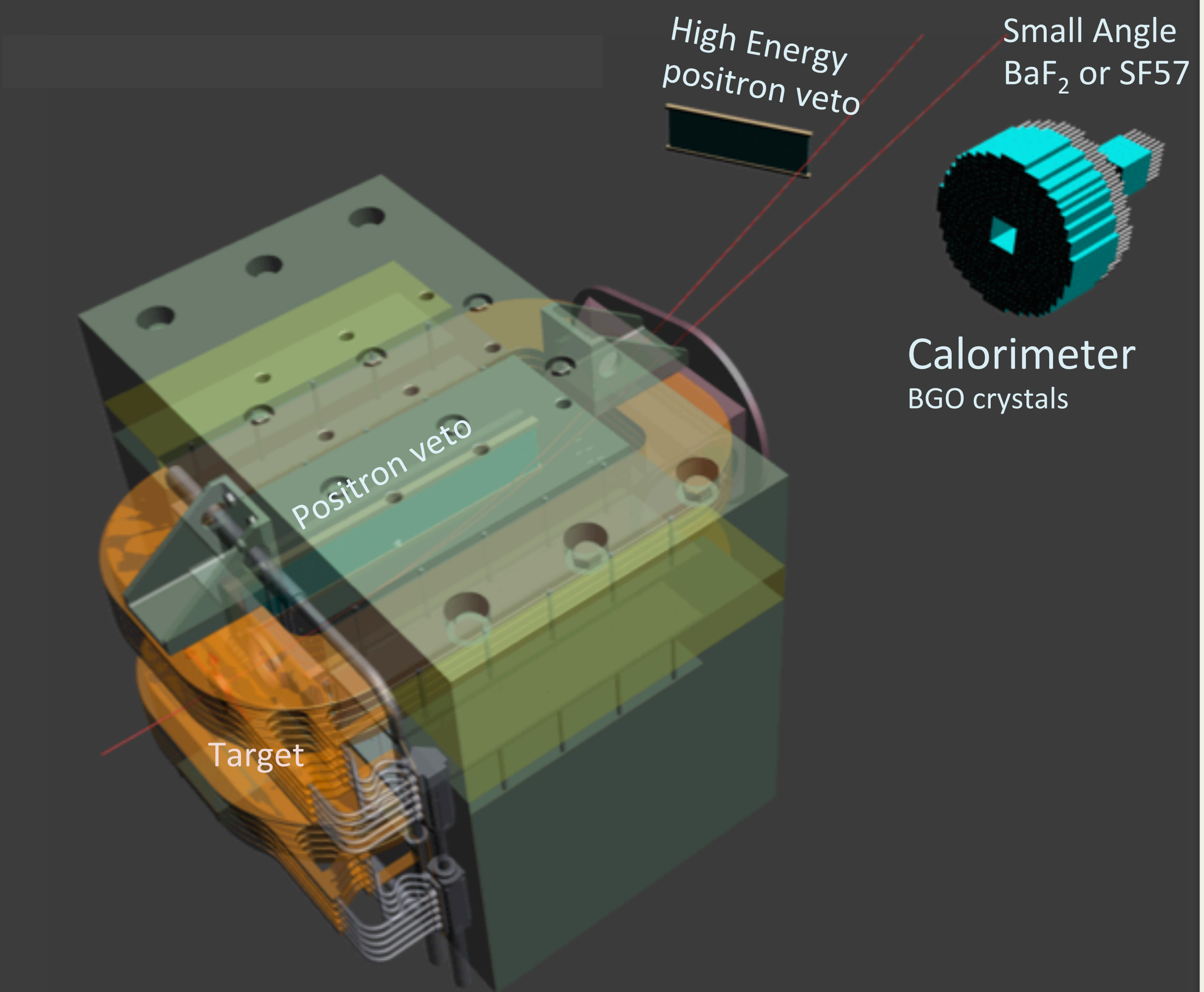
Momentum resolution of few % based on impact position

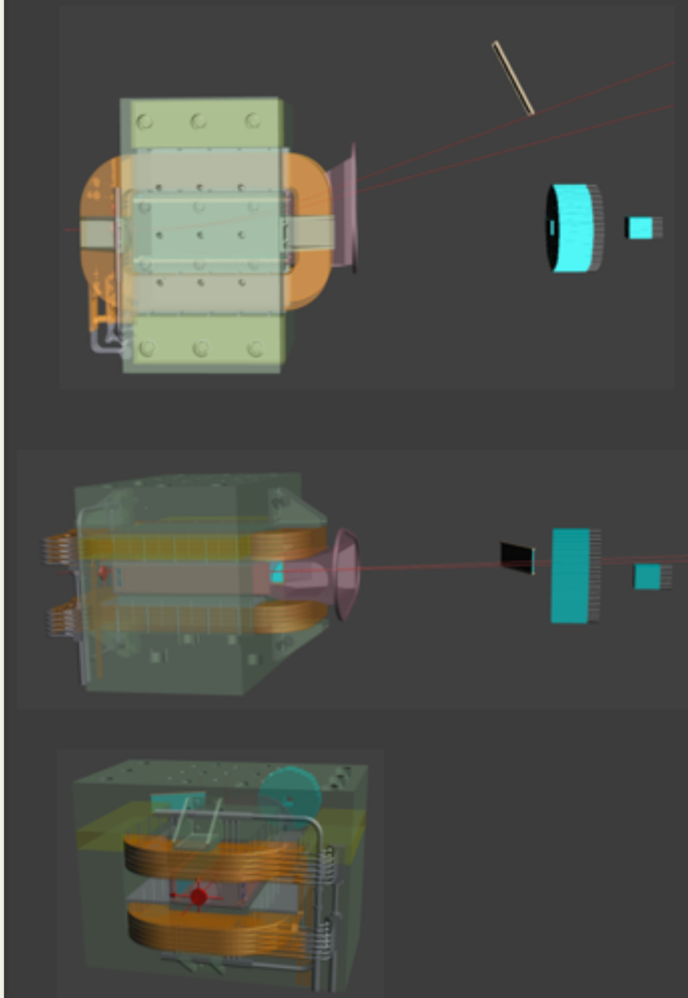
Efficiency better than 99.5% for MIPs

Low energy part inside the magnet gap

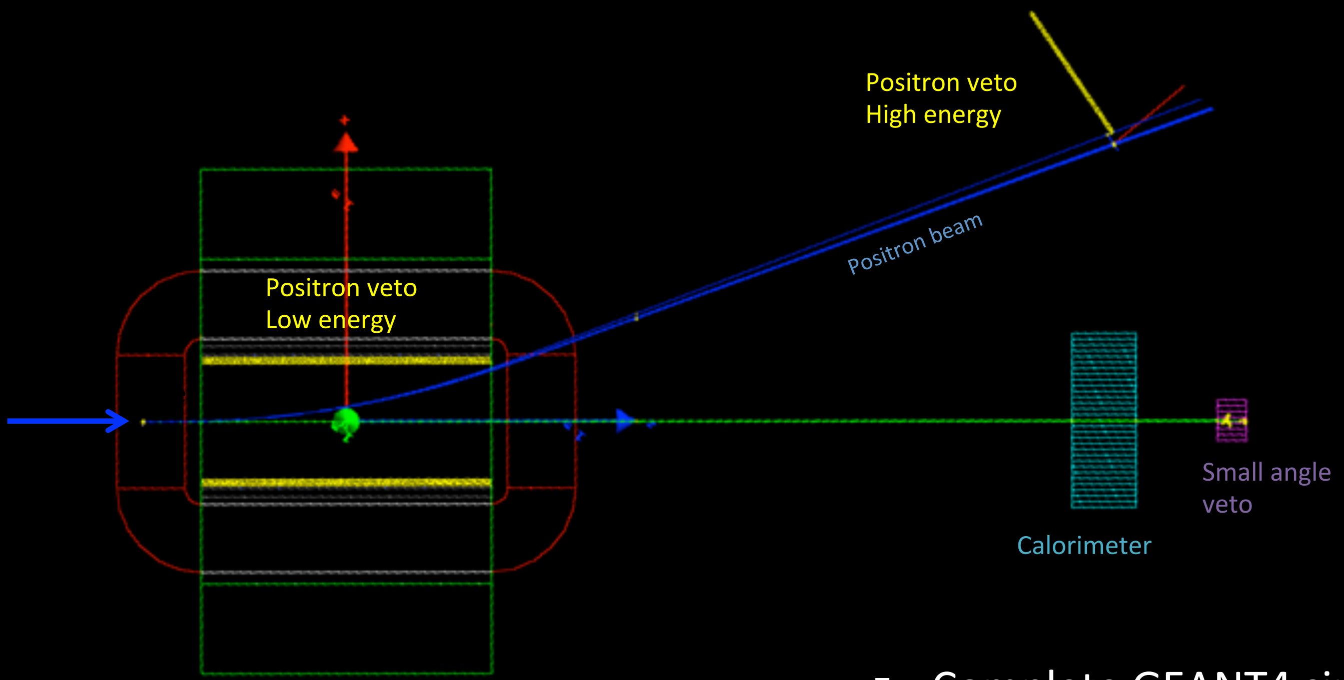
High energy part close to not interacting beam




High Energy
positron veto
Small Angle
BaF_2 or SF57
Calorimeter
BGO crystals
Positron veto
Target

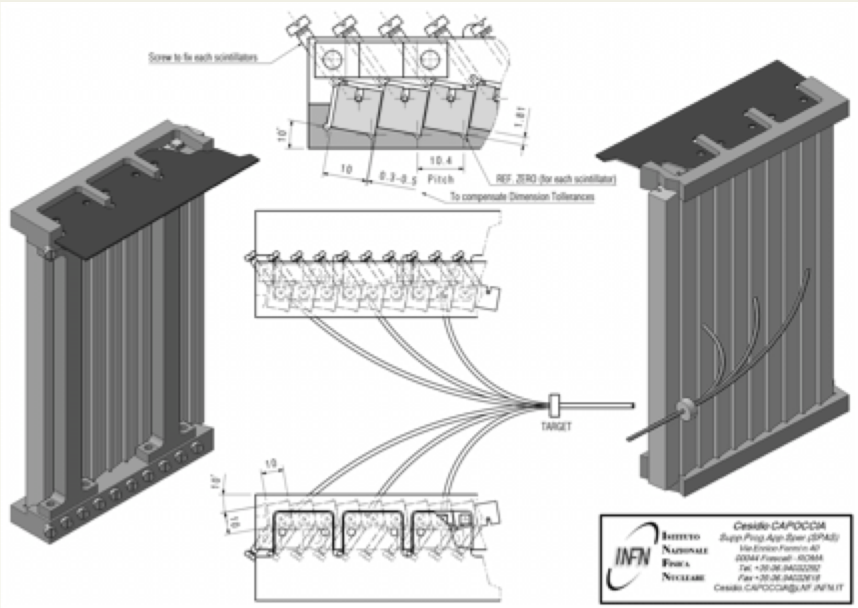


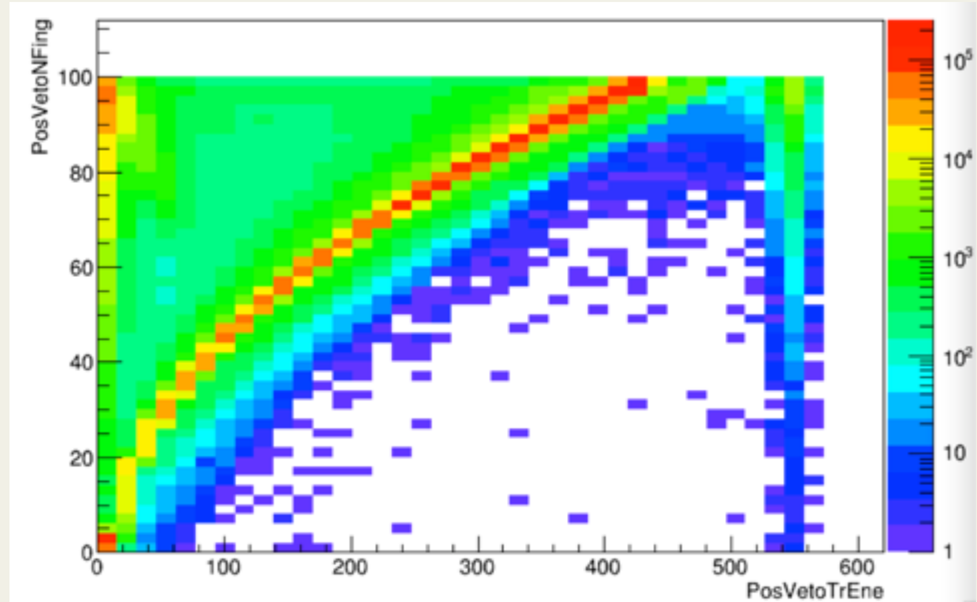
Monte Carlo simulation



- Complete GEANT4 simulation
- 3 γ production via CalcHEP

Positron veto





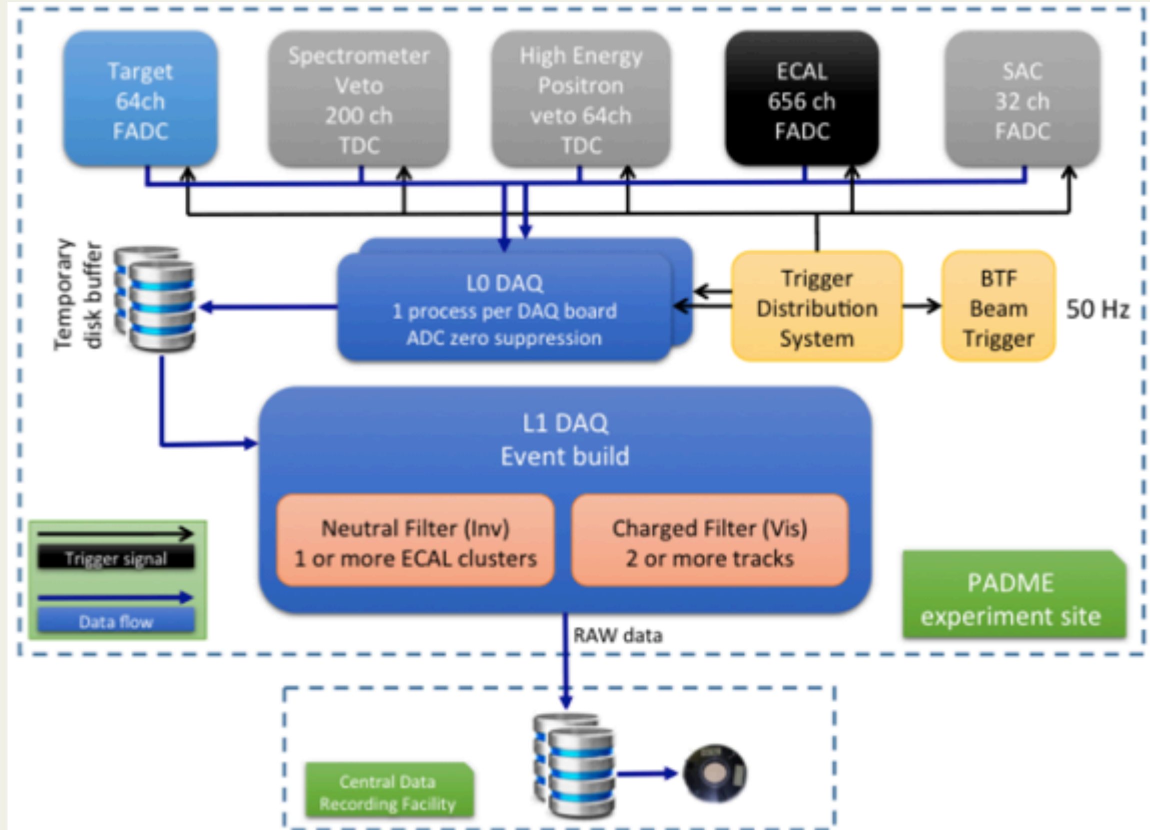
Low momentum losses are reduced for E_γ<400 MeV
Interesting positron energy starting at ~150 MeV

Which granularity?

- 1 cm scintillator bars, readout by SiPM
- Few % momentum resolution in a large part of the spectrum

PADME TDAQ

- Readout based on digitizers CAEN V1742
- ~1000 channels
- ~33 FADC boards



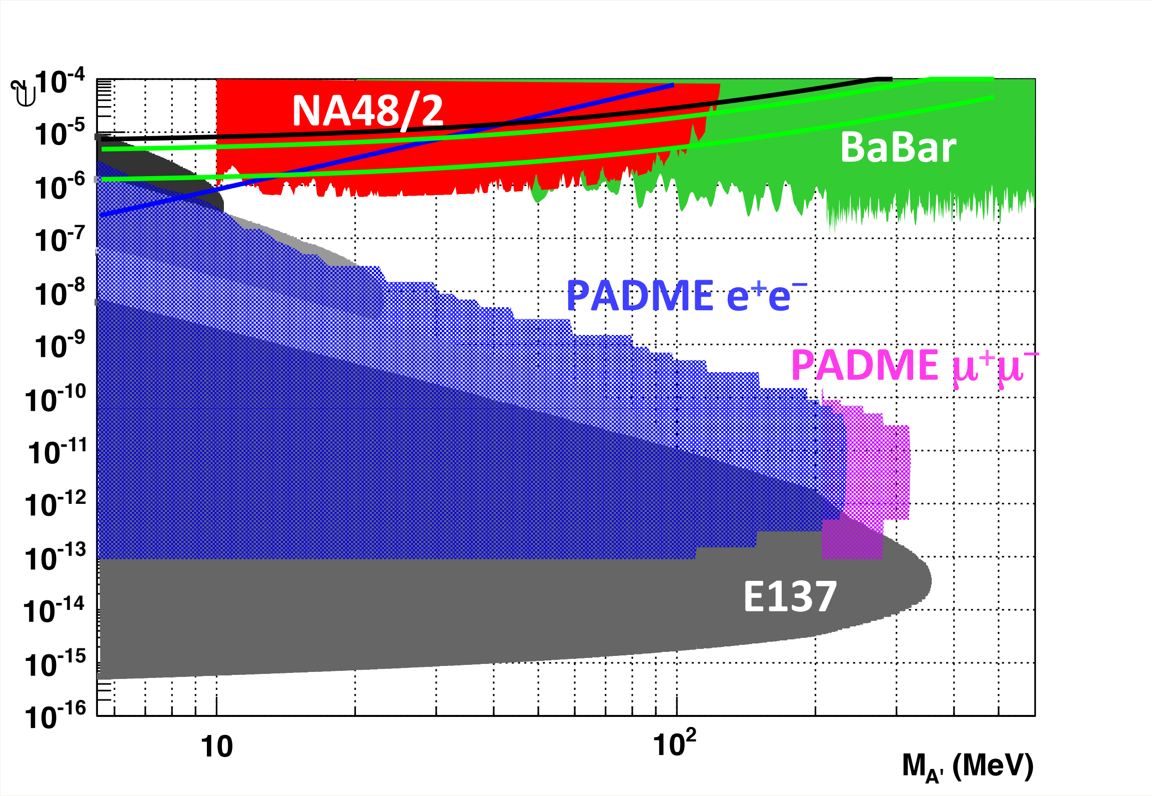
- Trigger and clock distribution to the 33 boards
- Online FADC zero suppression (L0)
- FADC boards synchronization to few 100ps needed

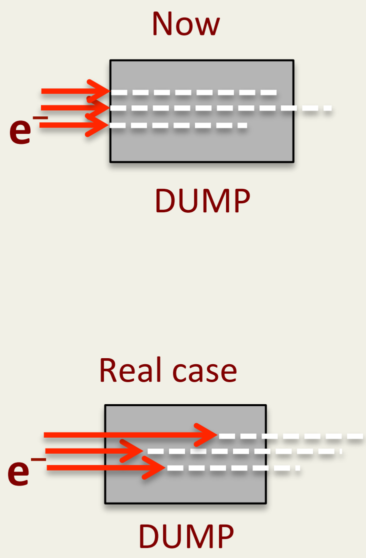
Decay to invisible signal selection

- Only one cluster in calorimeter
  - Rejects $e^+e^- \to \gamma\gamma$, $e^+e^- \to \gamma\gamma(\gamma)$ final states
- 30 mrad < θ_{Cl} < 65 mrad
  - Improve shower containment $\sigma(E)/E$
- Positron veto: no tracks in the spectrometer in ±2 ns
  - Reject background from Bremsstrahlung identifying primary positrons
- Photon veto: no γ with E_γ>50 MeV in time in ±1 ns in the additional small angle veto (SAV), covering the hole acceptance
- Cluster energy within: $E_{min}(M_{A'}) < E_{Cl} < E_{max}(M_{A'})$ MeV
  - Removes low energy bremsstrahlung photons and piled up clusters
- Missing mass in the region: $M^2_{miss} \pm \sigma(M^2_{miss})$

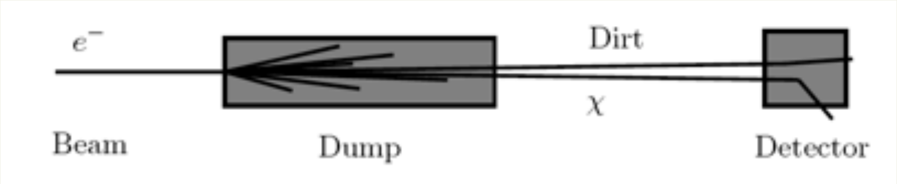
PADME-dump

- **10^{20} EOT, 1.2 GeV**; 20 cm aperture at 50 cm from 8 cm W dump
- Zero background hypothesis, in depth production to be refined, not yet a sensitivity plot



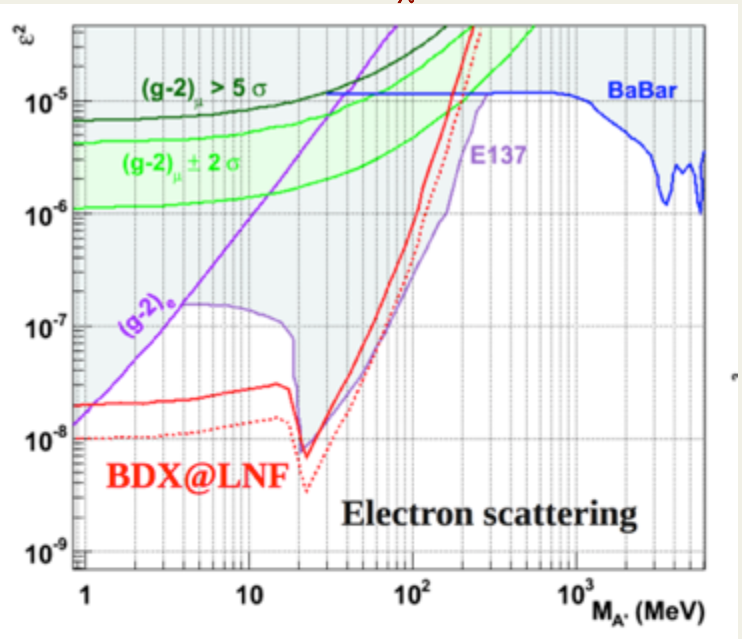


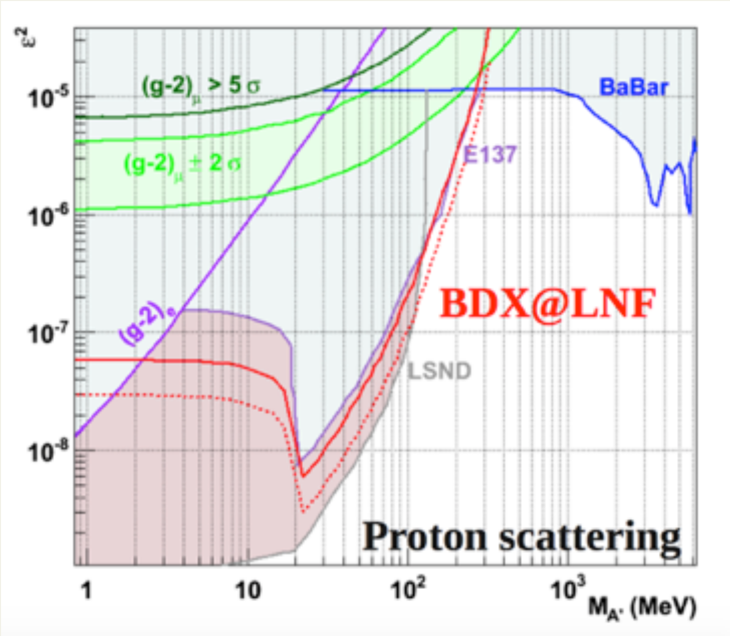
BDX @ LNF



From **A. Celentano**
Acceptance limit at ≈100 MeV coming from beam energy

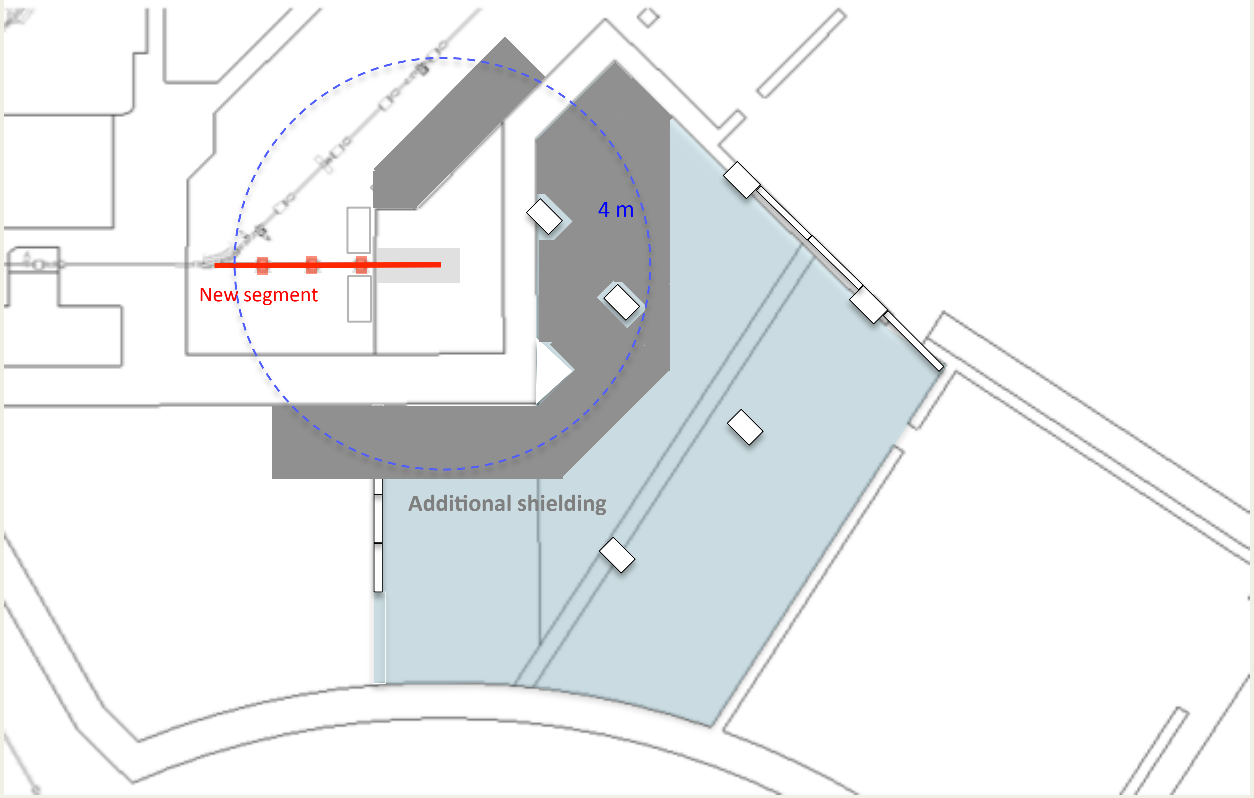
α_D=0.1 m_χ=10 MeV





Beam energy **1.2 GeV** (e^-)
CsI detector 60×60×225 cm^3 built with crystals from dismounted BaBar calorimeter?

LINAC beam dump



- A new **thin vacuum chamber**
- A straight vacuum pipe to the inside of the existing dump cavity
- **Additional shielding** for copying with neutron production
- Use **DR pumps hall** for shielding and experiment

DR pumps hall