

Searches for New Light Physics with A2@MAMI

1st Workshop on New Light Physics and Photon-beam Experiments

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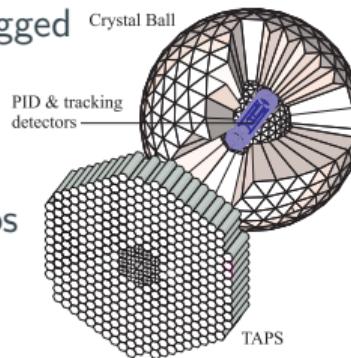


Discuss possible New Physics searches with A2@MAMI

Experimental setup

High intensity tagged photon beam

Excellent E/pos resolution



Possible NP searches

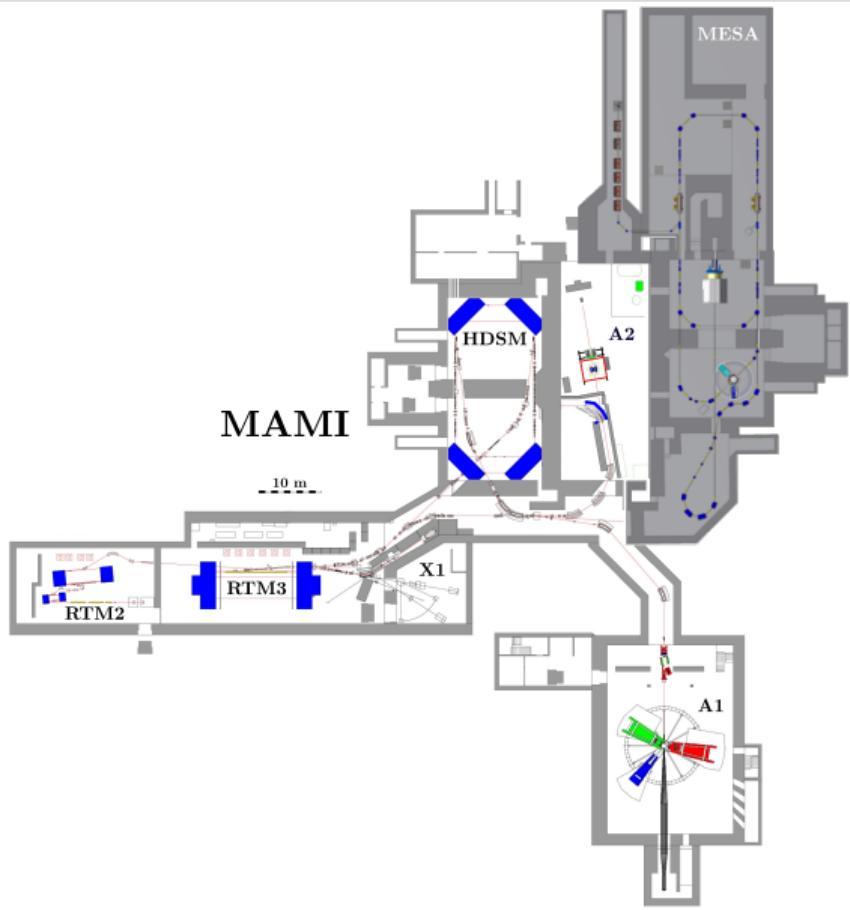
- ALP in Primakoff production
- In η/η' decays

Experimental setup

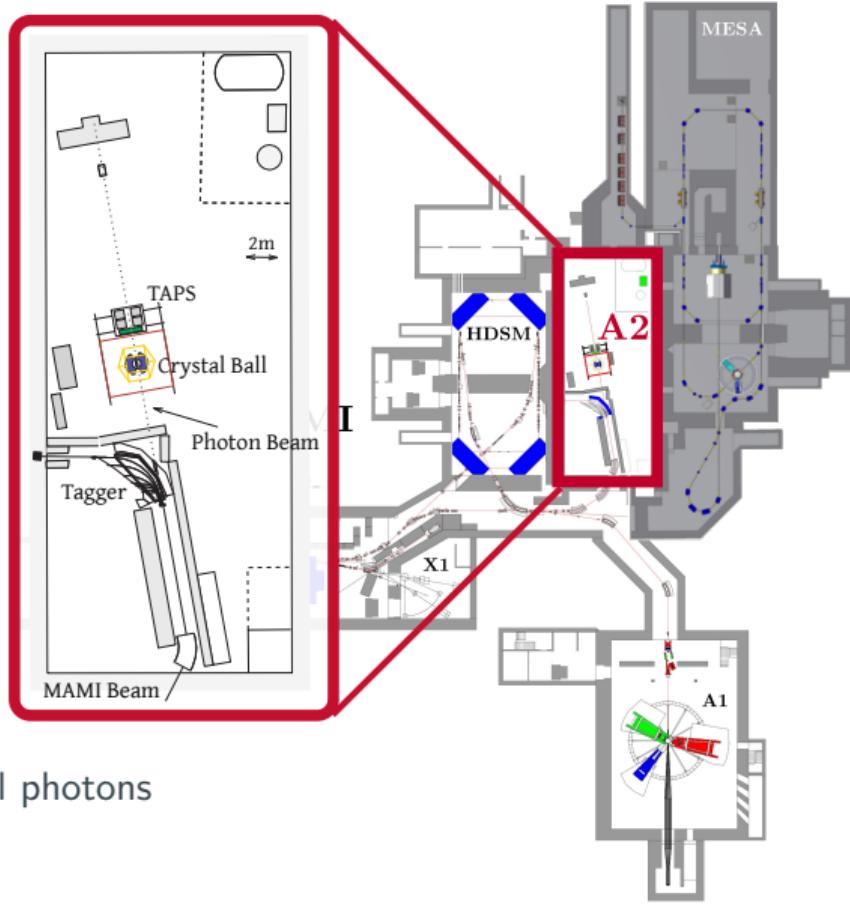
A2 experiment - The Mainz Microtron

A2

- Continuous electron beam
- Acceleration stages
 - Linac and 3 RTMs $\rightarrow E_{e^-}^{\max}$ 855 MeV
 - HDSM $\rightarrow E_{e^-}^{\max}$ 1508 MeV
- Polarised or unpolarised electrons
- $I_{e^-}^{\max}$ 20 μA or 100 μA (pol/unpol)



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A2 experimental hall

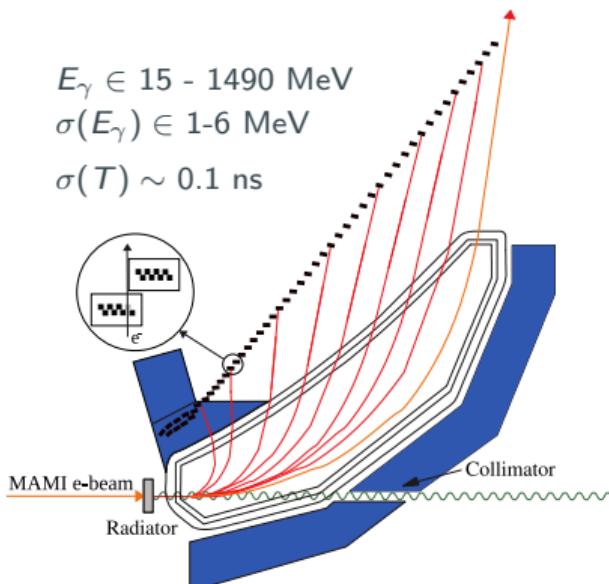
- $I_{e^-}^{\max} \sim \text{nA}$ and $E_{e^-}^{\max}$ 1604 MeV
- High precision nuclear experiments with real photons

A2 experiment - Photon beam

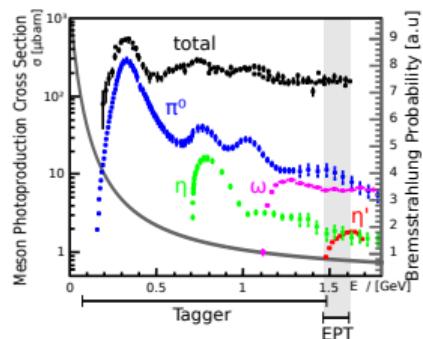
A2

Glasgow-Mainz Tagger

Update finalised 2019



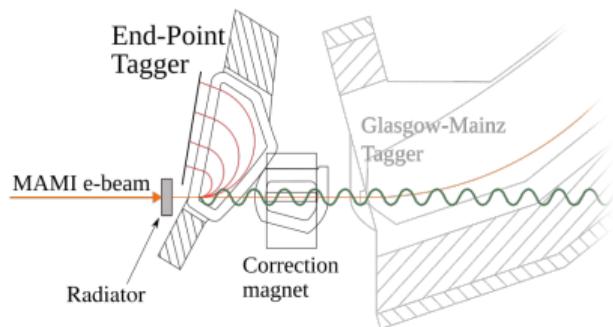
Energy



End Point Tagger

Supplemental for higher E_γ

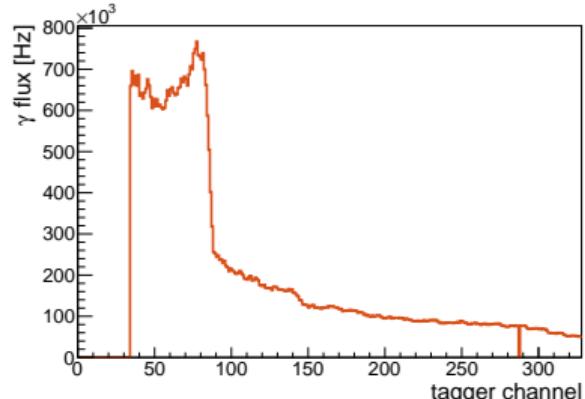
$E_\gamma \in 1420 - 1580$ MeV
 $\sigma(E_\gamma) \sim 1.5$ MeV



Flux

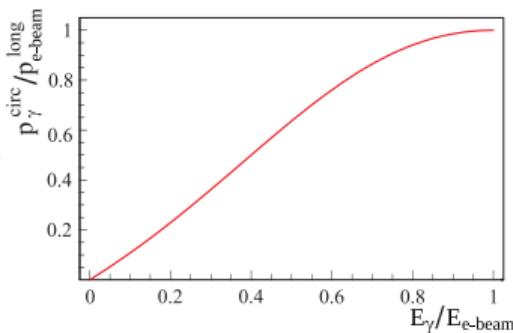
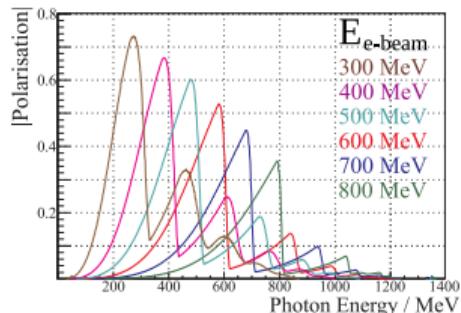
Depends on polarisation,
energy and collimator size

Example: High intensity run in 2018
 $\sim 6.2 \times 10^7 \gamma/\text{s}$



Polarisation

- None: Unpolarised e^- -beam + amorphous radiator
- Linear:
 Unpolarised e^- -beam
 + crystalline radiator
- Circular:
 Polarised e^- -beam
 + amorphous radiator



Unpolarised targets

- Liquid hydrogen/deuterium
 $d = 70.548(10)/163.24(2) \times 10^{-3} \text{ g/cm}^3$
 $L = 30.2(3), 47.2(5) \text{ or } 100(1) \text{ mm}$



- ${}^3\text{He}/{}^4\text{He}$
- Solid targets - C, Al, Pb,...

Frozen spin target

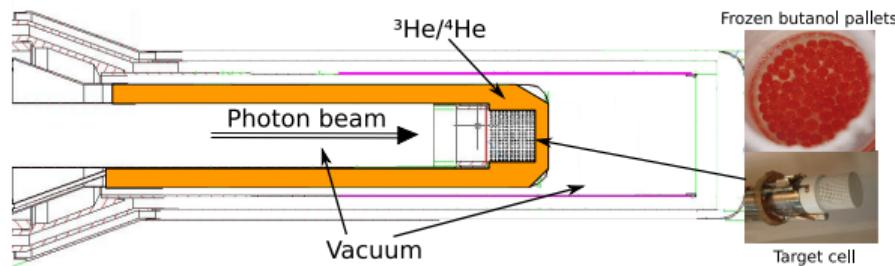
(Deuterated) butanol + Dynamic Nucleon Polarisation
→ polarised (neutrons)protons

$$P_p^{\text{avg}} = 70 \% \quad \delta P_p/P_p = 2 - 3 \%$$

$$P_n^{\text{avg}} = 50 \% \quad \delta P_n/P_n = 4 - 5 \%$$

Relaxation time $\sim 1 \text{ week}$

$$L = 20 \text{ mm}$$



Crystal Ball

Highly segmented EM calorimeter

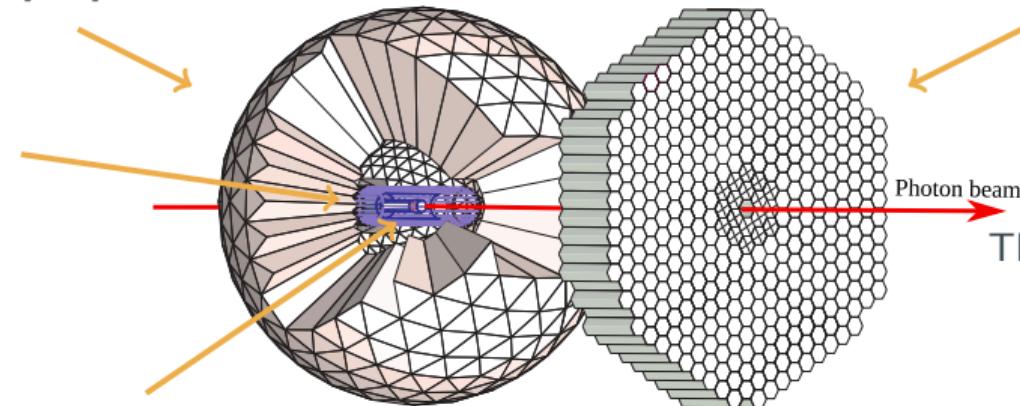
$$\Delta E/E = 0.020 \cdot E[\text{GeV}]^{0.36}$$

$$\sigma_\phi = \sigma_\theta / \sin \theta$$

$$\sigma_\theta = 2 - 3^\circ$$

Particle ID

Barrel of thin scintillators
 $\Delta\phi = 15^\circ$



Multiwire Proportional Chambers

Precise charged tracking/positioning

$$\sigma_\theta \sim 2^\circ$$

$$\sigma_\phi \sim 3^\circ$$

TAPS

Highly segmented EM calorimeter

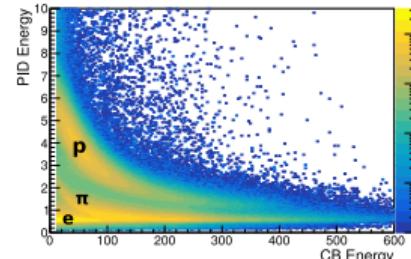
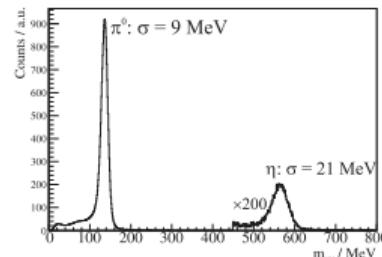
$$\Delta E/E = 0.018 + 0.008/E[\text{GeV}]^{0.5}$$

$$\sigma_\phi = 14 \dots 0.95^\circ$$

$$\sigma_\theta < 1^\circ$$

TAPS-Veto

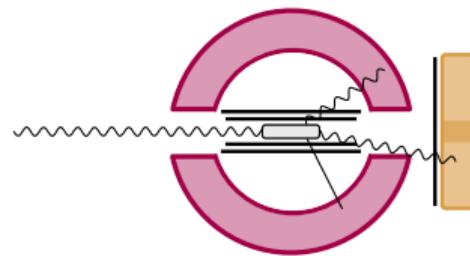
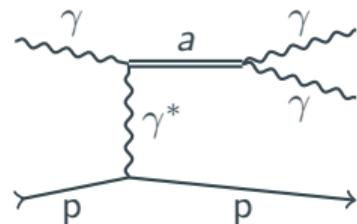
Thin scintillators before each TAPS crystal



Studies

Axion-like particles

Primakoff process:

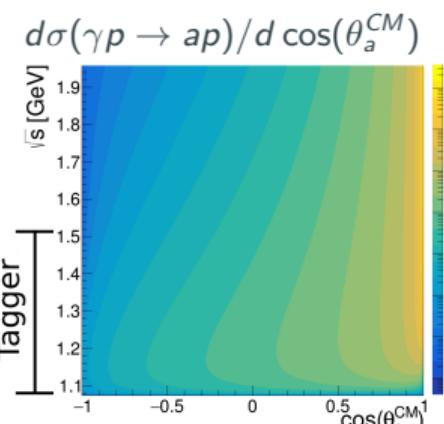
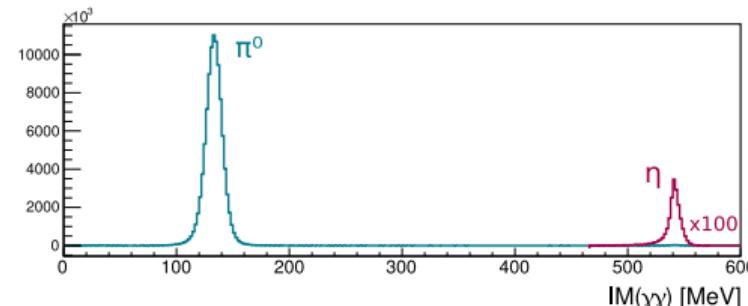


η and η' decays

- Large existing and future data-sets
- Highlight existing studies usable for NP searches
 - $\eta \rightarrow \pi^0 \gamma \gamma$
 - $\eta \rightarrow \pi^0 \pi^0 \pi^0$
 - $\eta' \rightarrow \eta \pi^0 \pi^0$



Available data (2018)
High statistics π^0 study

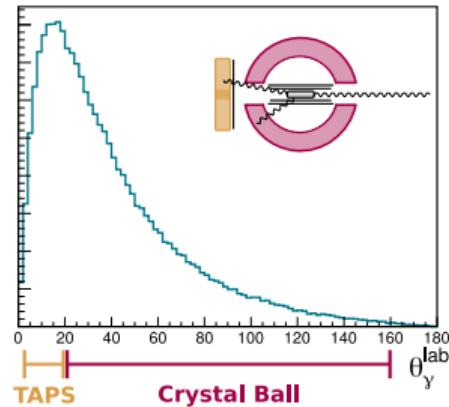


Signal dynamics

- $\frac{d\sigma}{d \cos(\theta)}$ in simulation
- Good detector coverage

Signal selection - ongoing project

$a \rightarrow \gamma\gamma - \theta^{lab}$ distribution




Old η -data (2007/2009)

- $6 \times 10^7 \eta$
- Many A2-publications

 η' -data (2014)

- $\sim 6 \times 10^6 \eta'$
- Special tagger developed

New η -data (2019)

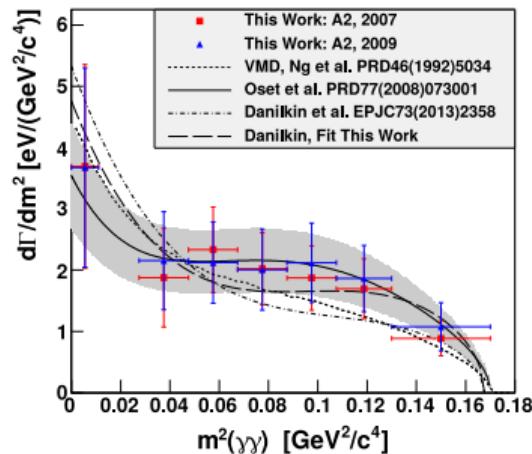
- $\sim 2\text{-}3$ times old data
- Goal: collect 3 times more

	Old η -data	New η -data	η' -data
$E_{\gamma beam}^{max}$:	$E_{Thr}^\eta + 695/740 \text{ MeV}$	$E_{Thr}^\eta + 780 \text{ MeV}$	$E_{Thr}^{\eta'} + 130 \text{ MeV}$
Trigger:	$E_{CB} > 320/340 \text{ MeV}$ + cluster multiplicity	$E_{CB} > 480 \text{ MeV}$	$E_{CB} > 540 \text{ MeV}$

A2 publication

[A2, Phys. Rev. C90(2) (2014) 025206]

- Old η data set
- 1.2×10^3 events measured
- Most precise results on $d\Gamma(\eta \rightarrow \pi^0 \gamma\gamma)/dm^2(\gamma\gamma)$



Possible new physics search

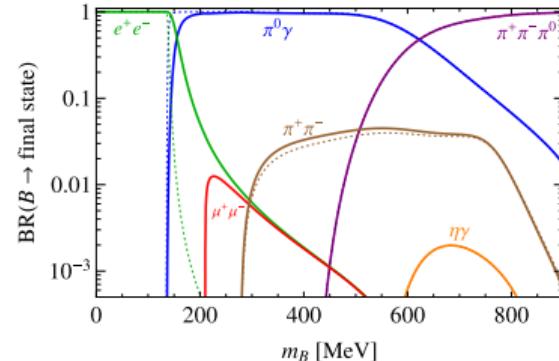
- Exclusion limit for hadrophilic S-boson *generalised* models

$$\eta \rightarrow \pi^0 S \rightarrow \pi^0 \gamma\gamma$$

- Exclusion limit for leptophobic B-boson

$$\eta \rightarrow B\gamma \rightarrow \pi^0 \gamma\gamma$$

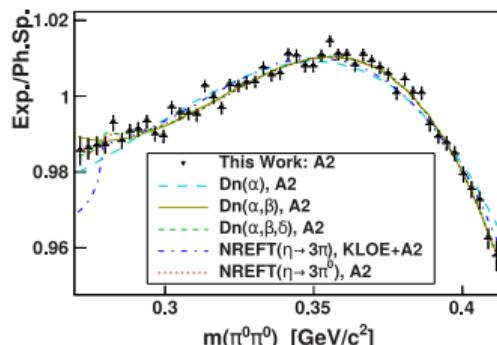
[Phys. Rev. D89 (2014) 114008]



A2 publication

[A2, Phys. Rev. C97 (2018) 065203]

- Old η data set
- 7×10^6 events measured
- Most precise study of dynamics
 - Parametrisation of Dalitz plot density
 - Cusp from $\pi^+\pi^- - \pi^0\pi^0$

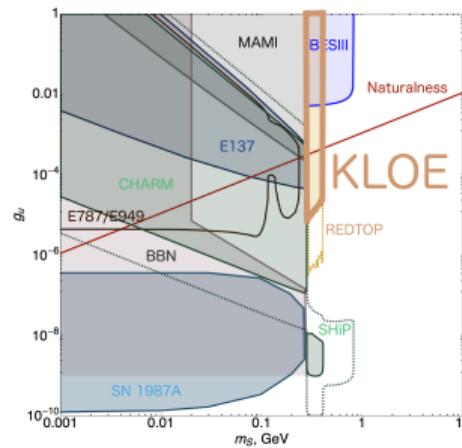


Possible new physics search

Exclusion limit for up/hadro-philic S-boson

$$\eta \rightarrow \pi^0 S \rightarrow \pi^0 \pi \pi$$

[Phys. Rev. D100 (2019) 095020]

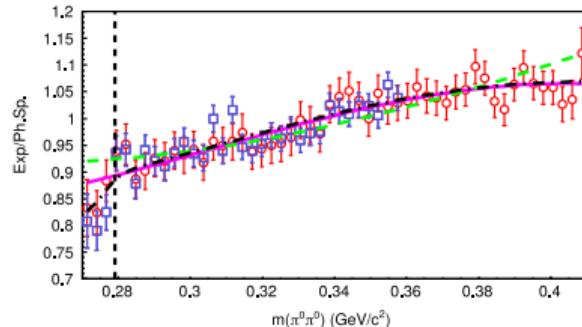


$\eta \rightarrow \pi^0\pi^+\pi^-$
Dalitz plot result
 4.7×10^6 events

A2 publication

[A2, Phys. Rev D98 (2018) 012001]

- η' -data set
- 1.2×10^5 events measured
- Most precise study of dynamics
 - Parametrisation of Dalitz plot density
 - Cusp from $\pi^+\pi^- - \pi^0\pi^0$

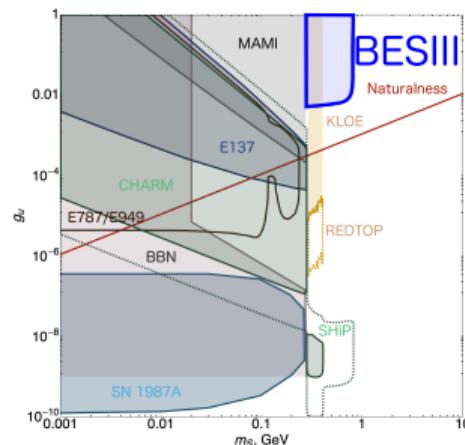


Possible new physics search

Exclusion limit for up/hadro-philic S-boson

$$\eta' \rightarrow \eta S \rightarrow \eta\pi\pi$$

[Phys. Rev. D100 (2019) 095020]

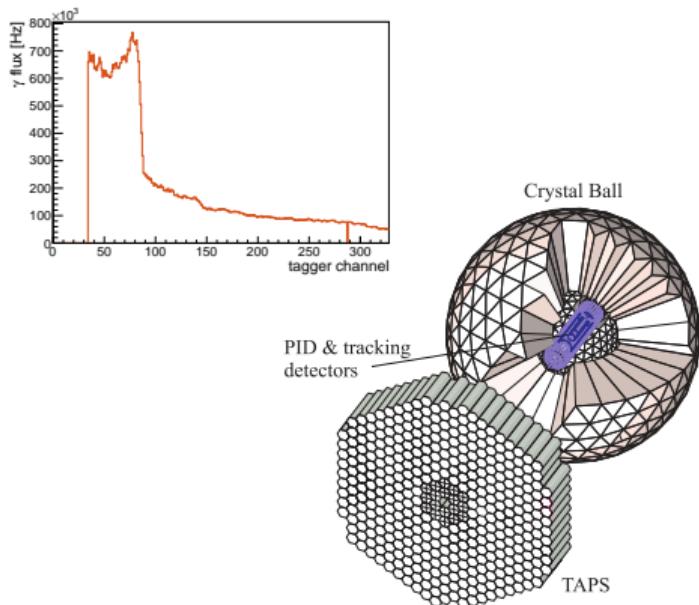


$\eta' \rightarrow \pi^0\pi\pi$
BR result

Summary

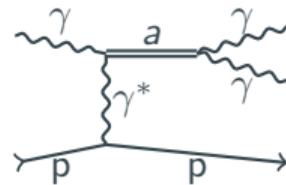
Searches for New Physics in the MeV to GeV region

A2 experimental setup



Possible new physics searches

- Axion-like particles in Primakoff production

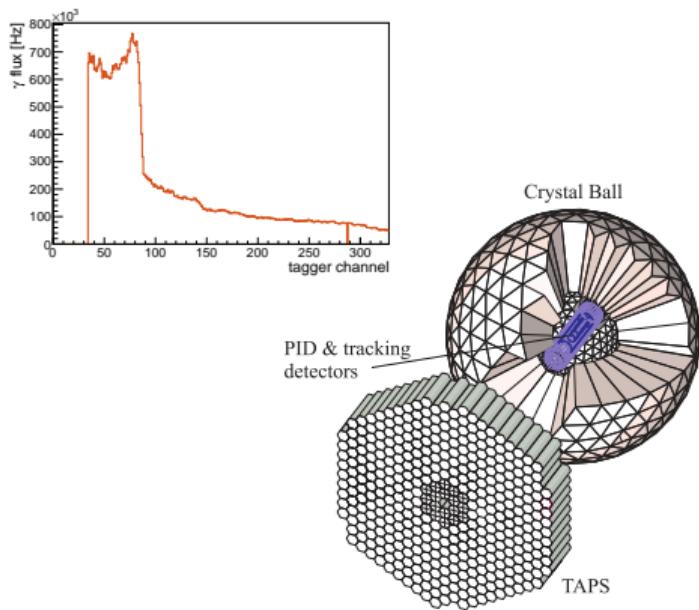


- η and η' decays

- $\eta \rightarrow \pi^0 \gamma \gamma$
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- $\eta' \rightarrow \eta \pi^0 \pi^0$

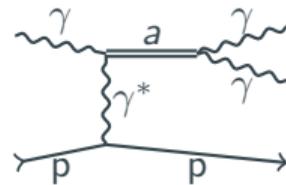
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Thank you for
your attention