Najnowsze wyniki z eksperymentu WASA-at-COSY: produkcja i rozpady mezonu η.

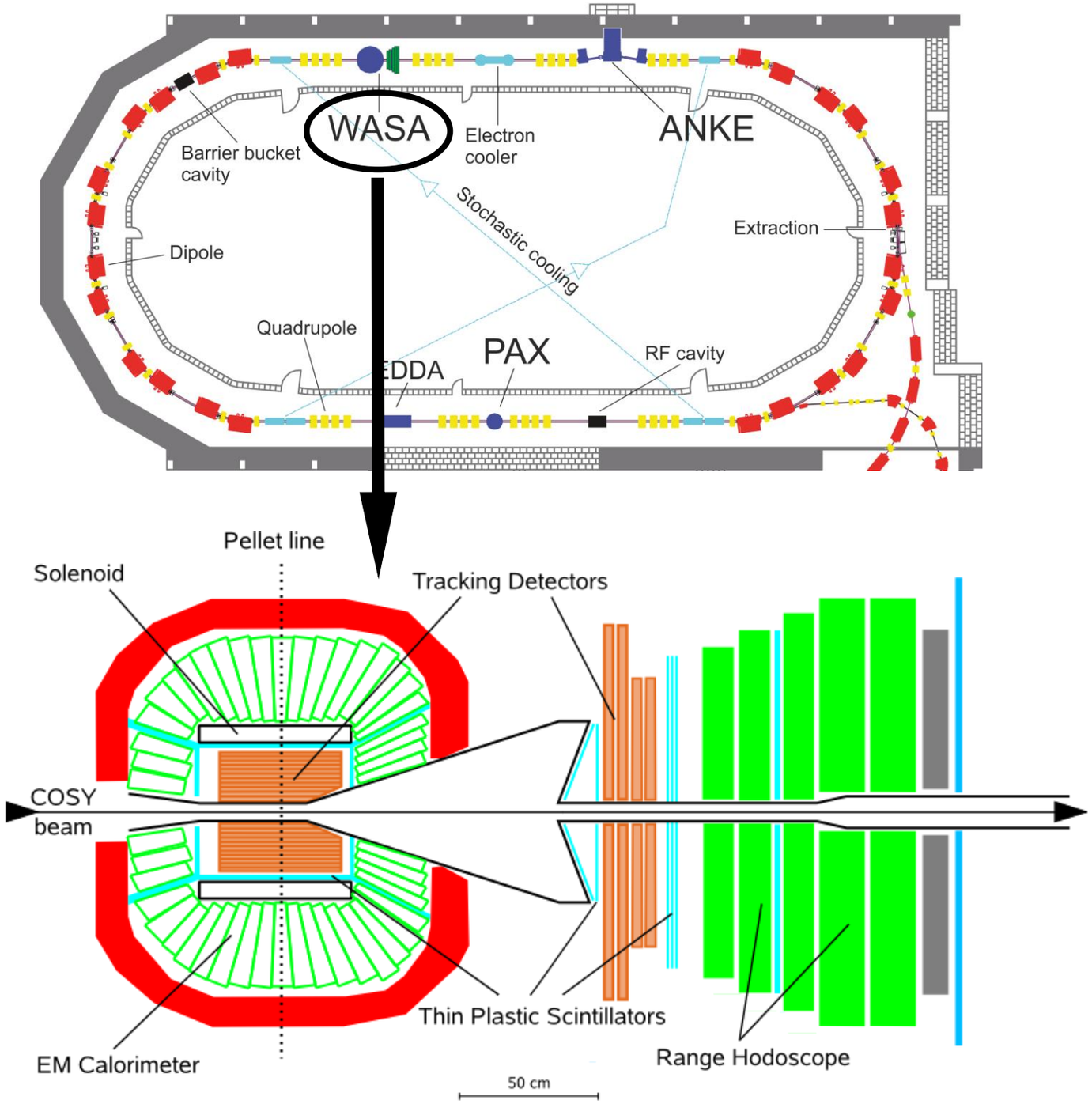
Recent results from WASA-at-COSY experiment:
η meson production and decays.

Damian Pszczel

WASA-at-COSY experiment

- **CO**oler **SY**nchrotron: polarised and unpolarised beams of protons and deuterons 0.3 - 3.7 GeV/c incident momentum

- **W**ide **A**ngle **S**hower **A**pparatus:
  - fixed internal (pellet) target experiment
  - CD with almost 4π coverage measures charged and neutral decay products
  - FD measures scattered particles

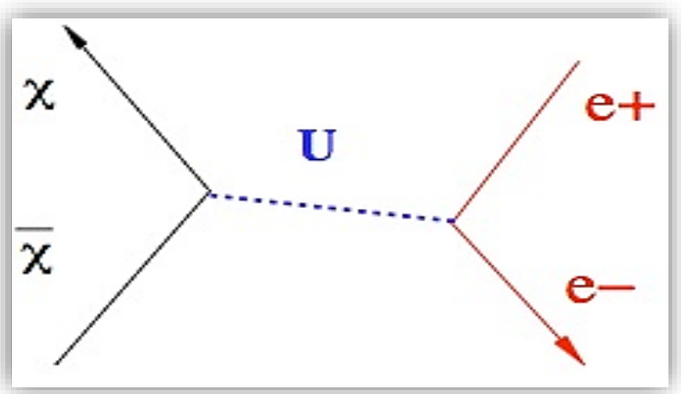


Motivation for physics beyond the standard model : dark matter

- Astrophysical anomalies:
  SPI/INTEGRAL, PAMELA, AMS, FERMI-LAT, HESS, ATIC
- Magnitudes and energy distributions of e^+ and e^-
- 511 keV photons from galaxy center

<u>Hypothesis</u>:

- Positrons created in annihilations of dark particles into e^+e^-, mediated by a hypothetical new „light” boson



ArXiv: 1304.0833v8 [astro.ph-IM] April 24, 2018

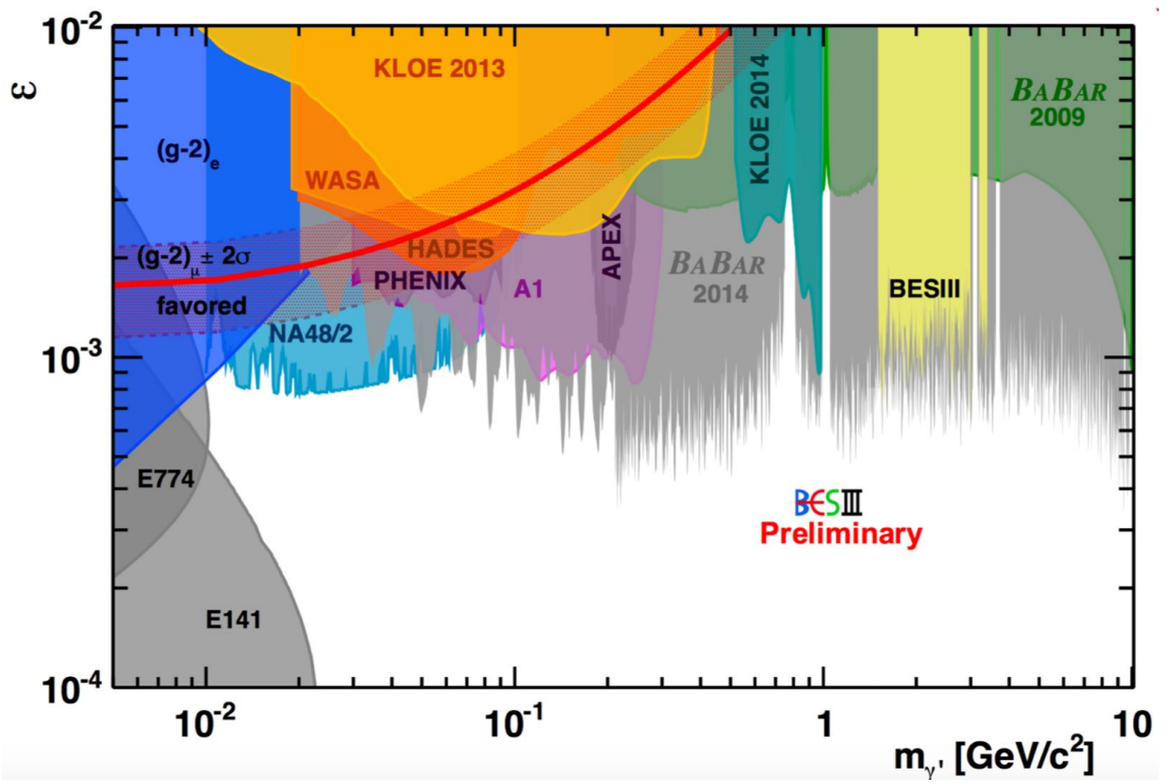
U boson = γ_{DARK}

- New „dark” gauge symmetry: the associated gauge boson U, with mass M_U, couple to SM through the kinetic small mixing term in the Lagrangian:

$$L_{mix} = \frac{1}{2}\,\varepsilon\, F_{\mu\nu}^{QED} F^{\mu\nu}_{DARK}$$

- U boson is also called „dark photon” since it can mix with SM photon in all processes

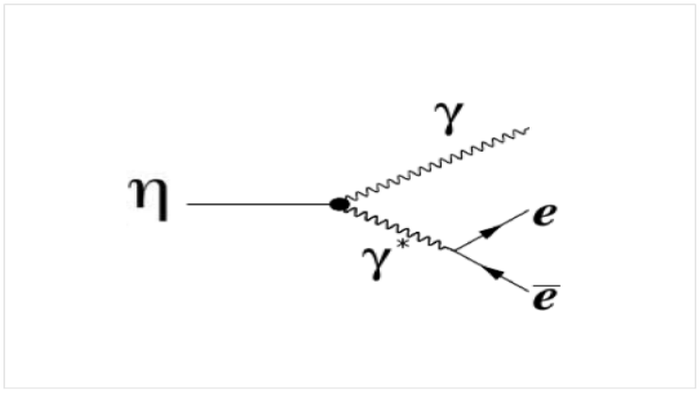
($\varepsilon=\sqrt{(\alpha'/\alpha)}$, M_U)

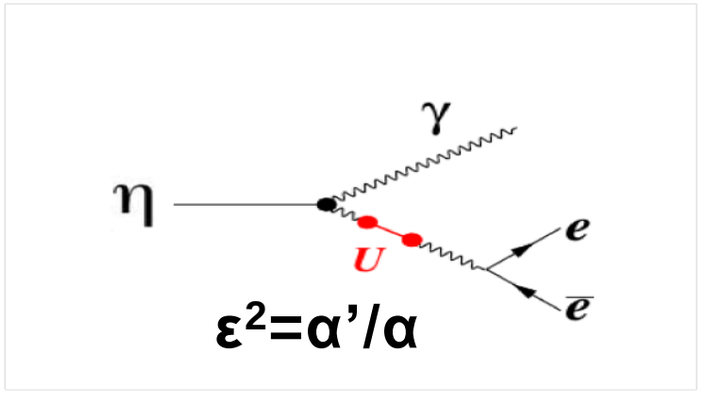


BESIII, Dayong Wang, *Int. J. Mod. Phys. Conf. Ser.* **46**, 1860046 (2018)

WASA-at-COSY search for the dark photon in $pp \rightarrow pp\pi^0(\rightarrow e^+e^-\gamma)$

- Dark photon signature could be observed in meson Dalitz decays $\pi^0/\eta \rightarrow e^+e^-\gamma$

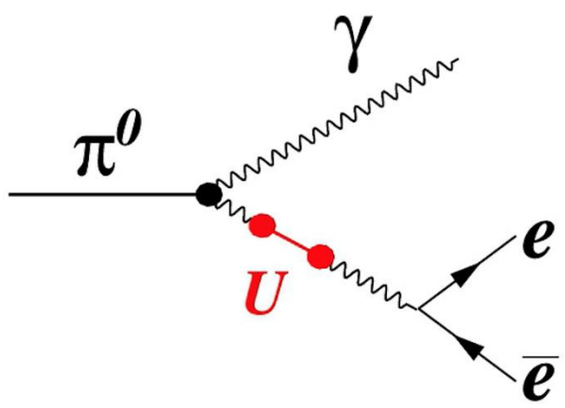


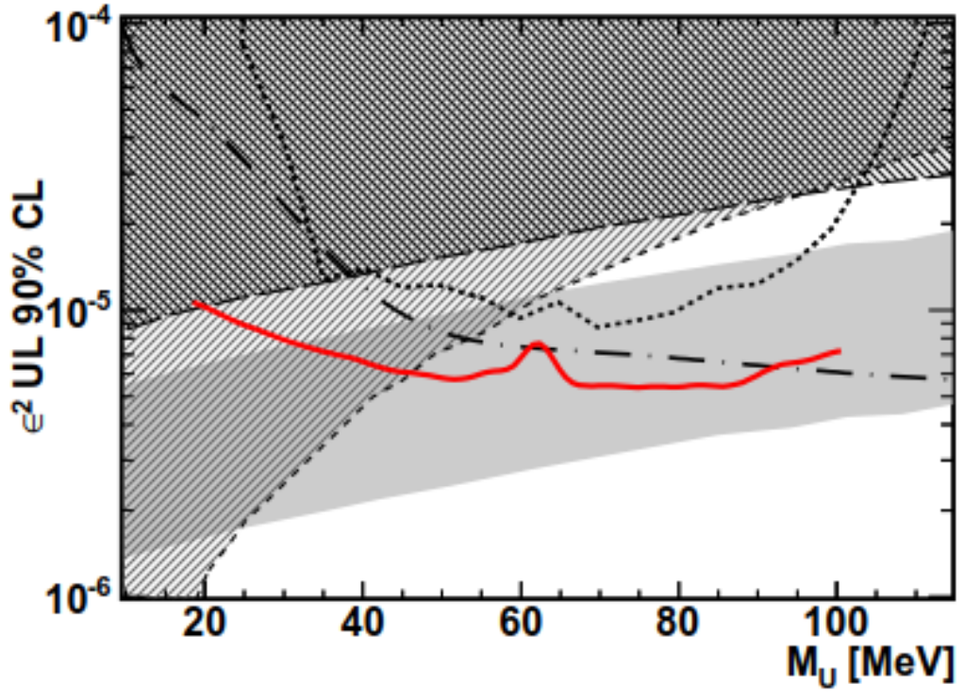


- $pp \rightarrow pp\pi^0(\rightarrow e^+e^-\gamma)$ WASA-at-COSY analysis published in Phys. Lett. B 726 (187-193) 2013

127 citations

Limit on $\varepsilon^2=f(M_U)$ at 90% CL





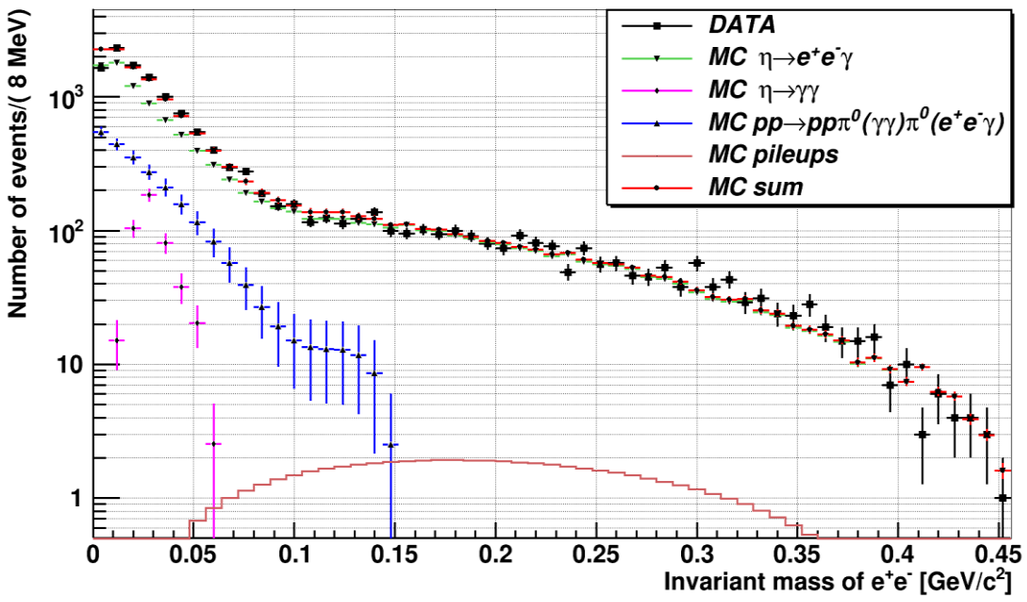
WASA-at-COSY search for the dark photon in $pp \to pp\eta(\to e^+e^-\gamma)$

- $\eta \to e^+e^-\gamma$ analysis completed and described in Damian Pszczel PhD

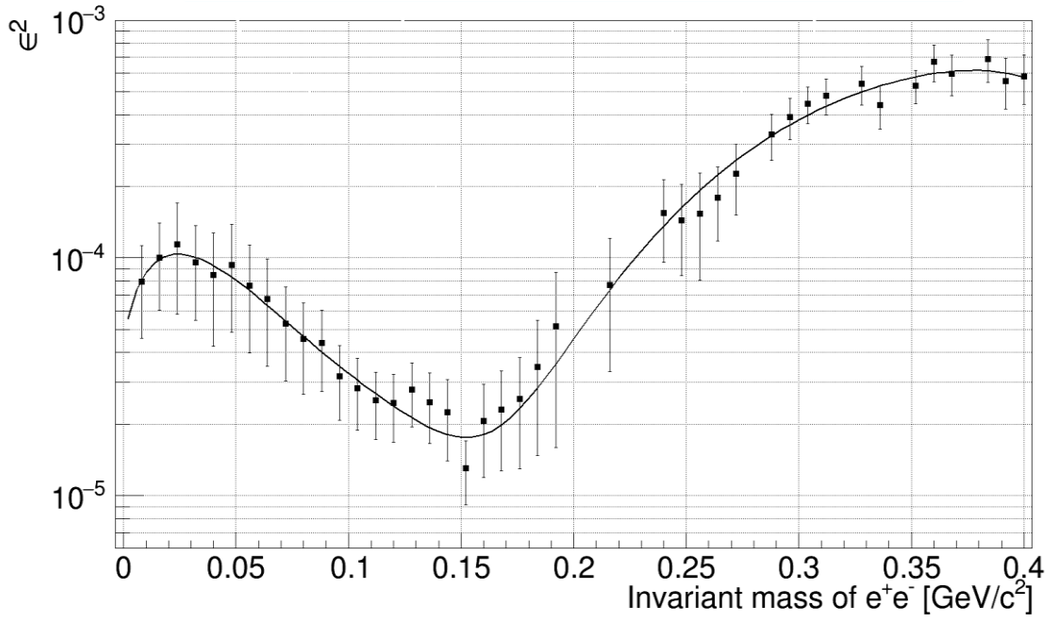
  ✚ $M_\eta > M_{\pi 0}$ $548 > 135$ [MeV/c^2]

  ▬ $N_{\eta Dal} << N_{\pi Dal}$ $10^4 << 5 \cdot 10^5$

- We scan the e^+e^- invariant mass spectrum, for each IM_{ee} (M_U), probability of non-SM events admixture depends on $BR(\eta \to U(\to e^+e^-)\gamma)$ thus ε



Limit on $\varepsilon^2 = f(M_U)$ at 90% CL



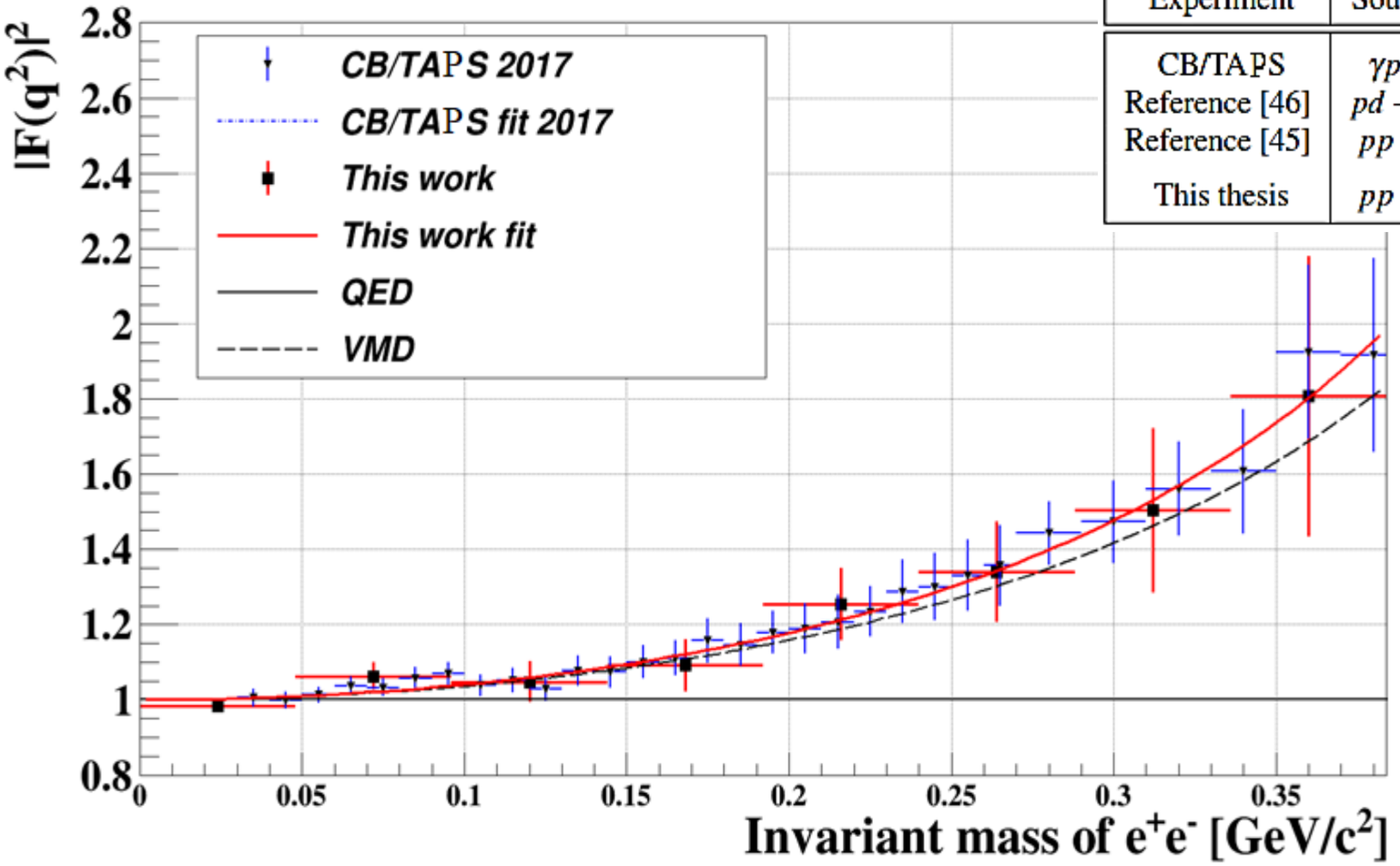
Transition form factor of η meson

- Mesons are composite objects - TFF function contains all the information about their inner electromagnetic structure

$$\frac{d\sigma}{dq^2} = \left|\frac{d\sigma}{dq^2}\right|_{QED} \left|F(q^2)\right|^2$$

q^2: invariant mass of e^+e^-

- We measure the ratio between data ($\eta \to e^+e^-\gamma$ selected candidates) and pure QED simulation (pointlike particles)



Experiment	Source of η	$\eta \to e^+e^-\gamma$ candidates	Λ^{-2} [GeV^{-2}]
CB/TAPS	$\gamma p \to \eta p$	$5.4 \cdot 10^4$	$(1.97 \pm 0.11_{\text{tot}})$
Reference [46]	$pd \to {}^3He\eta$	$5.2 \cdot 10^2$	$(2.27 \pm 0.73_{\text{stat}} \pm 0.46_{\text{sys}})$
Reference [45]	$pp \to pp\eta$	$3.1 \cdot 10^3$	$(1.9 \pm 0.33_{\text{stat}})$
This thesis	$pp \to pp\eta$	$1.1 \cdot 10^4$	$1.97 \pm 0.29_{\text{stat}}{}^{+0.13_{\text{sys}}}_{-0.23_{\text{sys}}}$

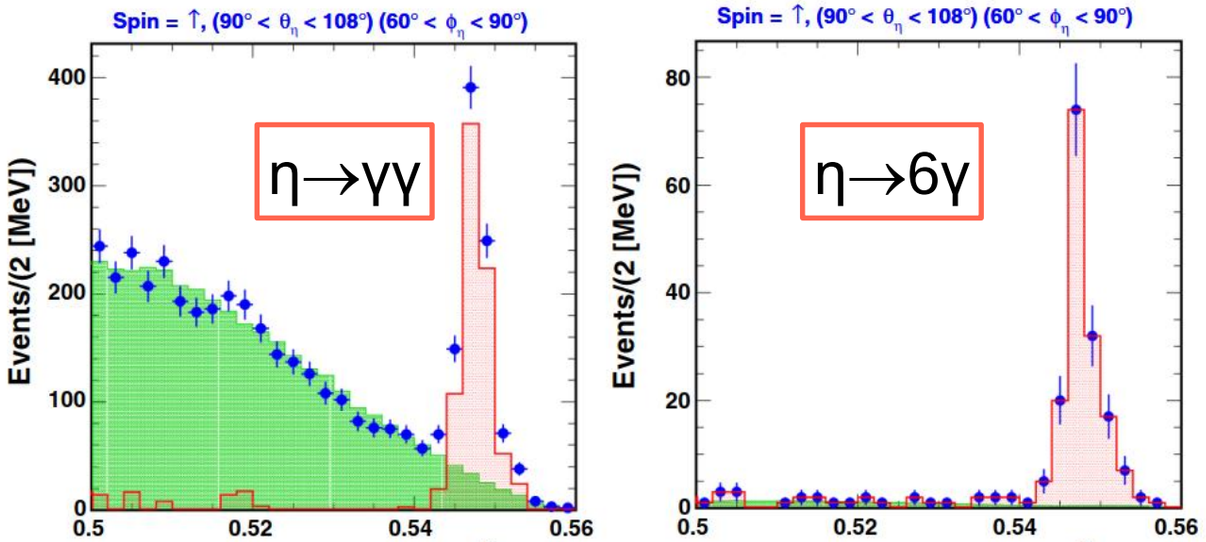
Second most precise measurement worldwide

Publication in progress

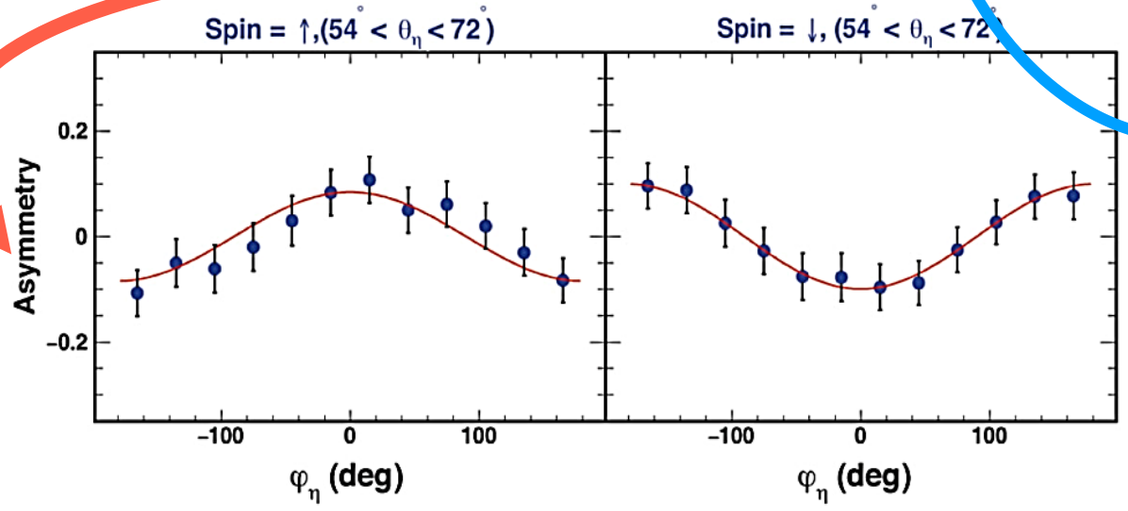
Spin dependence of η meson production

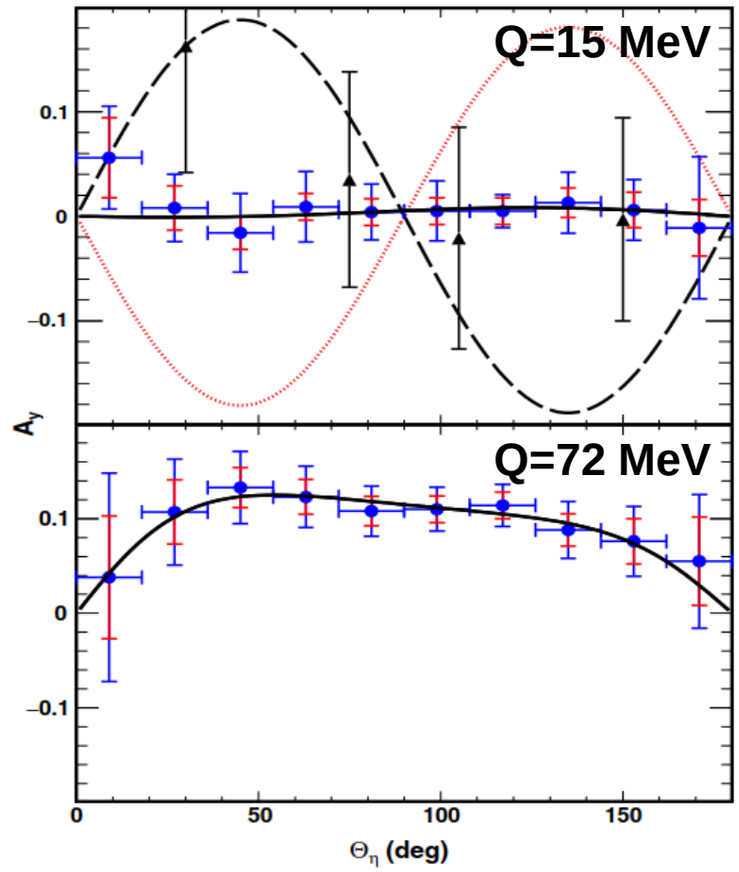
Phys. Rev. Lett. 120 (2018), 022002

- *p*p →ppη close to threshold (Q = 15 MeV and 72 MeV)
- Two spin orientations *p* ↑ and *p* ↓
- Two channels: η→γγ and η→3π^0→6γ



- η meson production yields $N_\eta(\theta_\eta,\phi_\eta)$
- The analyzing power $A_y(\theta_{\eta\,CMS})$ was determined from the assymetry of N_η





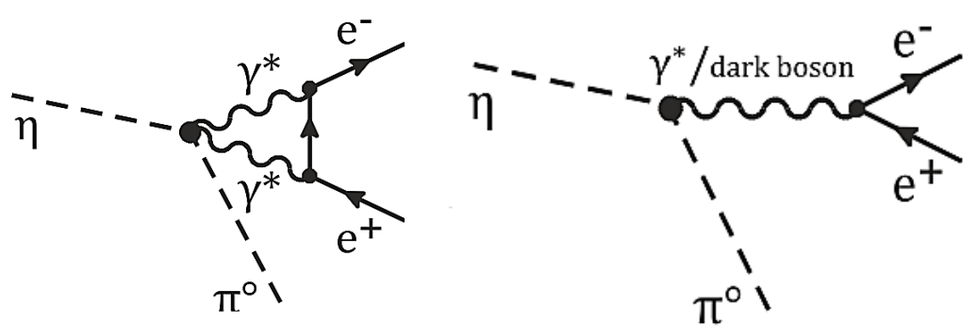
η meson production in pure s wave

Evidence of higher partial waves waves

Analysis of C-violating $\eta \to \pi^0 e^+ e^-$ from $pd \to {}^3He\eta$

Phys. Lett. B 784 (2018) 378-384

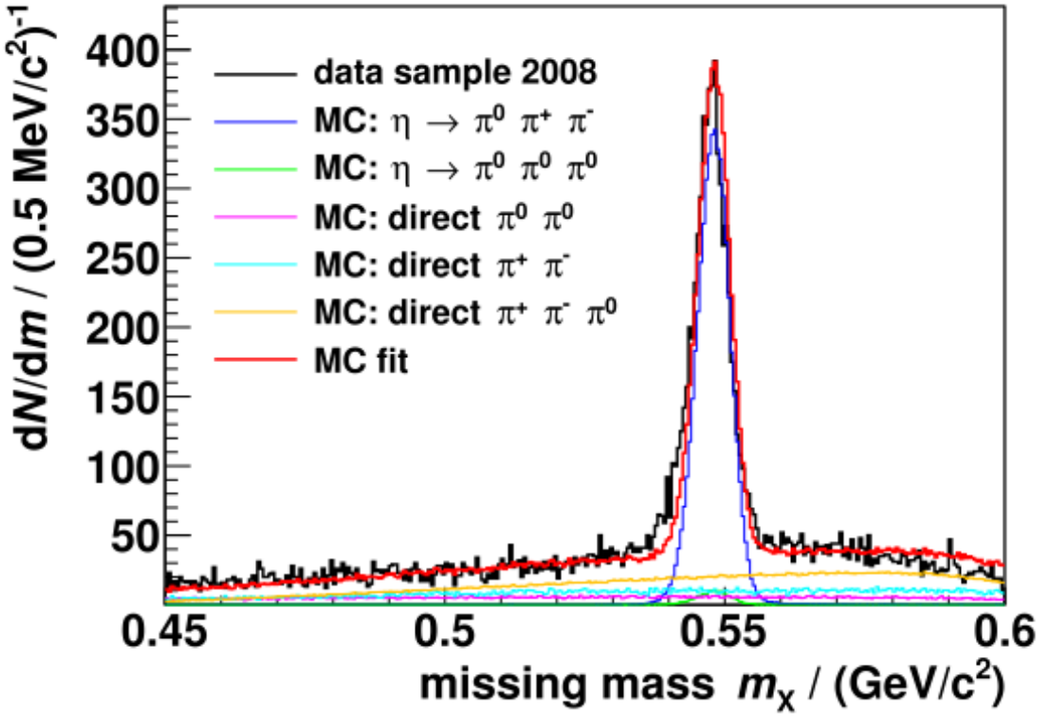
- $\eta \to \pi^0 \gamma^* \gamma^* \to \pi^0 e^+ e^-$ conserve C-parity:
  $C(\pi^0/\eta)=+1$, $C(\gamma)=-1$,
  expected theoretical BR ~ 10^{-9} – 10^{-12}



- $\eta \to \pi^0 \gamma^* \to \pi^0 e^+ e^-$ violate C-parity

- Current BR experimental limit < $4 \cdot 10^{-5}$ (90% CL): 4 orders of magnitude between exp. and SM theory…
  physics beyond SM?

- W@C upper limit from $pd \to {}^3He\eta$:
  $BR(\eta \to \pi^0 e^+ e^-) < 7.5 \cdot 10^{-6}$ (90 % CL)



$m_x = |\mathbf{P}_p + \mathbf{P}_d - \mathbf{P}_{^3He}|$

pp→ppη data: analysis in progress

Publication record (2018)

1. *Spin dependence of η meson production in proton-proton collisions close to threshold*, Phys. Rev. Lett. 120 (2018), 022002

2. *Search for C violation in the $\eta \to \pi^0 e^+ e^-$ decay with WASA-at-COSY*, Phys. Lett. B 784 (2018) 378-384

3. *Isotensor dibaryon in the $pp \to pp\pi^+\pi^-$ reaction?*, Phys. Rev. Lett. 121 (2018), 052001

4. *Importance of d-wave contributions in the charge symmetry breaking reaction $dd \to {}^4He\pi^0$*, Phys. Lett. B 781 (2018), 645-650

5. *Total and differential cross sections of η-production in proton–deuteron fusion for excess energies between Q_η = 13 MeV and Q_η = 81 MeV*, Phys. Lett. B 782 (2018), 297-304

6. *Search for a new light boson in meson decays*, Damian Pszczel PhD thesis (2018)

Upcoming: $\eta \to e^+e^-\gamma$ transition form factor results, $\eta \to e^+e^-$

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PHYSICAL REVIEW LETTERS **120,** 022002 (2018)

Spin Dependence of η Meson Production in Proton-Proton Collisions Close to Threshold

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(WASA-at-COSY Collaboration)

Physics Letters B 784 (2018) 378–384

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Search for C violation in the decay $\eta \to \pi^0 e^+ e^-$ with WASA-at-COSY

The WASA-at-COSY Collaboration

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