A heavy ion flashlight for discovering axions

Tom Melia, Berkeley

with Simon Knapen, Tongyan Lin, Tim Lou

A heavy ion flashlight for discoing axions

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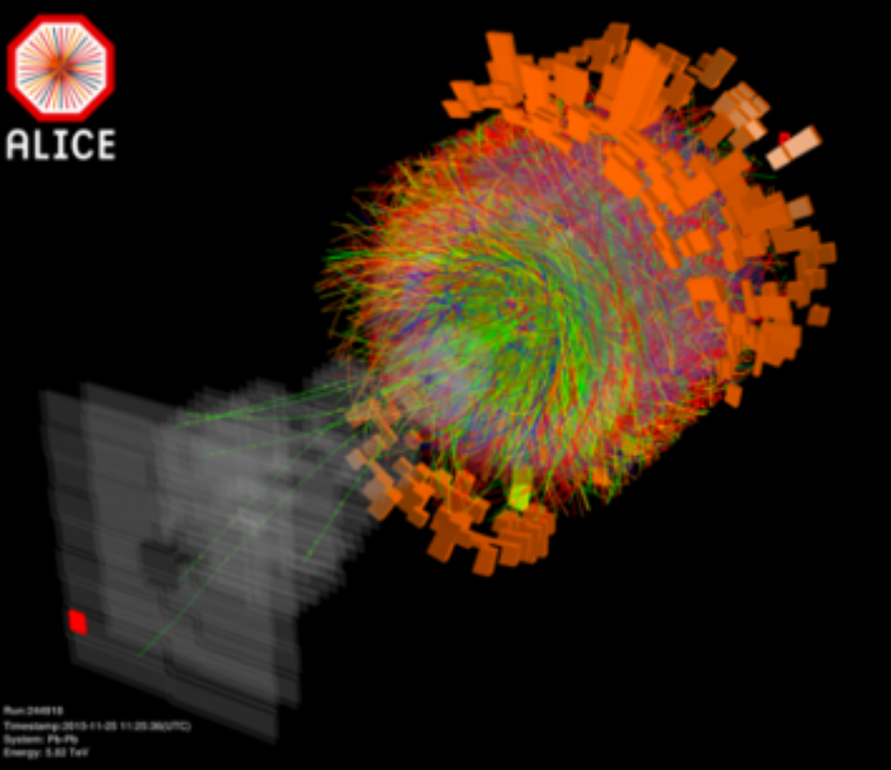
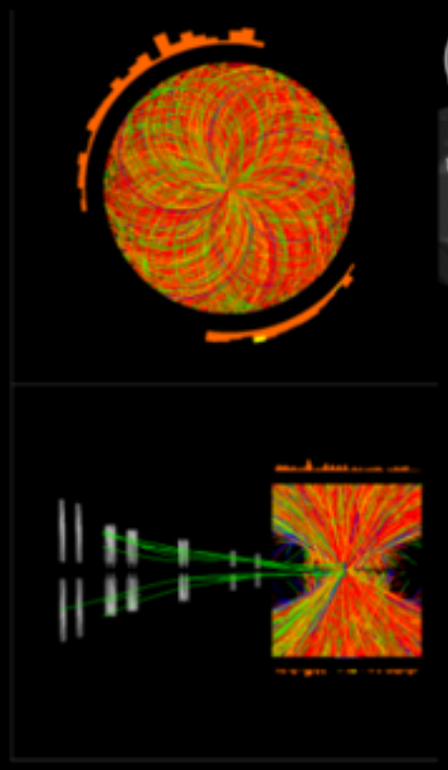
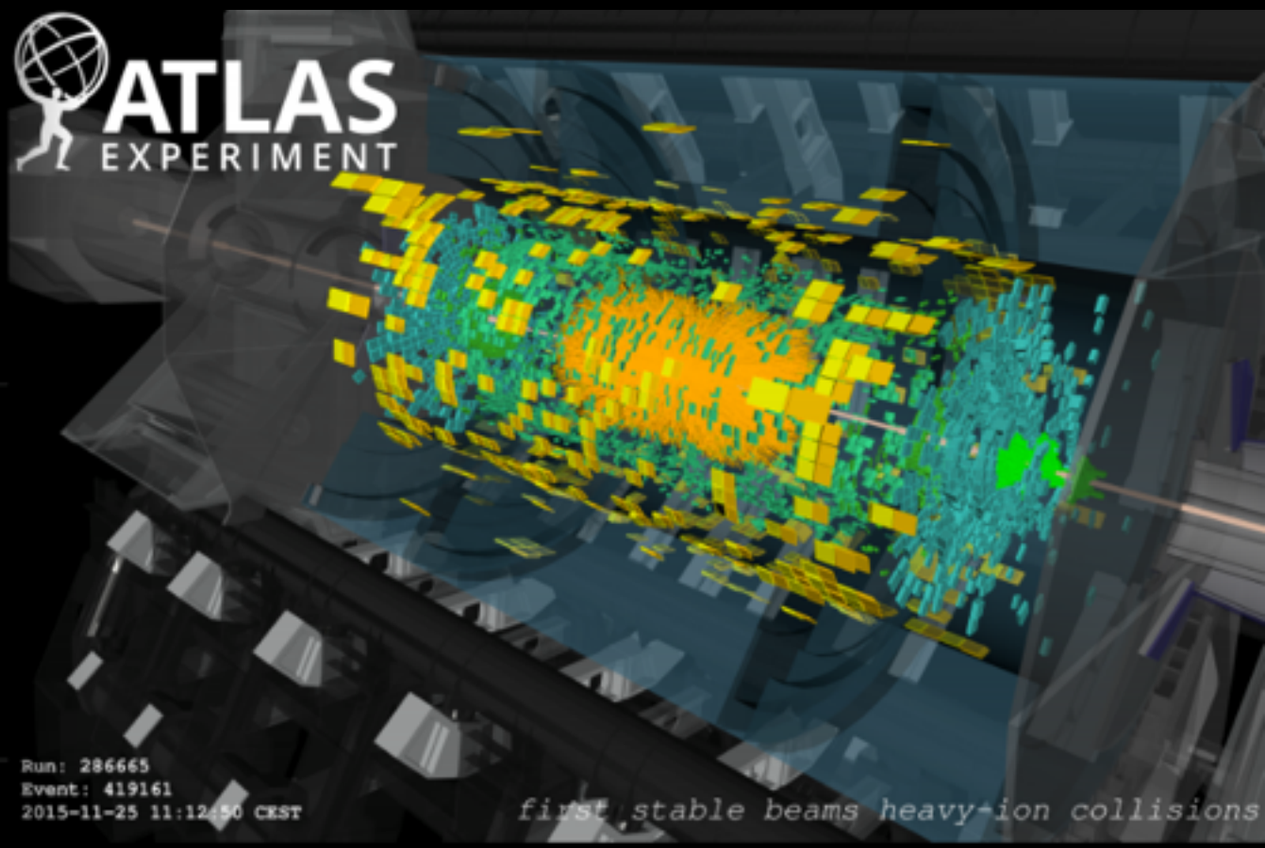
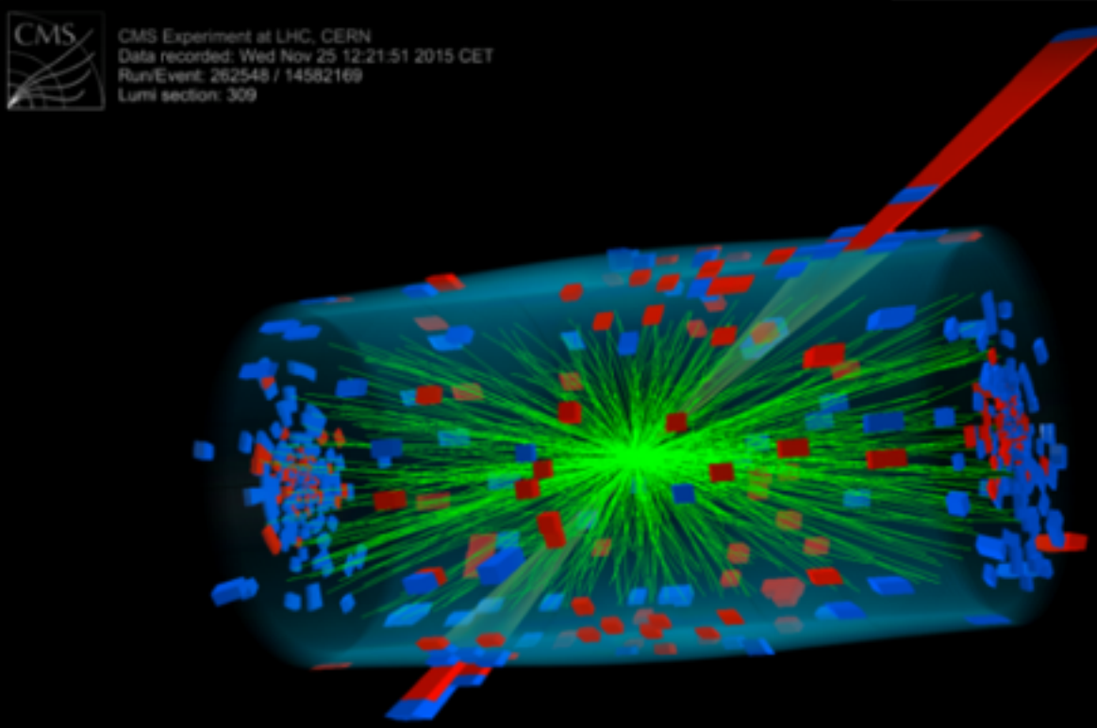
A heavy ion flashlight for discoing axions

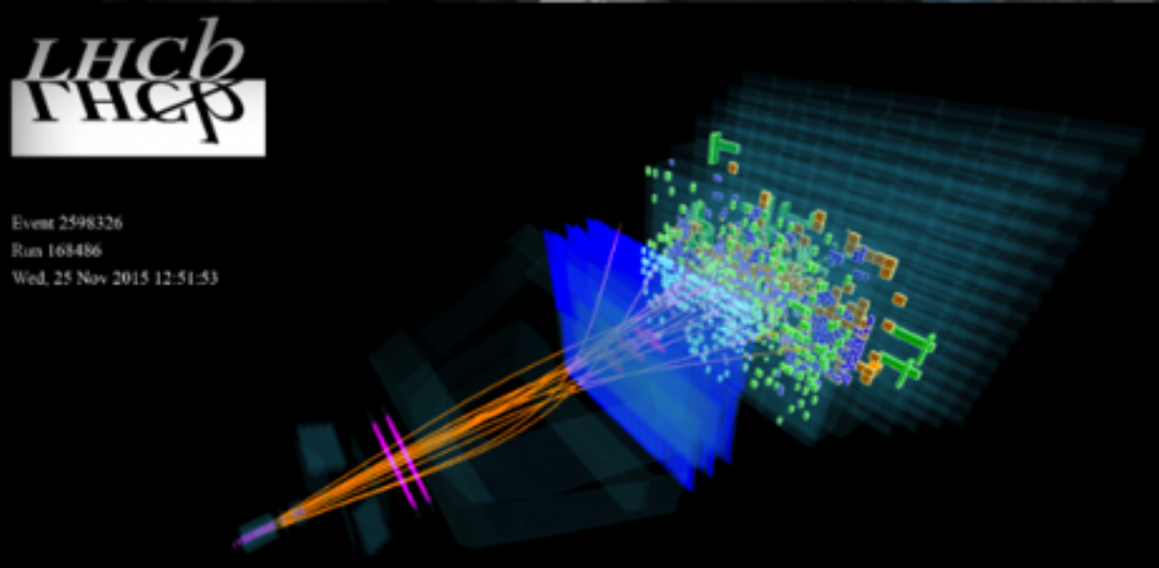
Pb-Pb in each experiment



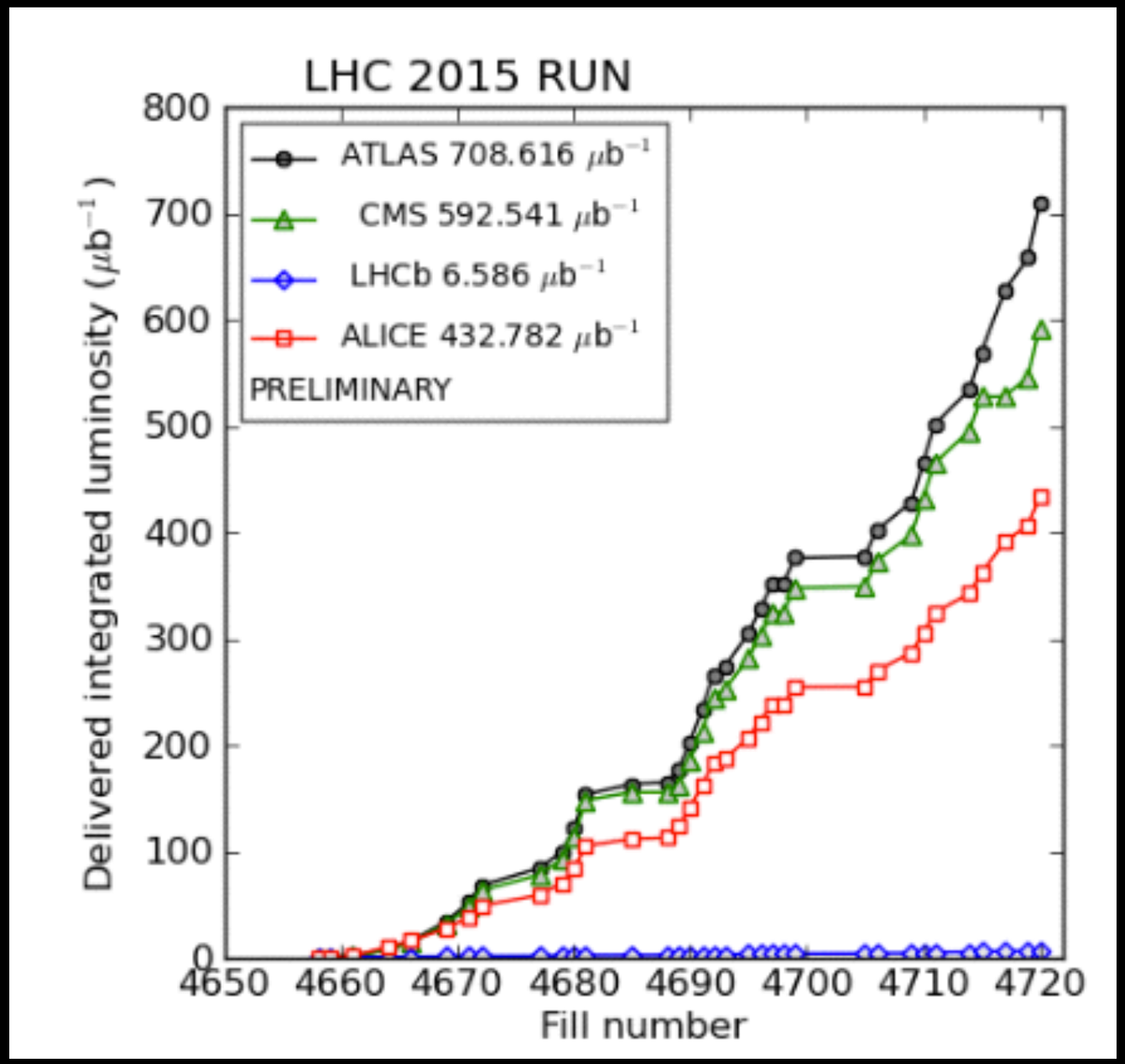




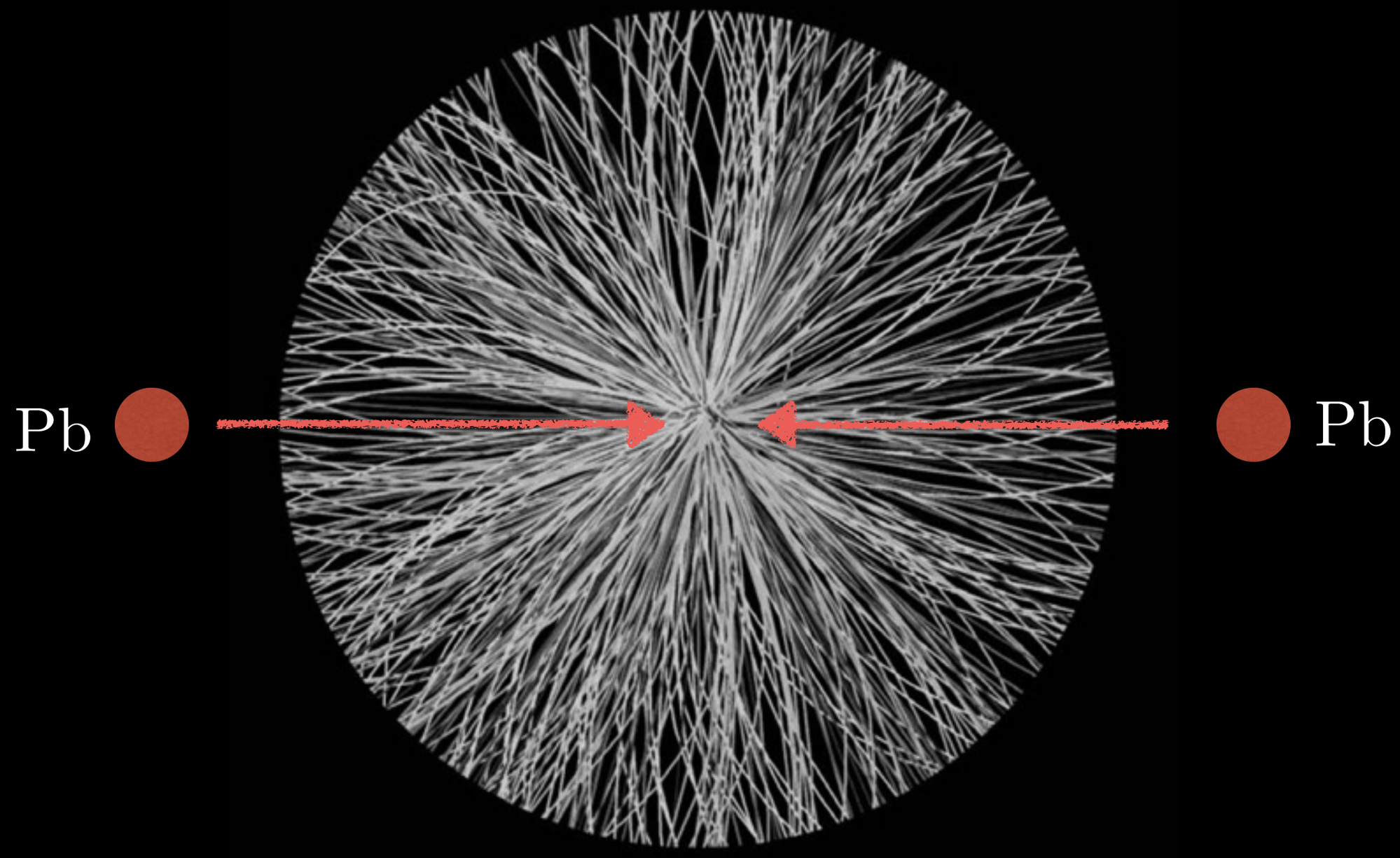




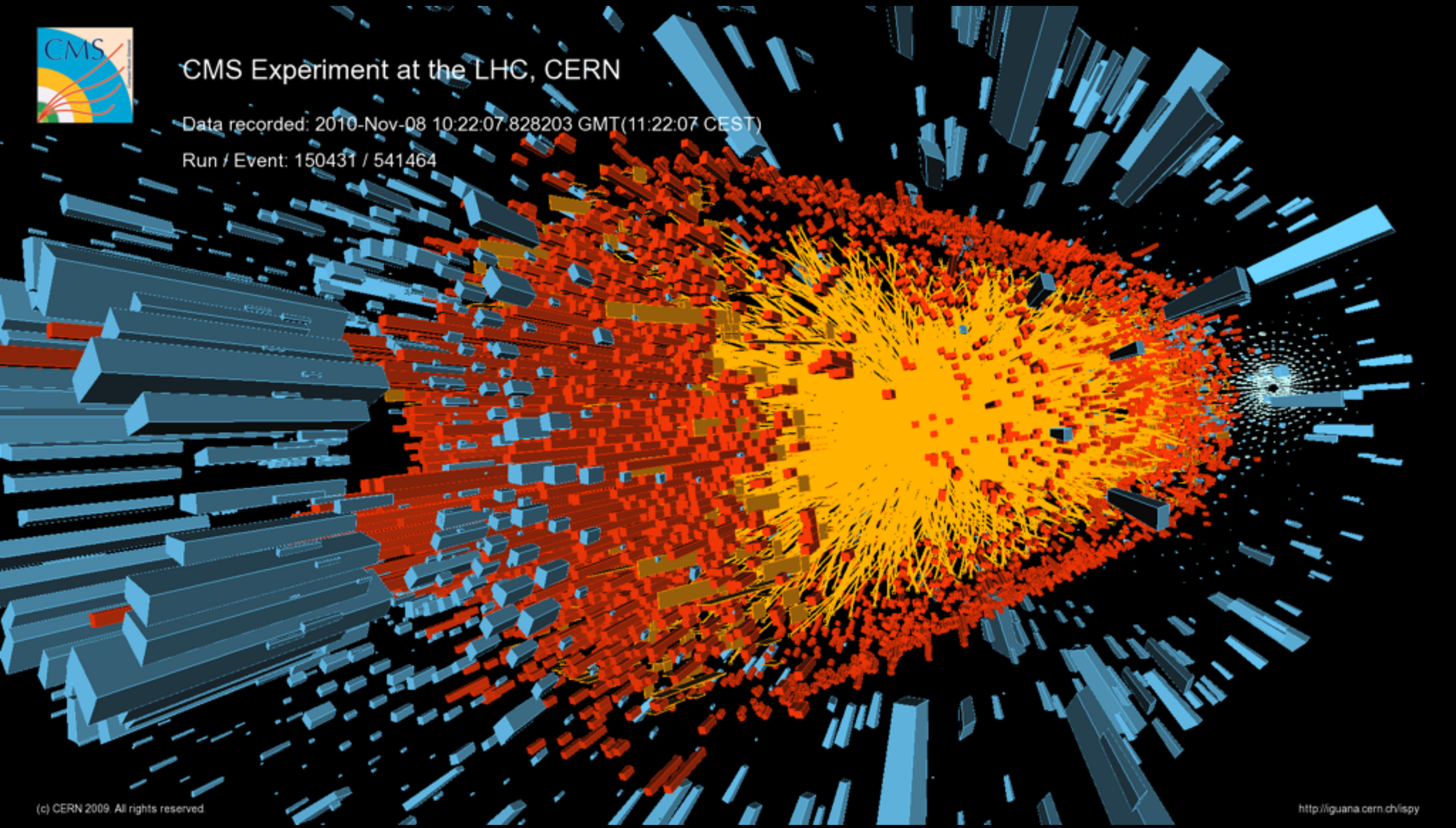
LHC Pb-Pb collisions



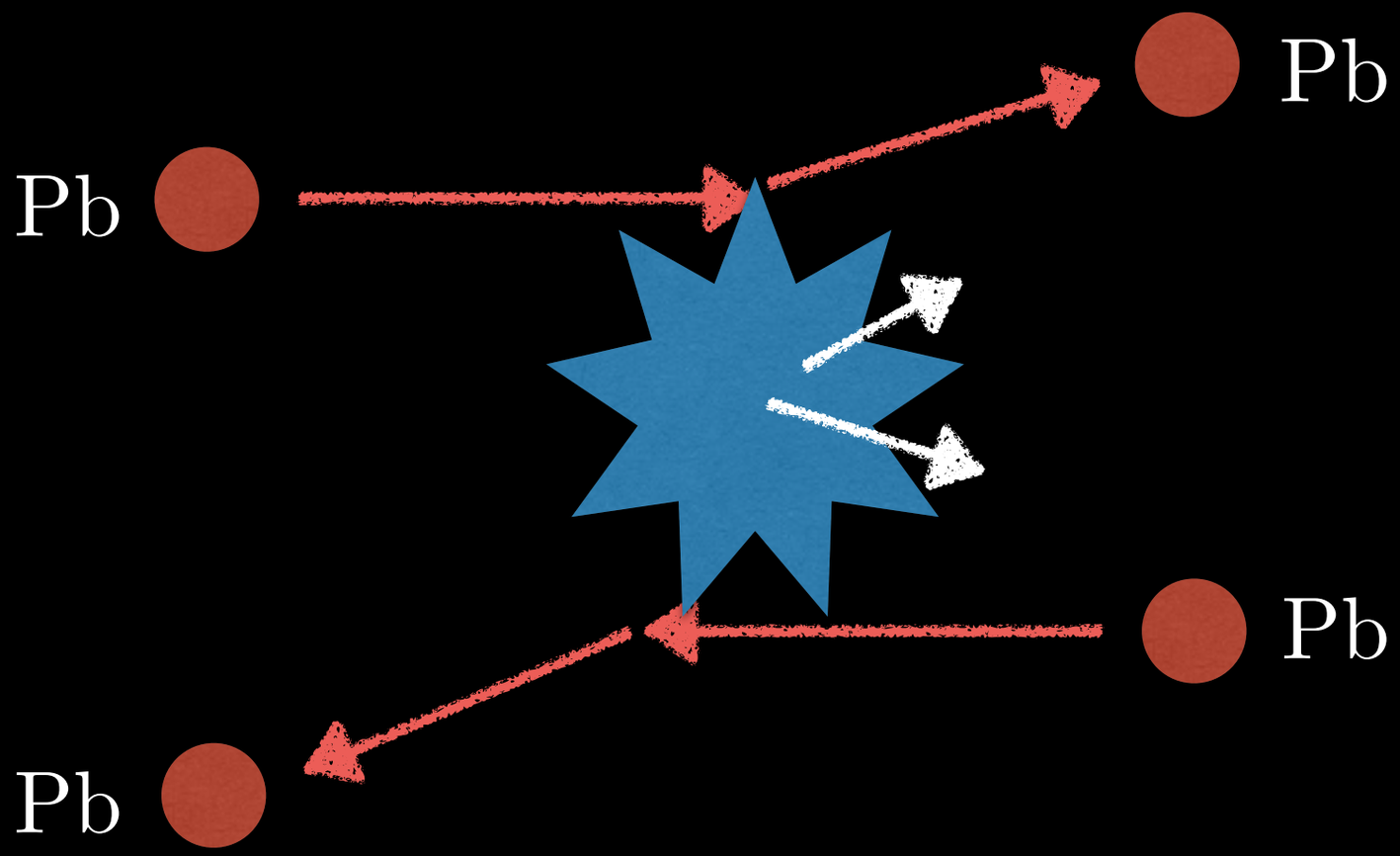
Head-on collisions (5.5 TeV nuc-nuc)



1 PeV ‘fireballs’



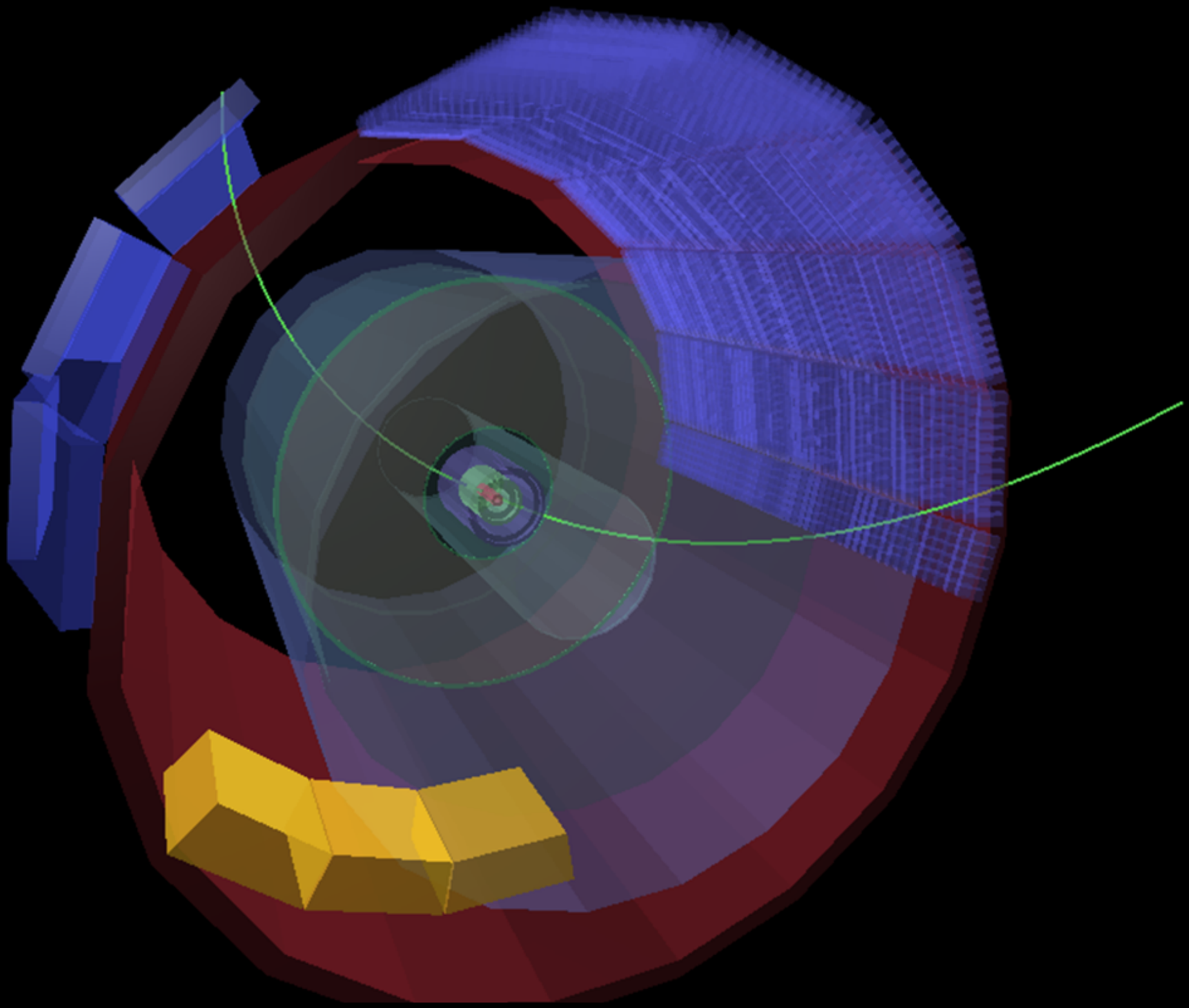
Ultra-peripheral collision



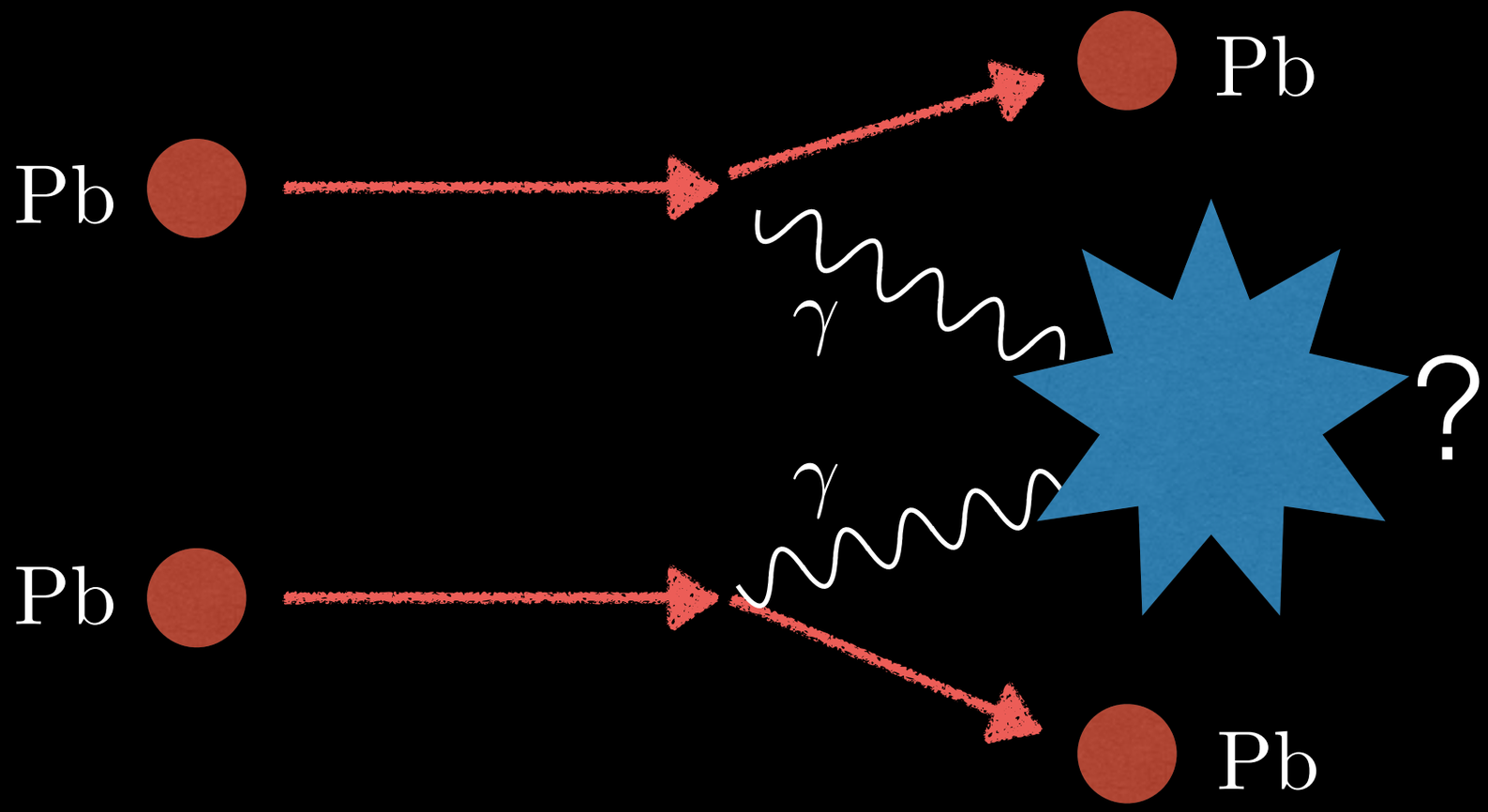
no ion break-up

low multiplicity

Ultra-peripheral collision



Heavy ion ‘photon collider’



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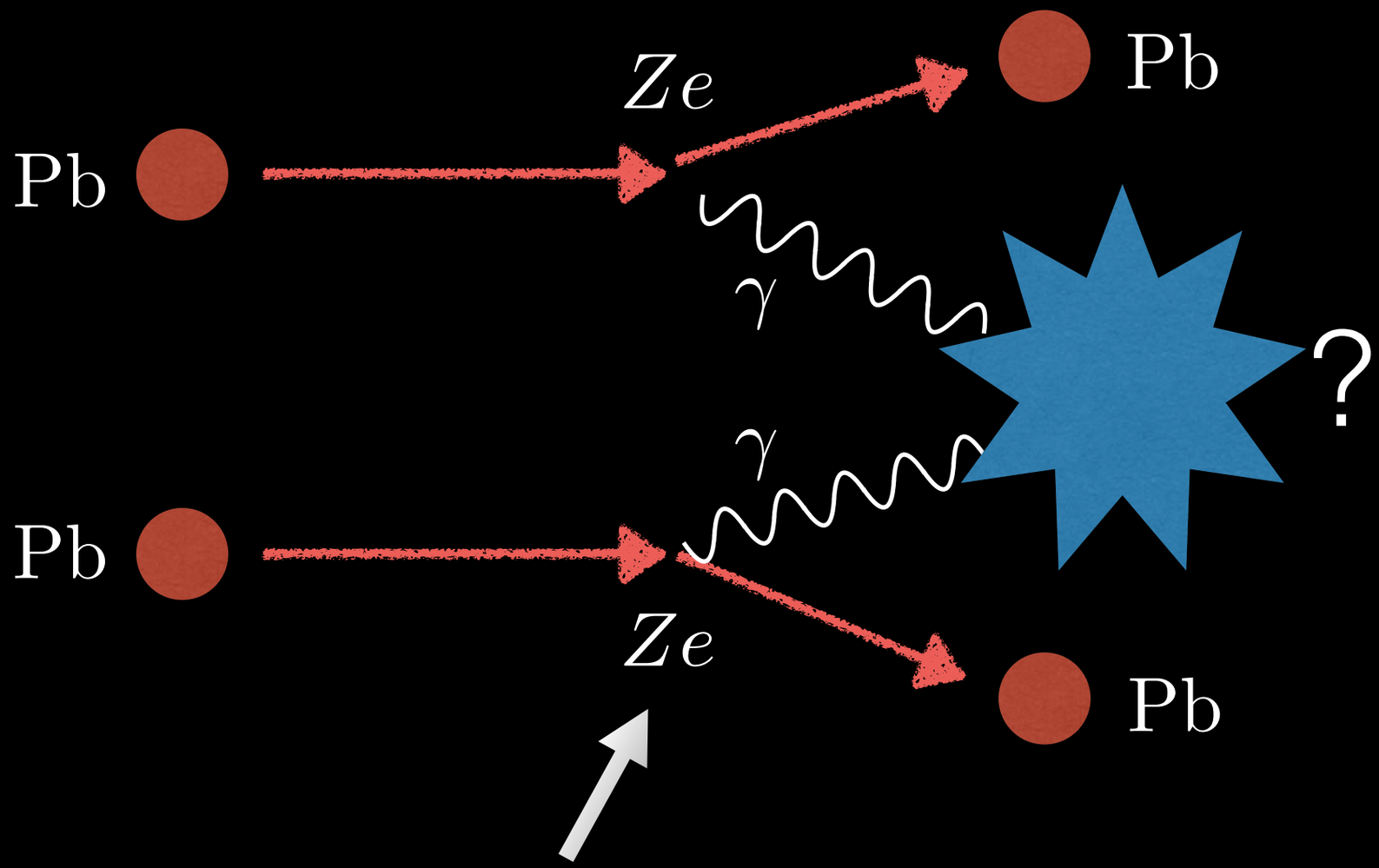
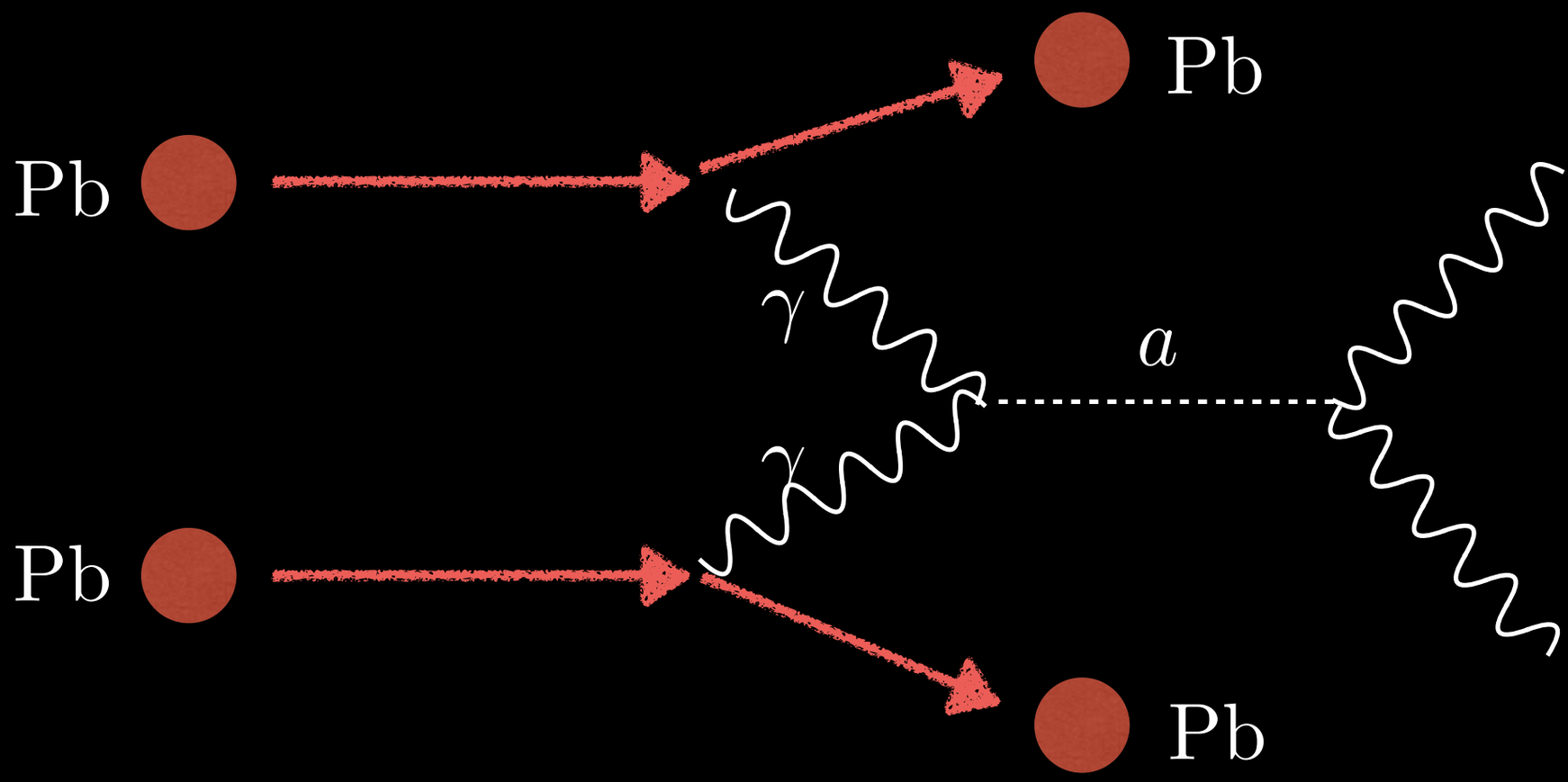


Heavy ion ‘photon collider’



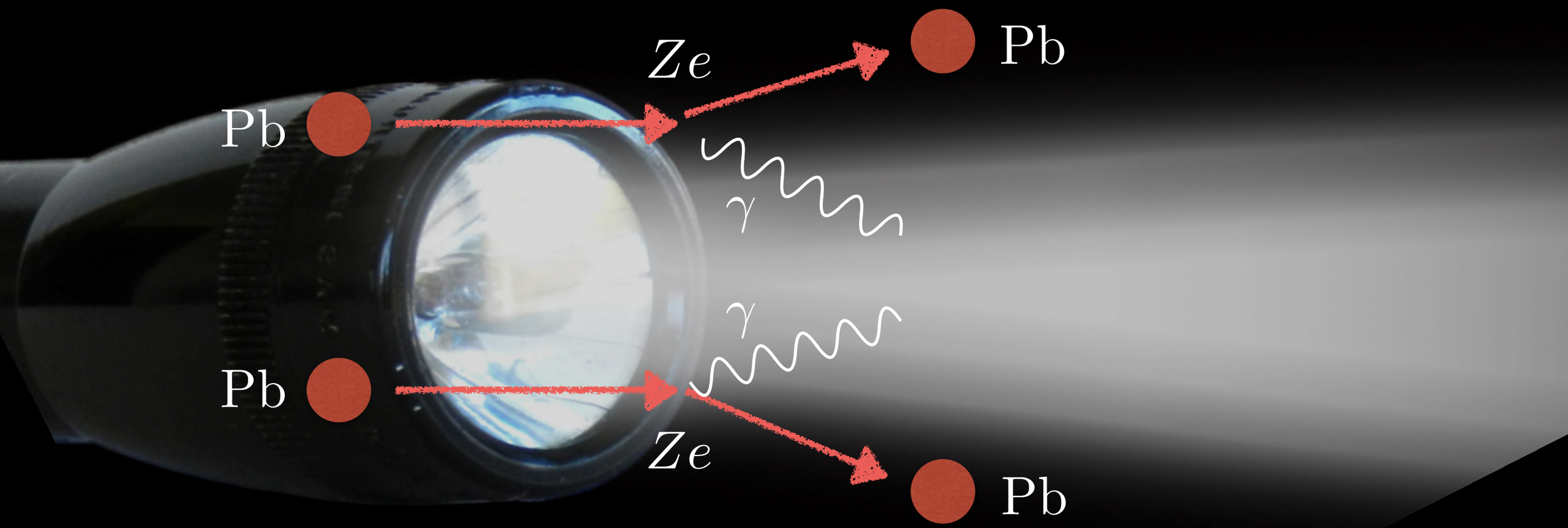
s/a

A. B. Balantekin, C. Bottcher, M. R. Strayer, and S. J. Lee
Phys. Rev. Lett. **55**, 461 (1985)

A.A. NATALE, *Mod. Phys. Lett. A*, **09**, 2075 (1994)

Heavy ion ‘photon collider’

RHICs ‘Gold Flashlight’-> LHCs ‘Lead Flashlight’



Worlds most powerful* flashlight

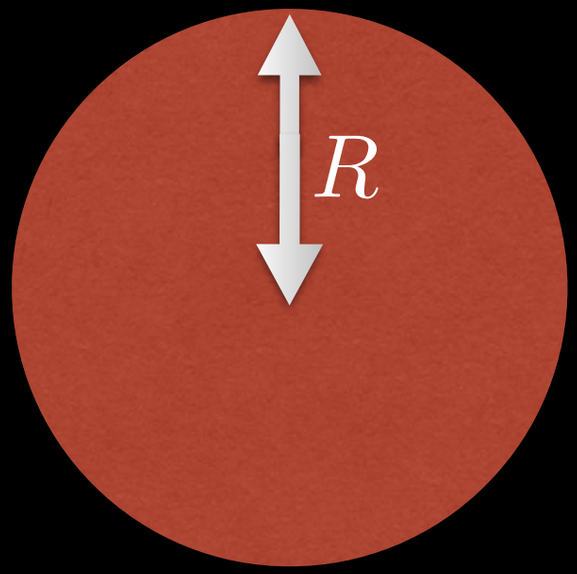
*GeV

Heavy ion ‘photon collider’

Pb-Pb collisions are not optimized for typical beyond the SM searches (low luminosity, lower per nucleon collision energy)

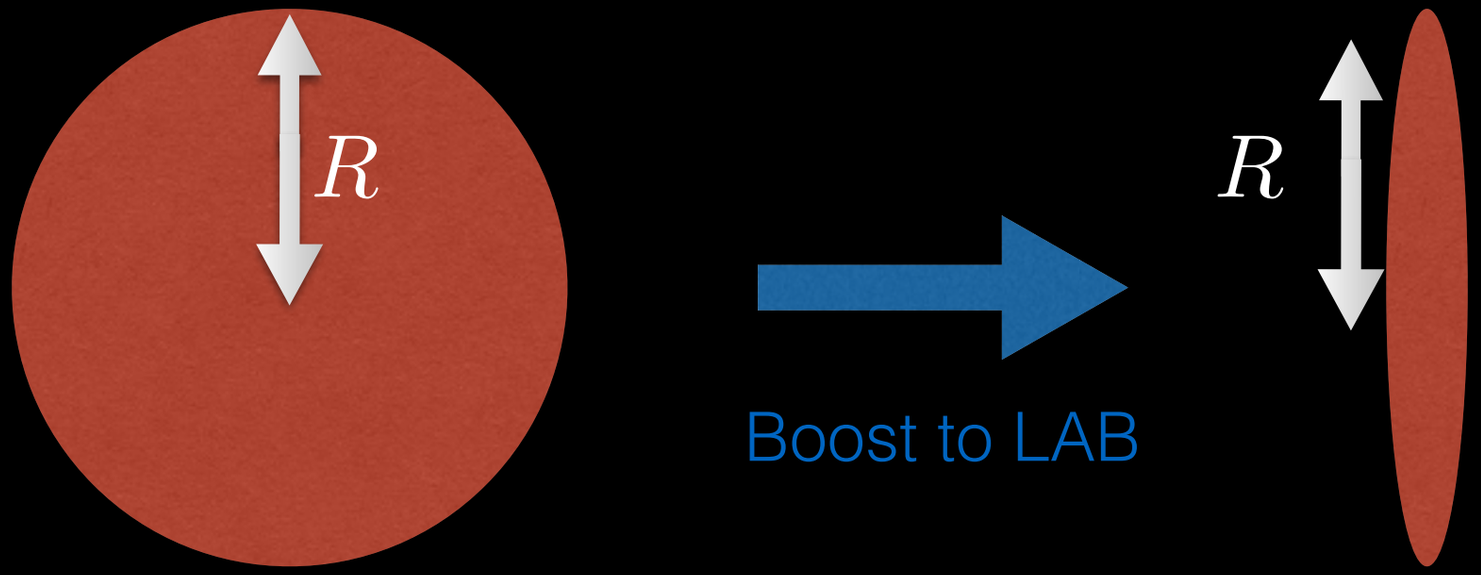
On our side: huge Z^4 enhancement
extremely efficient bkg rejection

Mass reach—quick estimate



$w_{max} \sim 1/R$

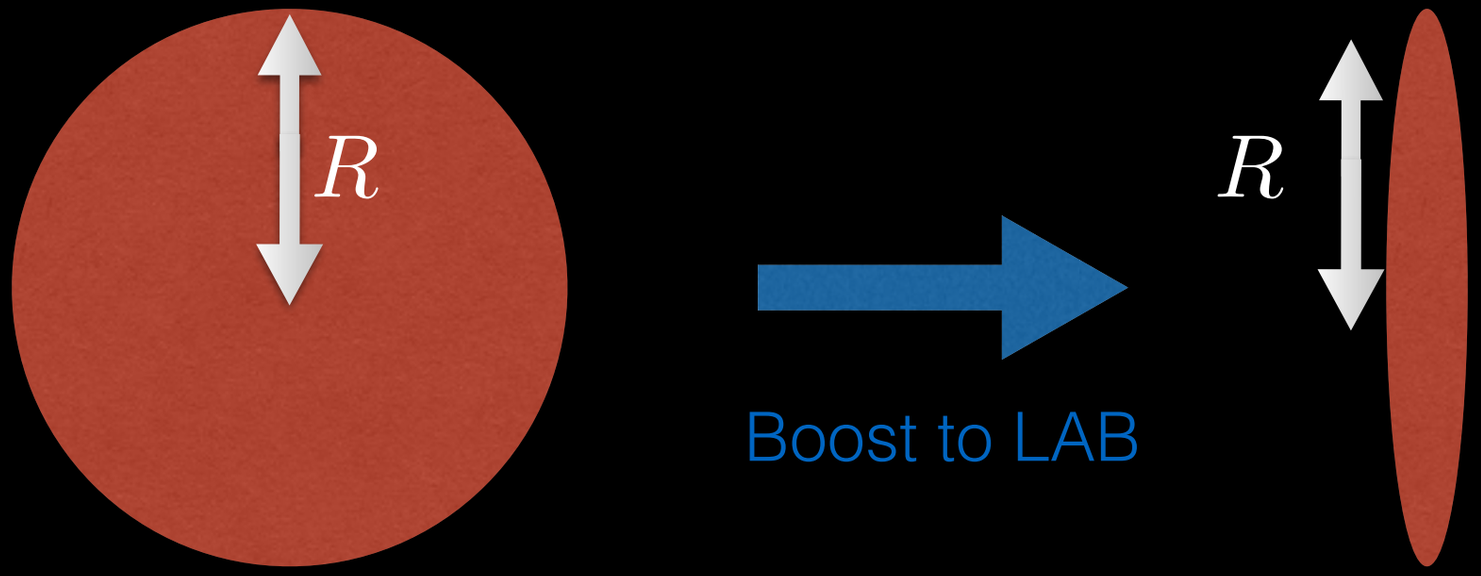
Mass reach—quick estimate



$w_{max} \sim 1/R$

$w_{max} \sim \gamma/R$

Mass reach—quick estimate

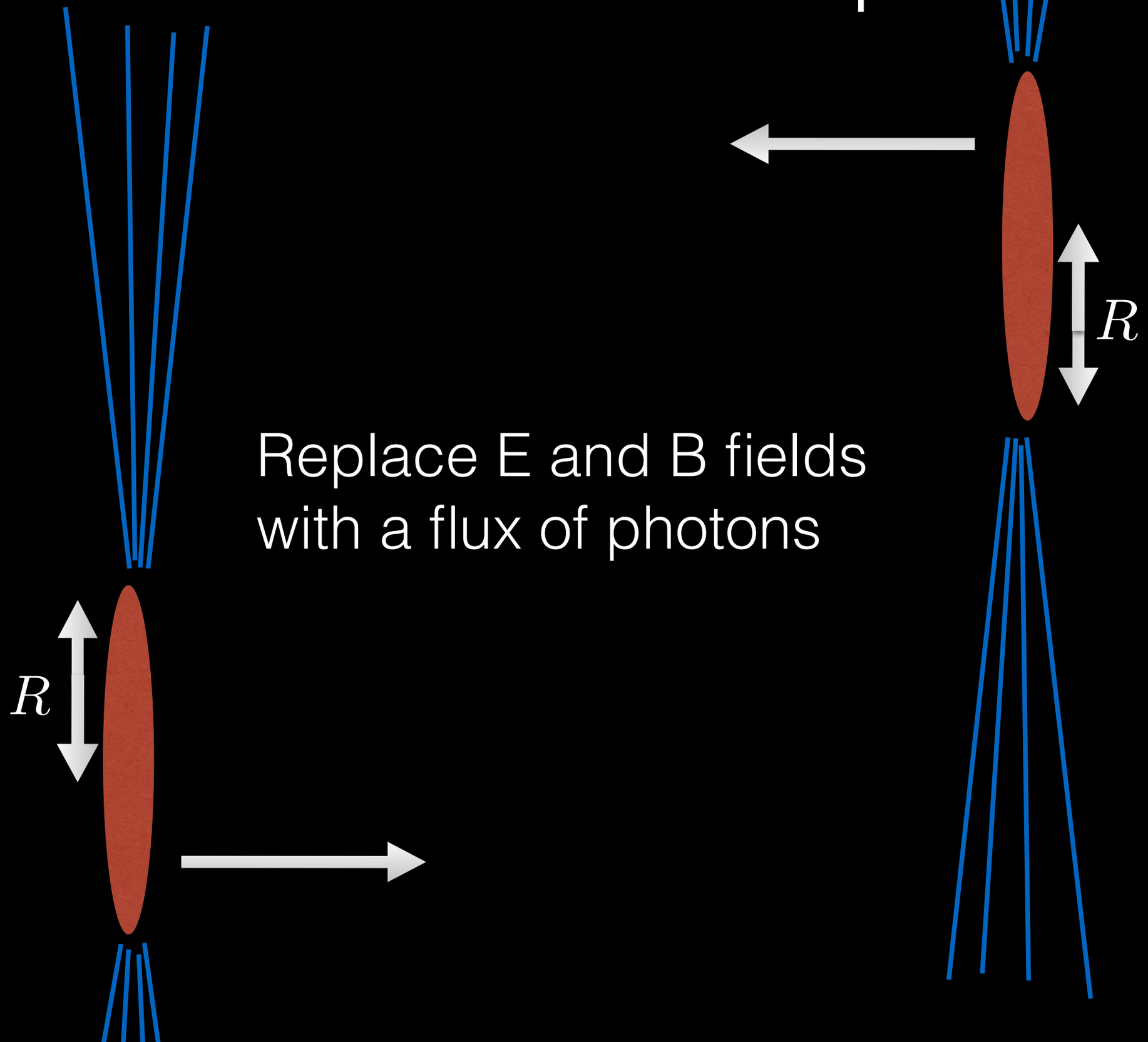


$w_{max} \sim 1/R$

$w_{max} \sim \gamma/R$

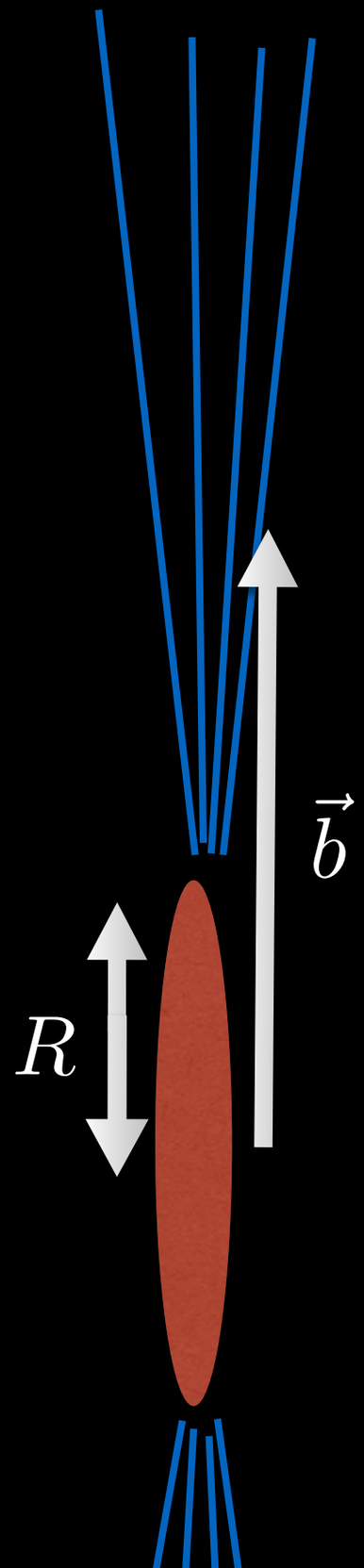
	$b_{\min} = 2R$	E_{nucleon}	$2\omega_{\max}$
p	1.6 fm	7.5 TeV	1500 GeV
Pb	14 fm	5.6 TeV	160 GeV

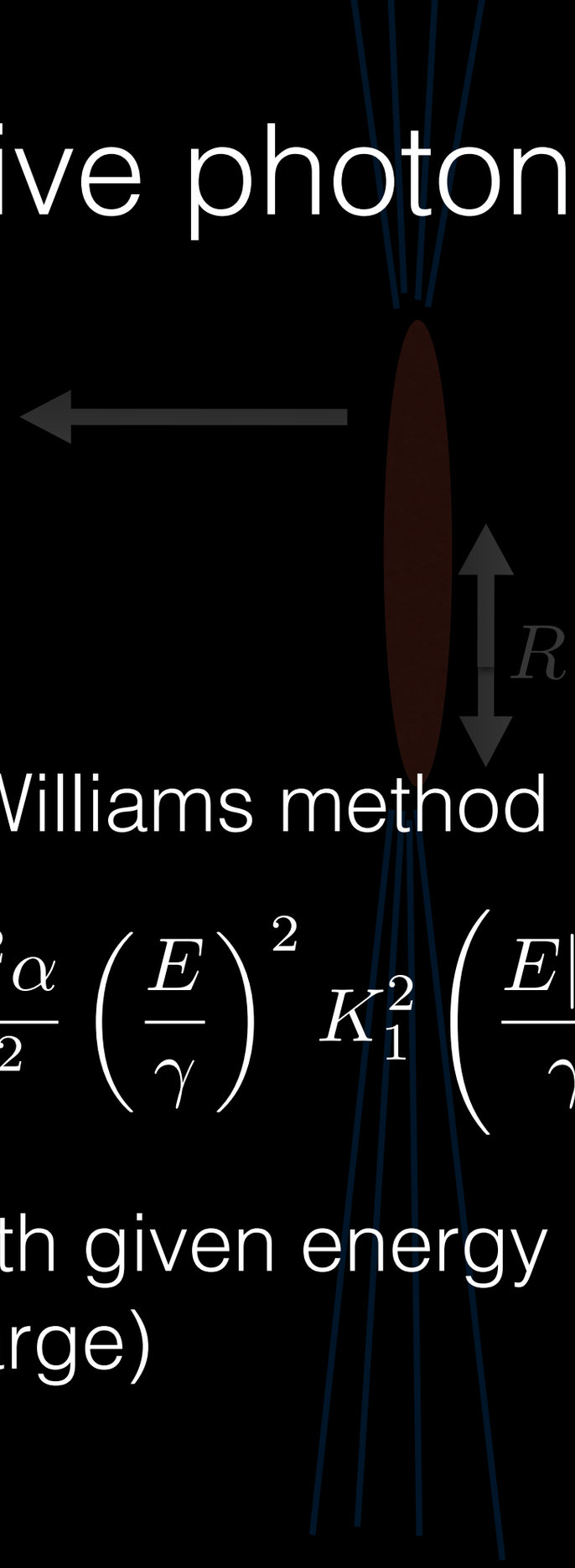
Enrico Fermi's effective photons



Replace E and B fields
with a flux of photons

Enrico Fermi's effective photons



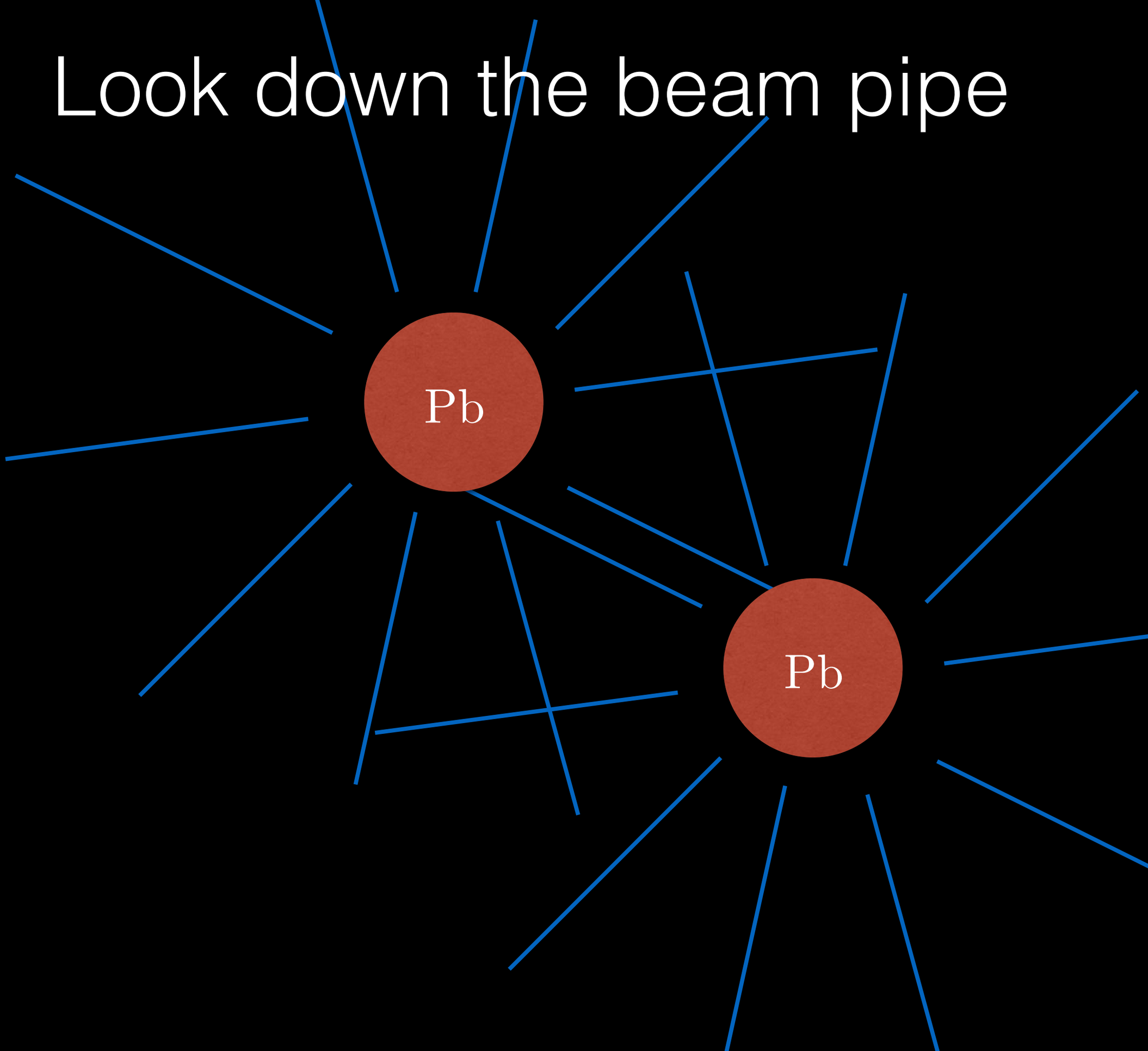


Weizsäcker—Williams method

$$N(E,\vec{b}) = \frac{Z^2\alpha}{\pi^2}\left(\frac{E}{\gamma}\right)^2 K_1^2\left(\frac{E|\vec{b}|}{\gamma}\right)$$

photon flux with given energy E
(point-like charge)

Look down the beam pipe



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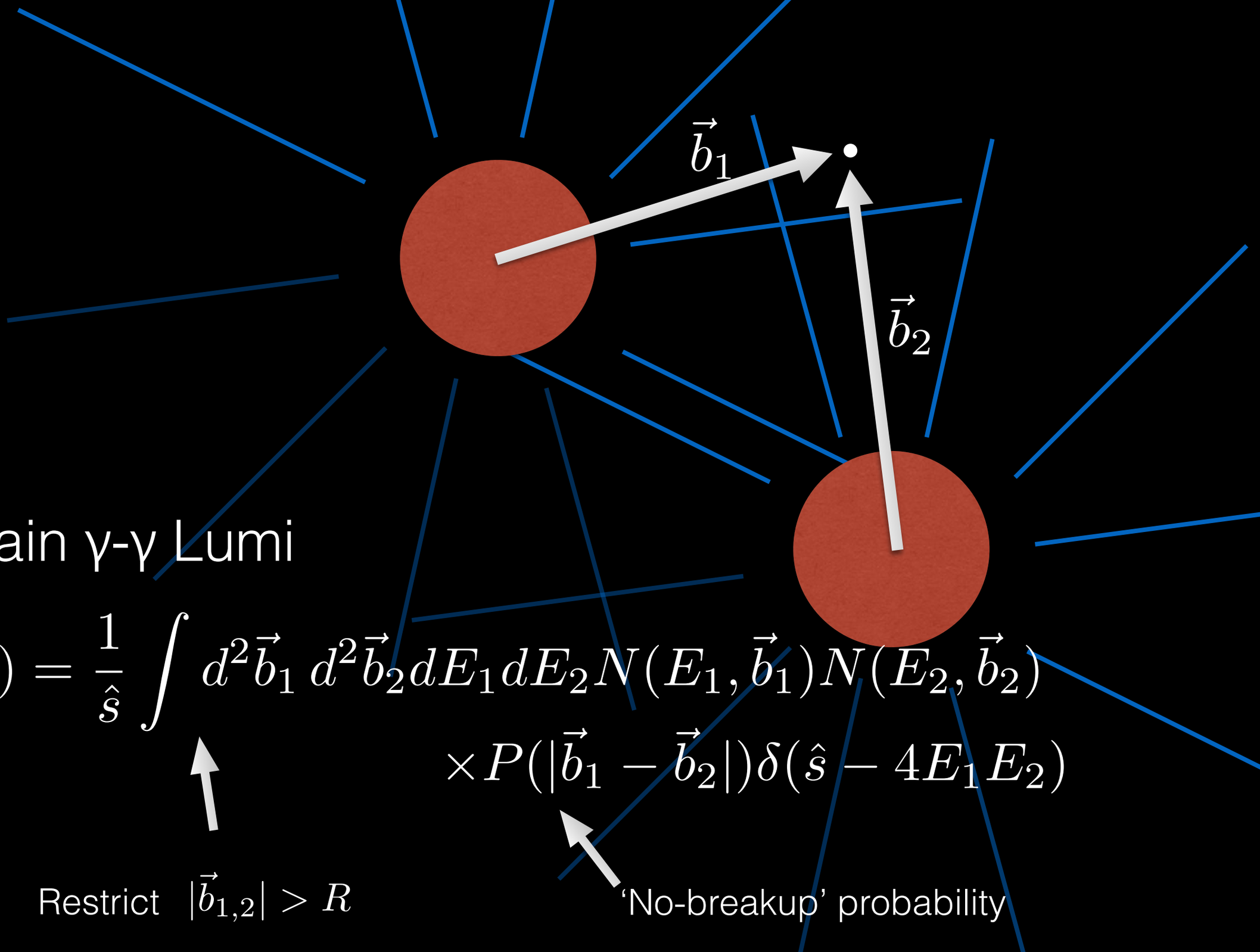


Obtain γ-γ Lumi

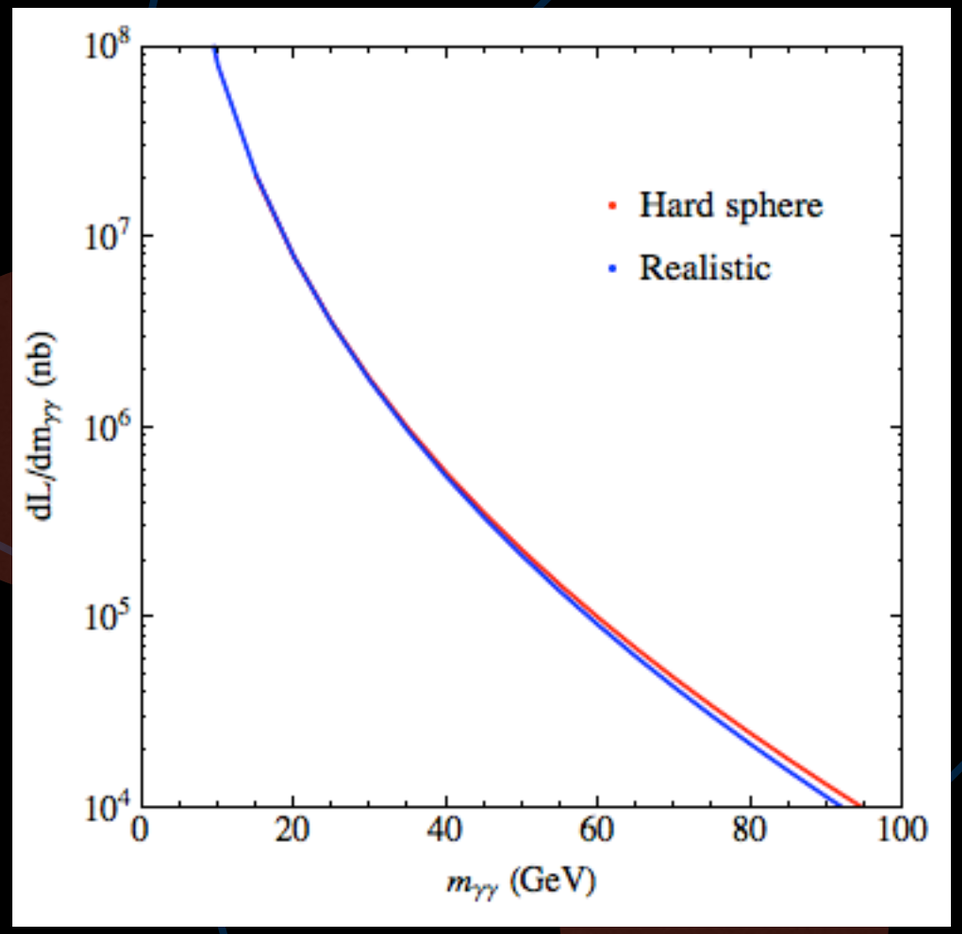
$$\mathcal{L}_{\gamma\gamma}(\hat{s}) = \frac{1}{\hat{s}} \int d^2\vec{b}_1\, d^2\vec{b}_2 dE_1 dE_2 N(E_1, \vec{b}_1) N(E_2, \vec{b}_2)$$
$$\times P(|\vec{b}_1 - \vec{b}_2|)\delta(\hat{s} - 4E_1E_2)$$

Restrict $|\vec{b}_{1,2}| > R$

'No-breakup' probability

STARlight public code…

S. R. Klein, J. Nystrand, J. Seger, Y. Gorbunov, and J. Butterworth



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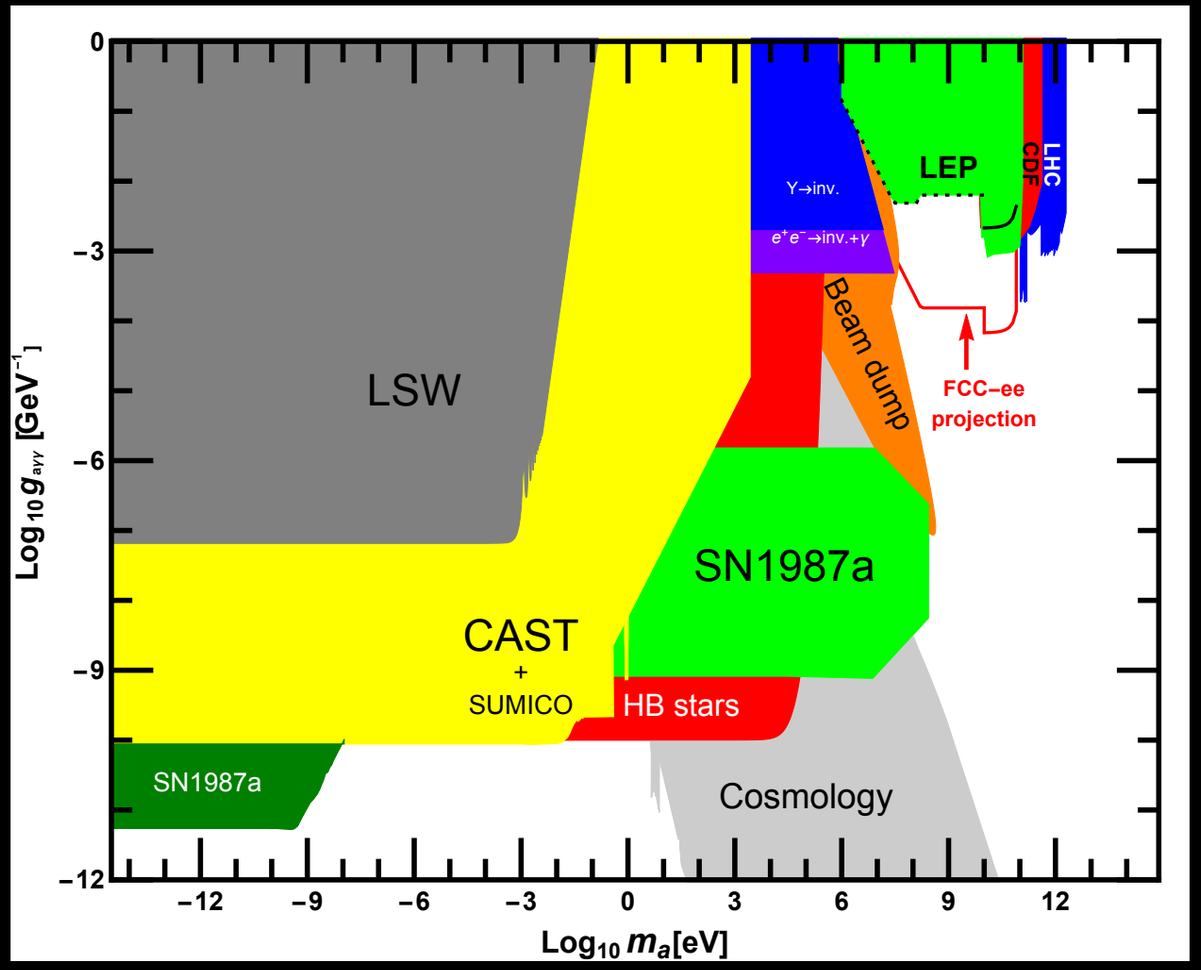
‘No-breakup’ probability

Search for axion like particles

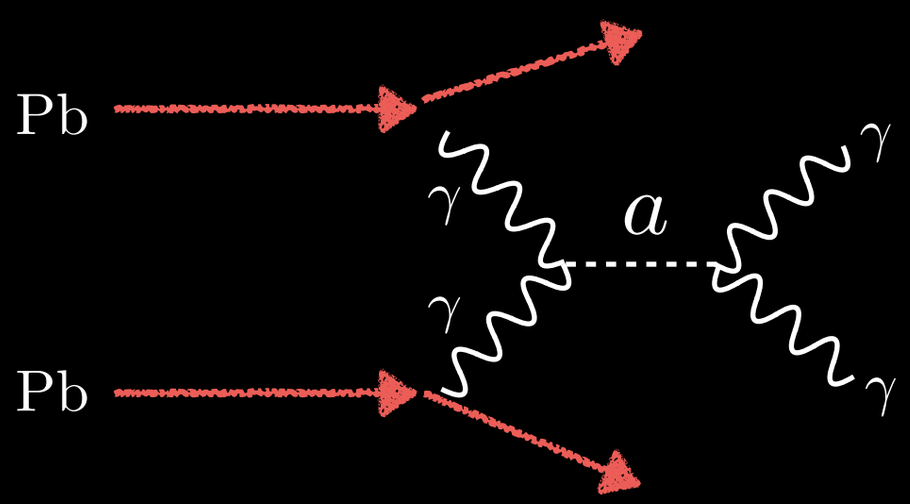
Knapen, Lin, Lou, TM 16

$$\frac{1}{2}(\partial a)^2 - \frac{1}{2}m_a^2 a^2 - \frac{1}{4}\frac{a}{\Lambda}F\widetilde{F}$$

e.g. pseudo Nambu-Goldstone boson from some spontaneously broken symmetry



Jaeckel, Spannowsky 15



Sensitive to mass range M~GeV

Search for axion like particles

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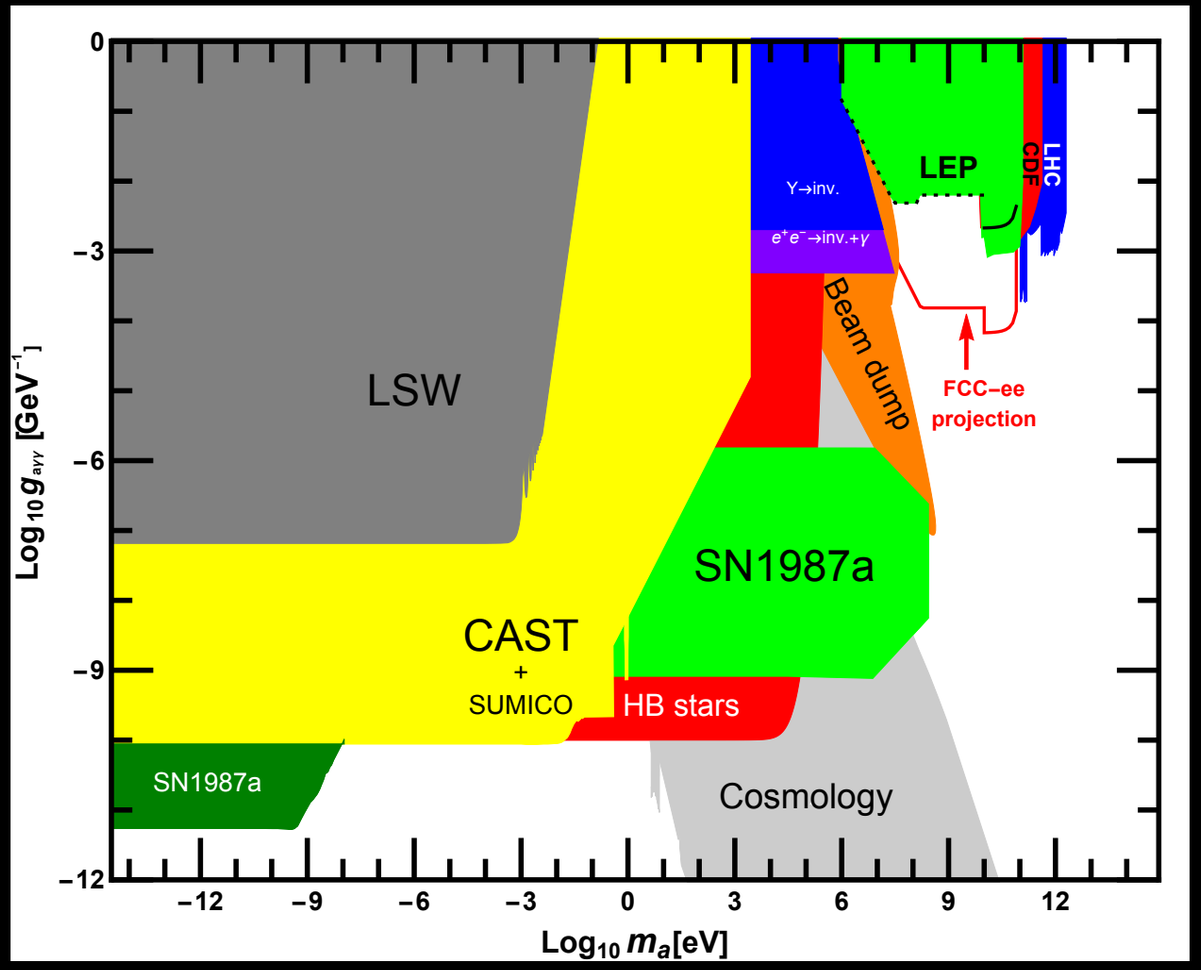

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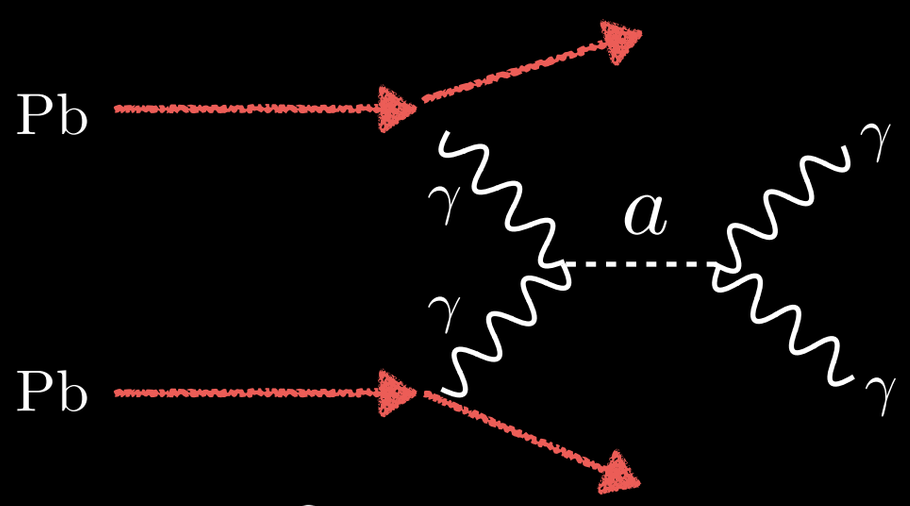


$$\sigma_a = \frac{8\pi^2}{m_a}\Gamma(a \to \gamma\gamma)\mathcal{L}_{\gamma\gamma}(m_a^2)$$

$$\Gamma = \frac{1}{64\pi}\frac{m_a^3}{\Lambda^2}$$

How to trigger?

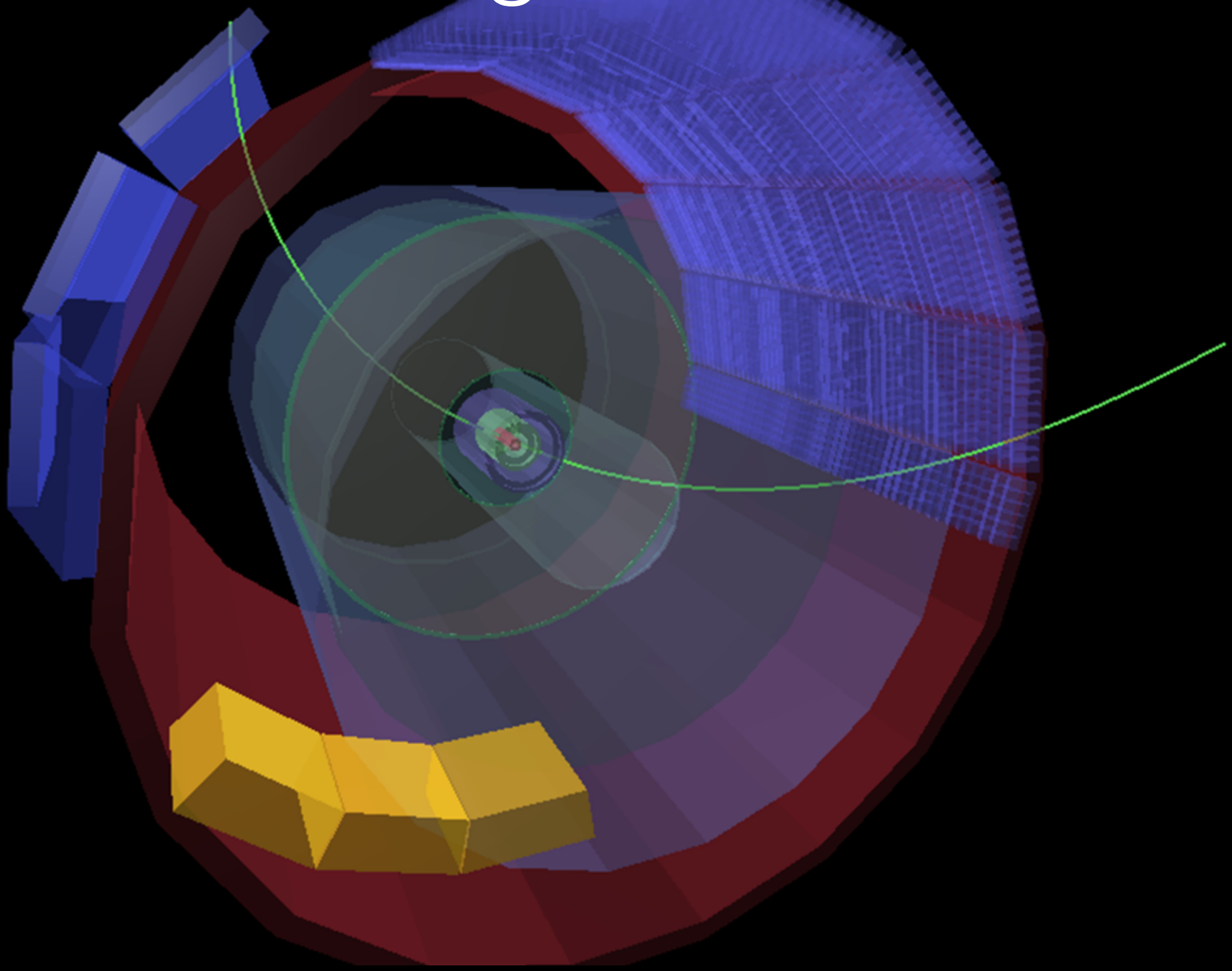
Two new triggers prepared (CMS Ultra-Peripheral Collisions working group analysis, to appear)

Two photons with E > 2 GeV and no hadronic activity in one of the forward calorimeters

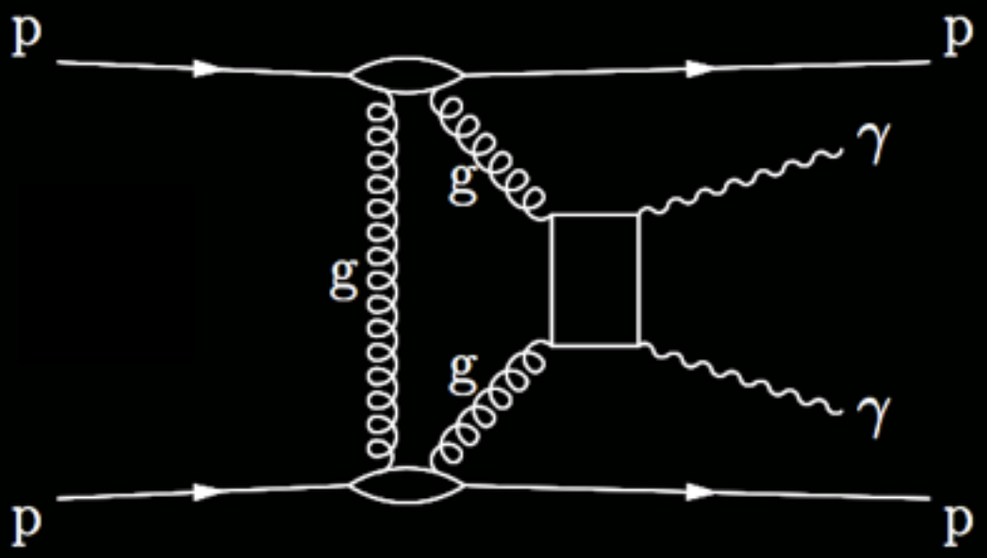
One photon E > 5 GeV and no hadronic activity in one of the forward calorimeters

It's like LEP!

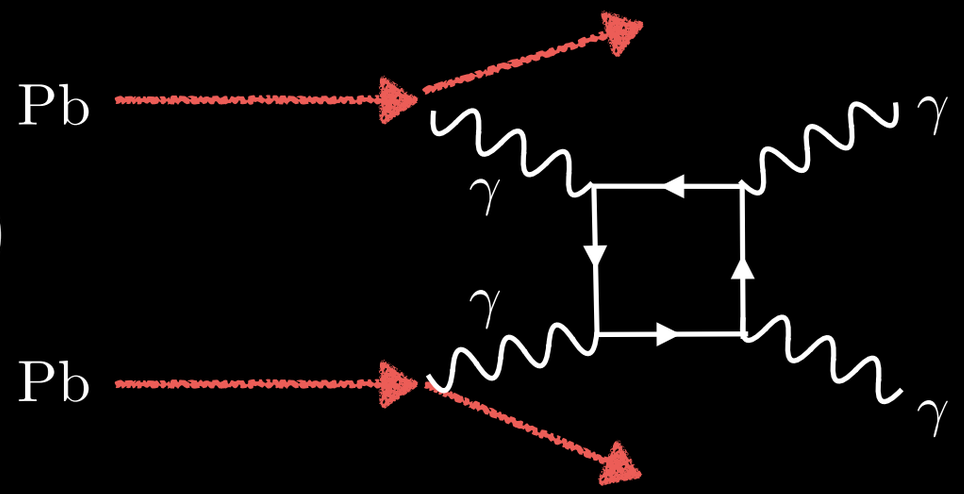
..but with LHC-grade detectors



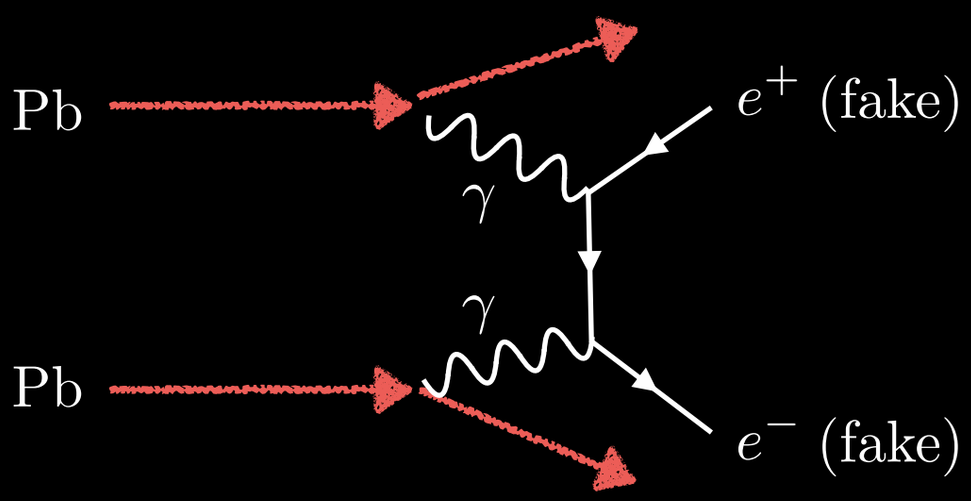
Backgrounds



CEP (Central exclusive production)

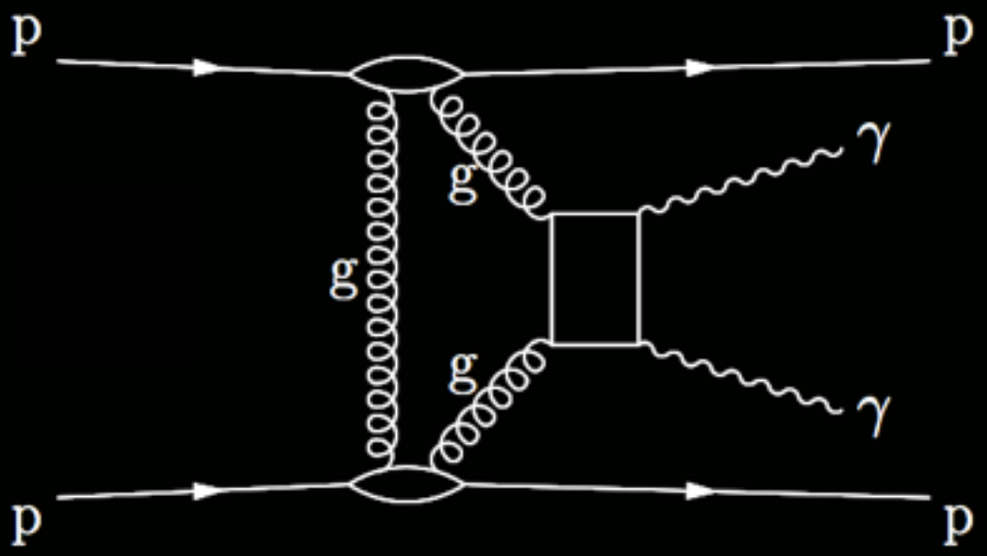


LBL (Light by light)



Fakes

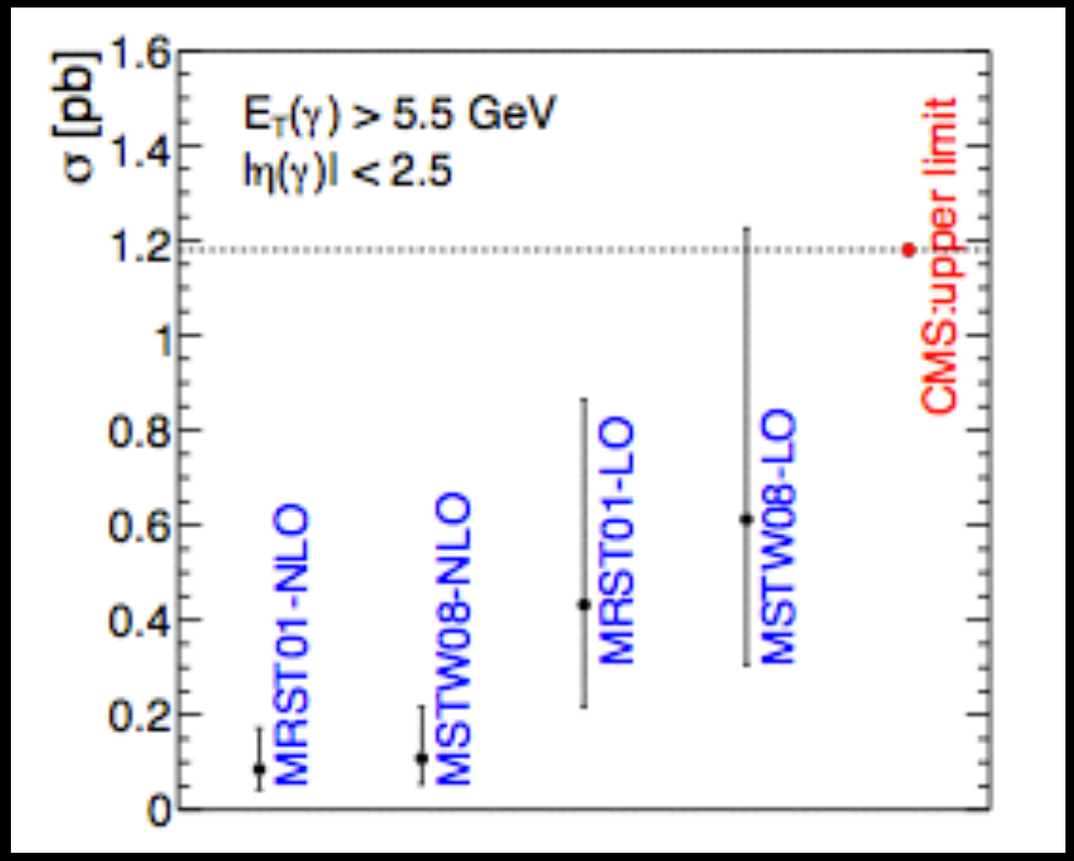
Backgrounds



CEP (Central exclusive production)

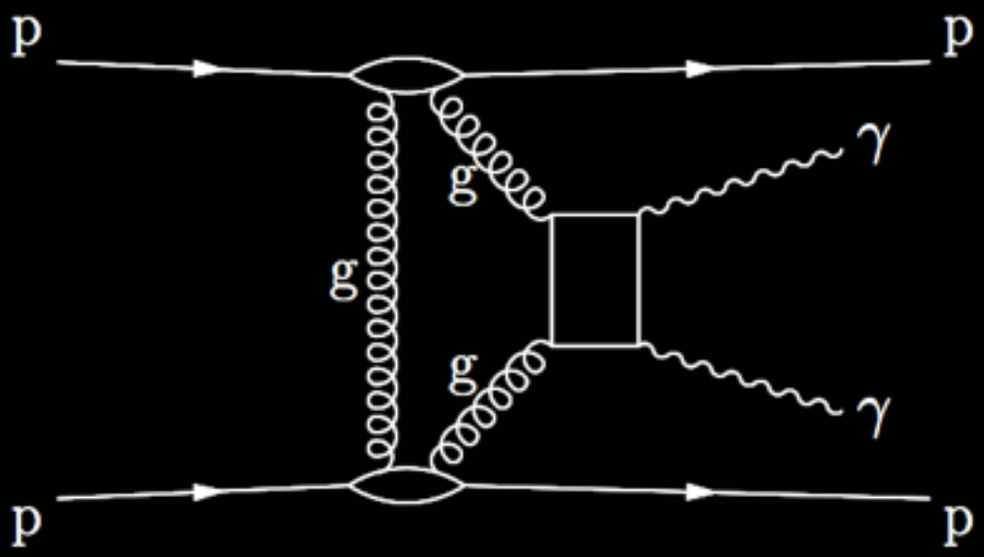
L. A. Harland-Lang, V. A. Khoze, M. G. Ryskin, and W. J. Stirling (2010-)
—SuperCHIC

In p-p collisions: theory and expt. upper bound



CMS 7 TeV, 36 pb^{-1}

Backgrounds



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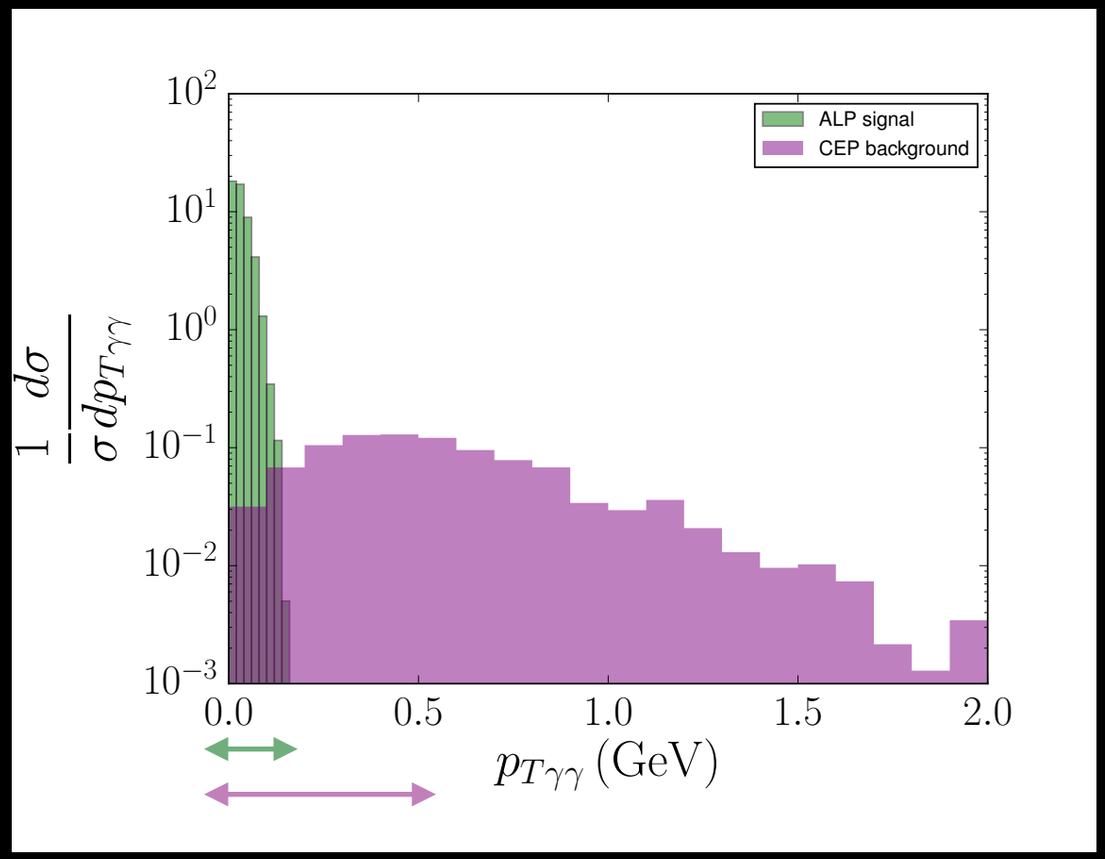
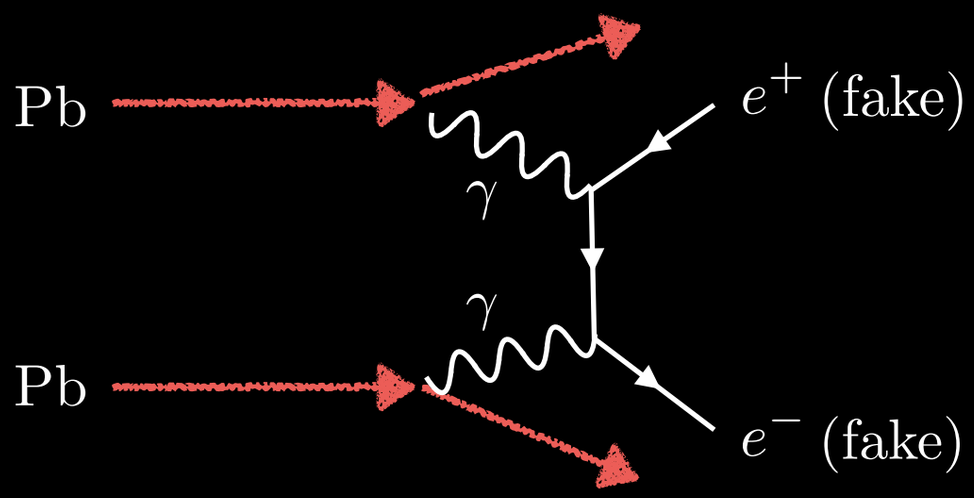


50 MeV ~ 1 / R_{Pb}
1 GeV ~ 1/ R_p

Scale to Pb-Pb?
Uncertain, but even A^2 scaling it is small and largely reducible

$A^{1/3}$ more reasonable?

Backgrounds



Fakes

S. R. Klein, J. Nystrand, J. Seger, Y. Gorbunov, and J. Butterworth

—STARlight

This process has a cross section around 0.1-1 millibarn

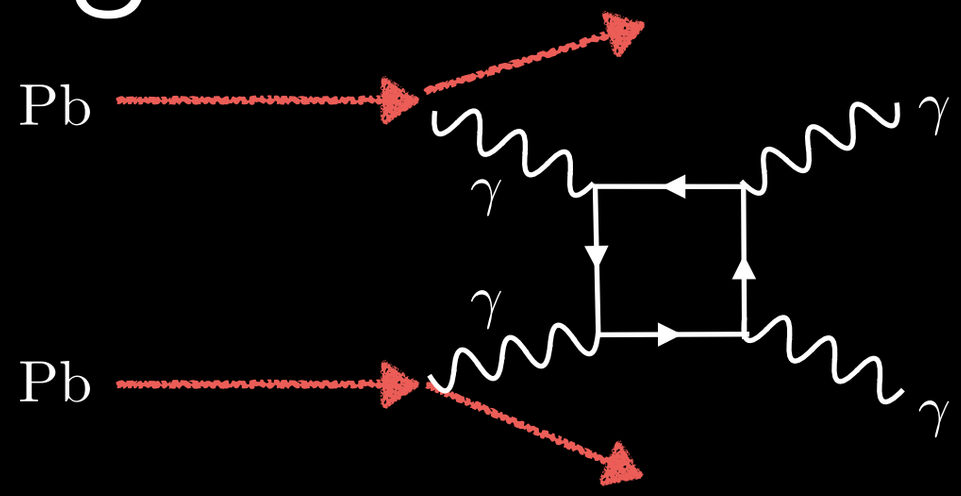
Assuming ~1% fake rate, this is in the 10-100 nb region

Backgrounds

LBL (Light by light)

D. d'Enterria and G. G. da Silveira (2013)

Z. Bern, A. De Freitas, L. J. Dixon, A. Ghinculov, and H. L. Wong (2001)

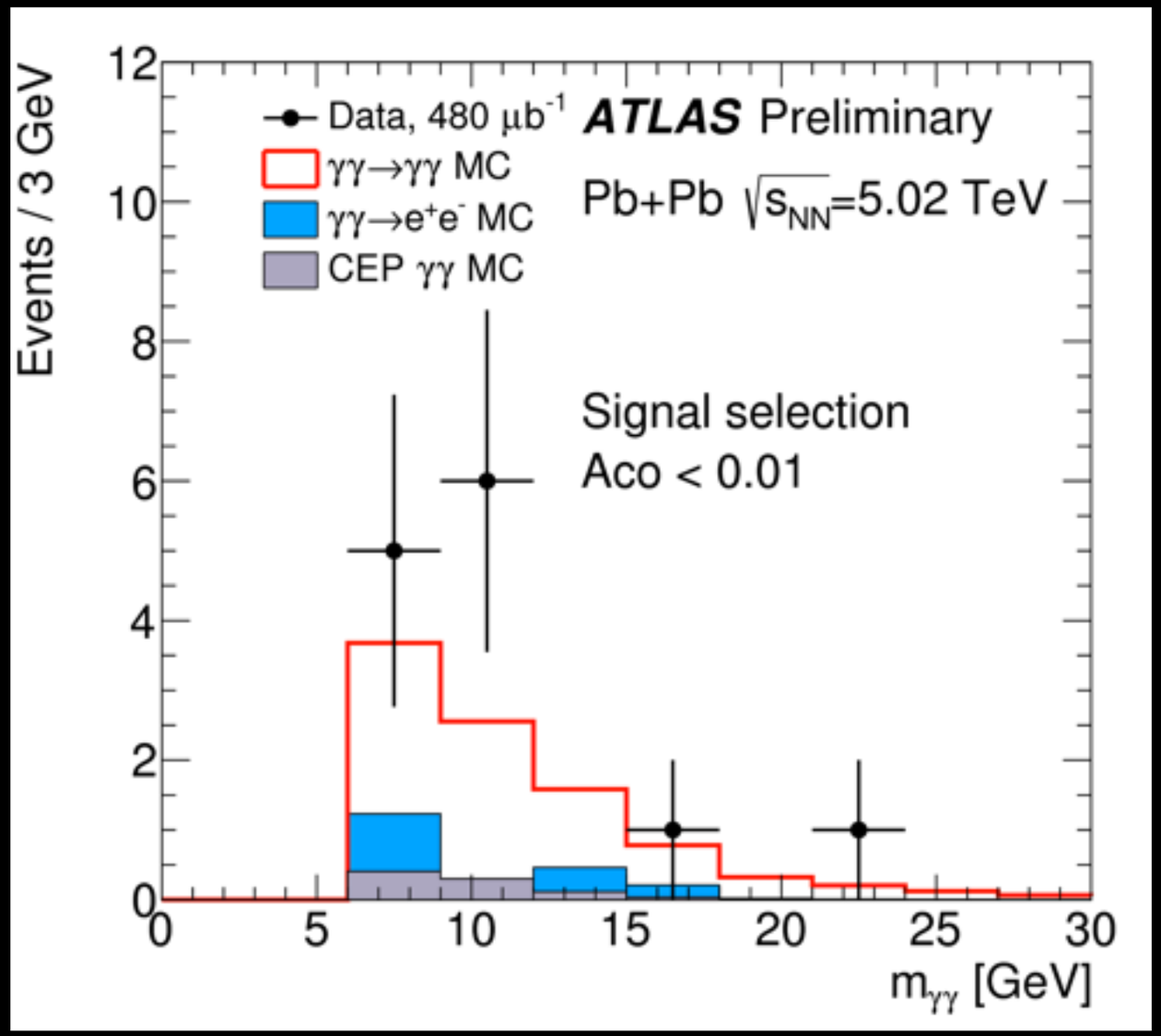


New!

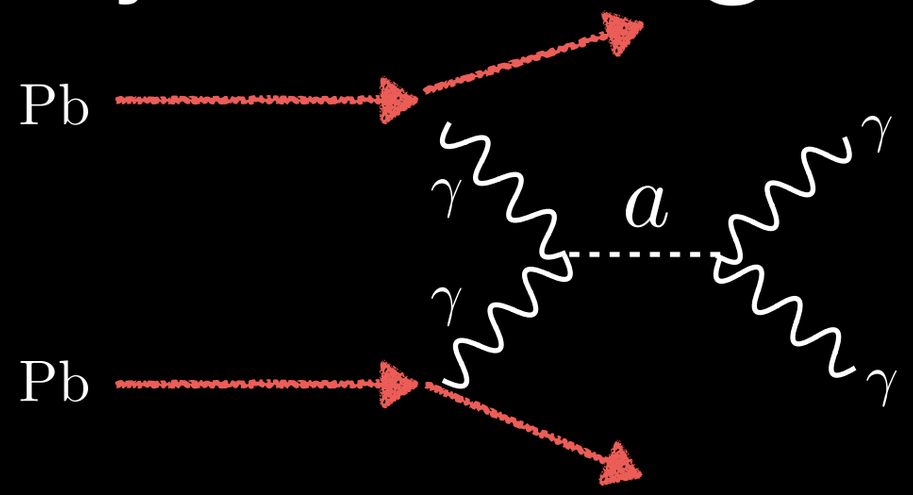
ATLAS-CONF-2016-111

4.4 sigma observation

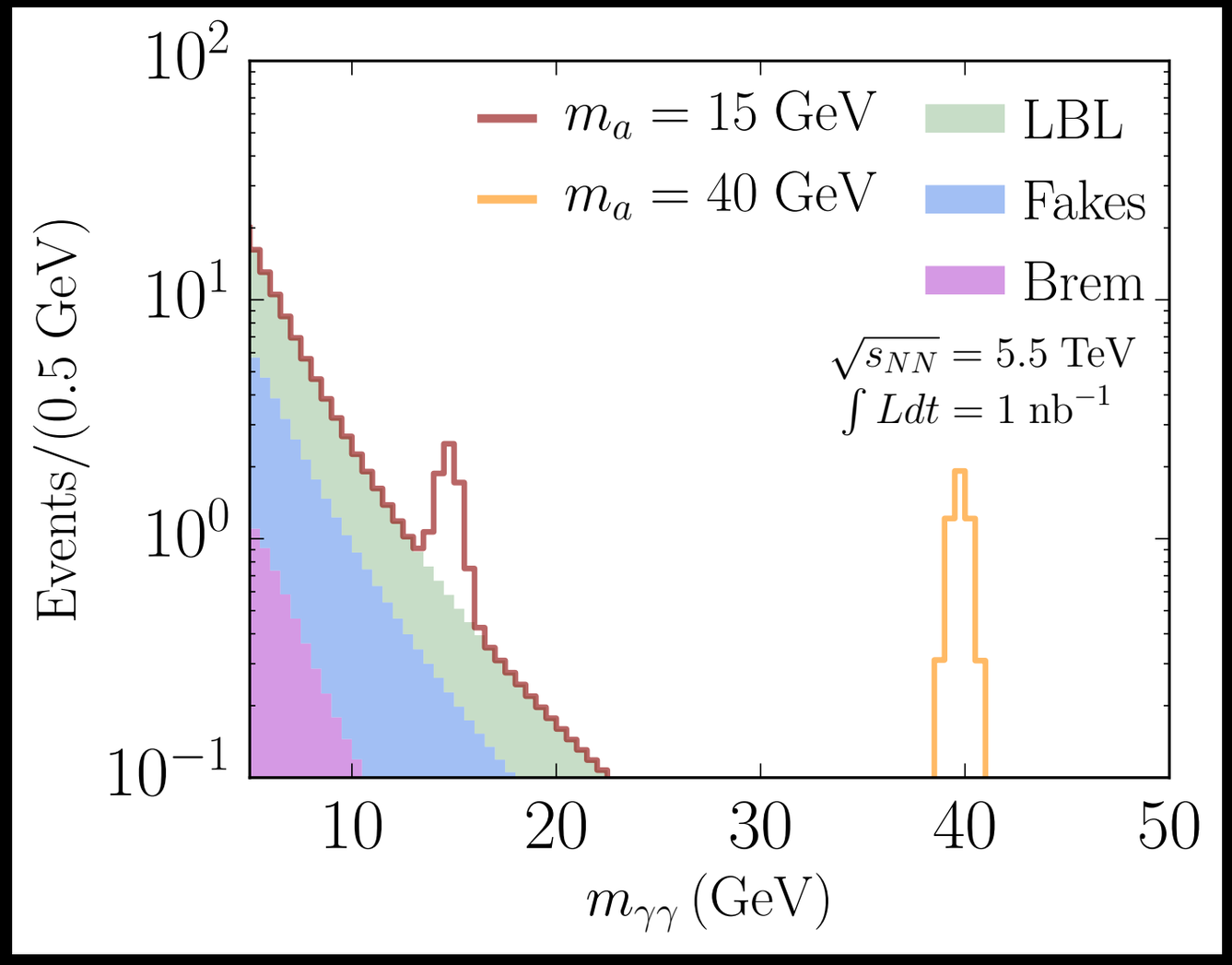
~50 nb cross section



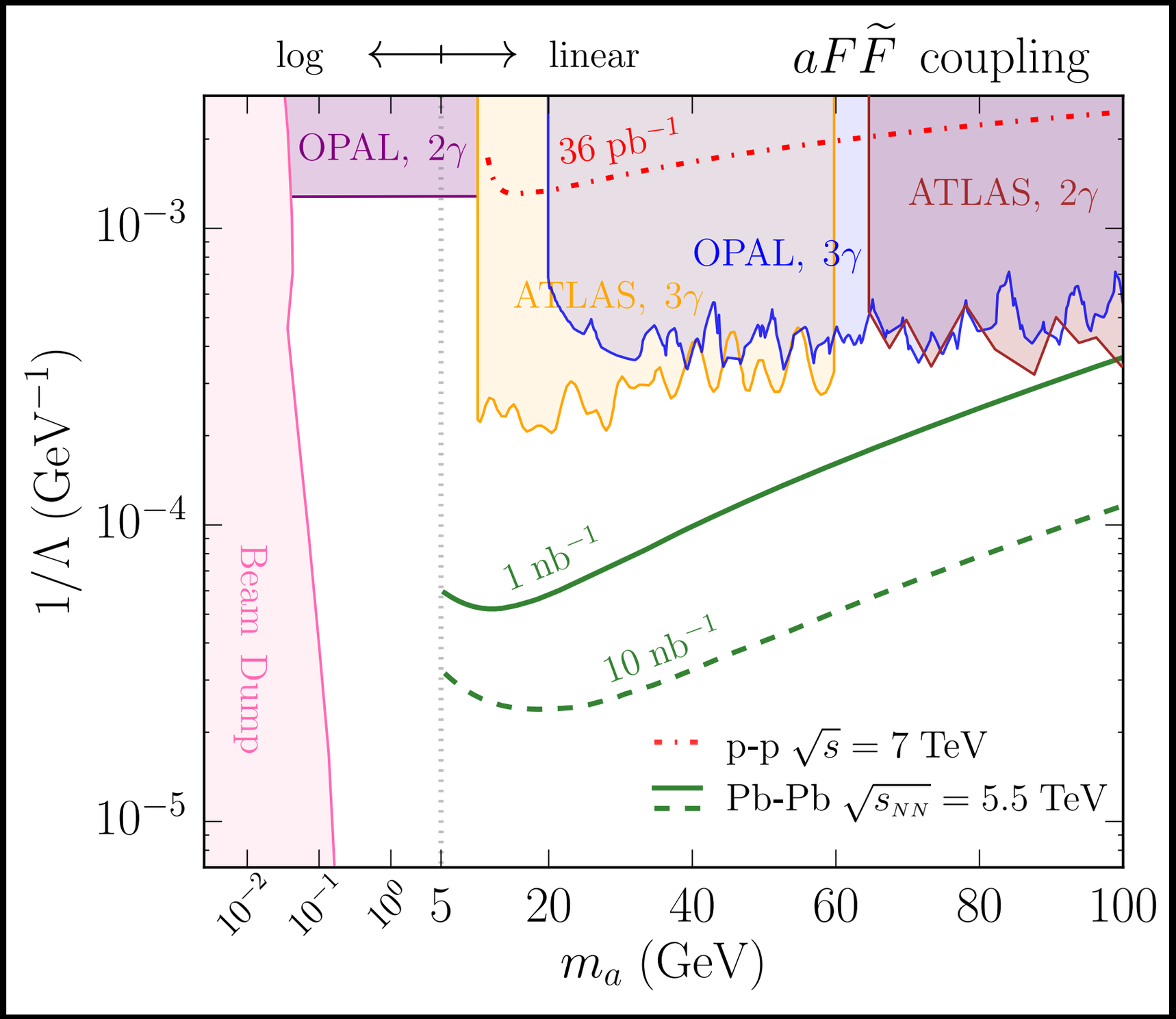
Injected signal



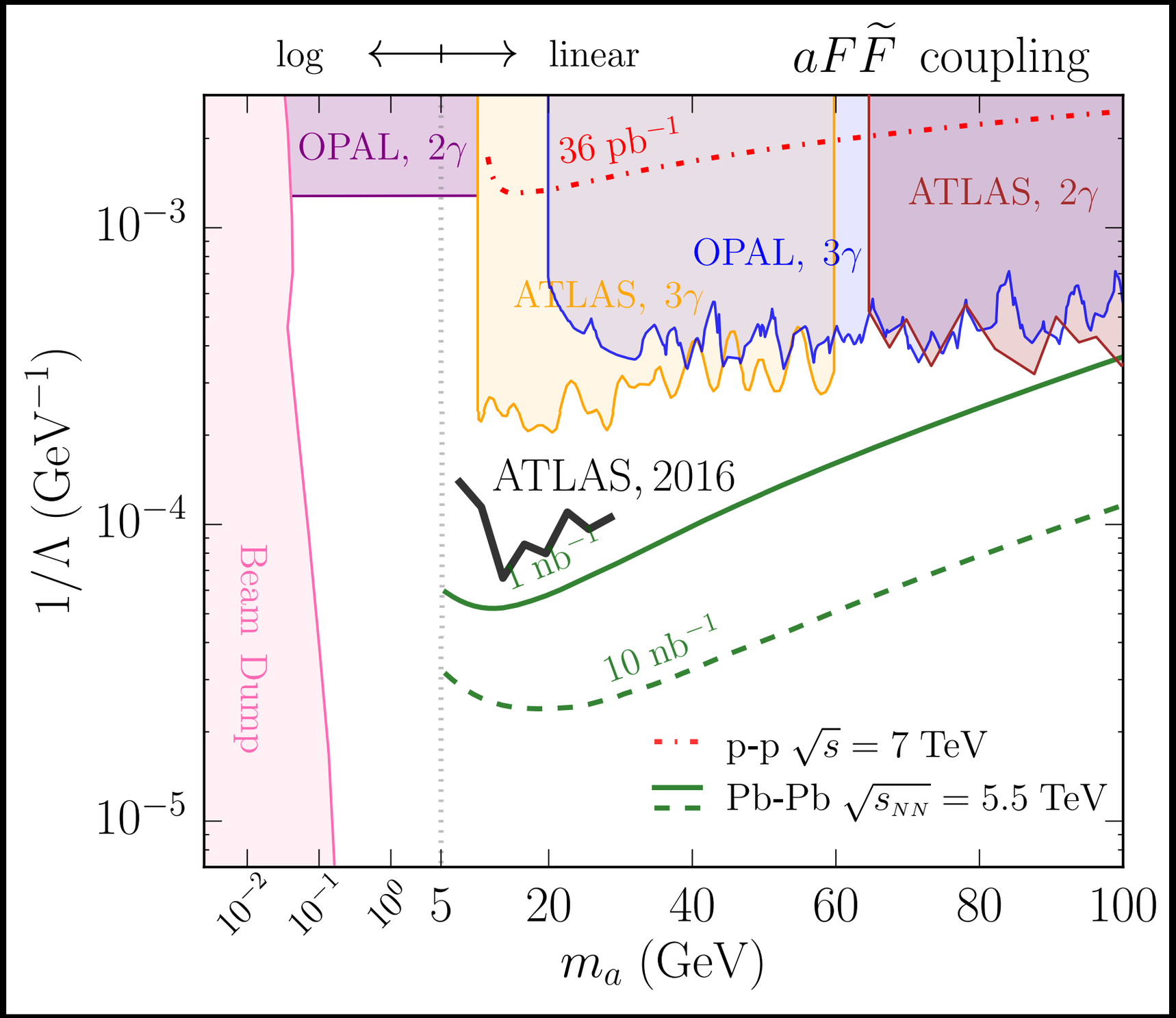
Further cuts: $|\eta_\gamma| < 2.5$ $|\Delta\phi - \pi| < 0.04$



Projected limit

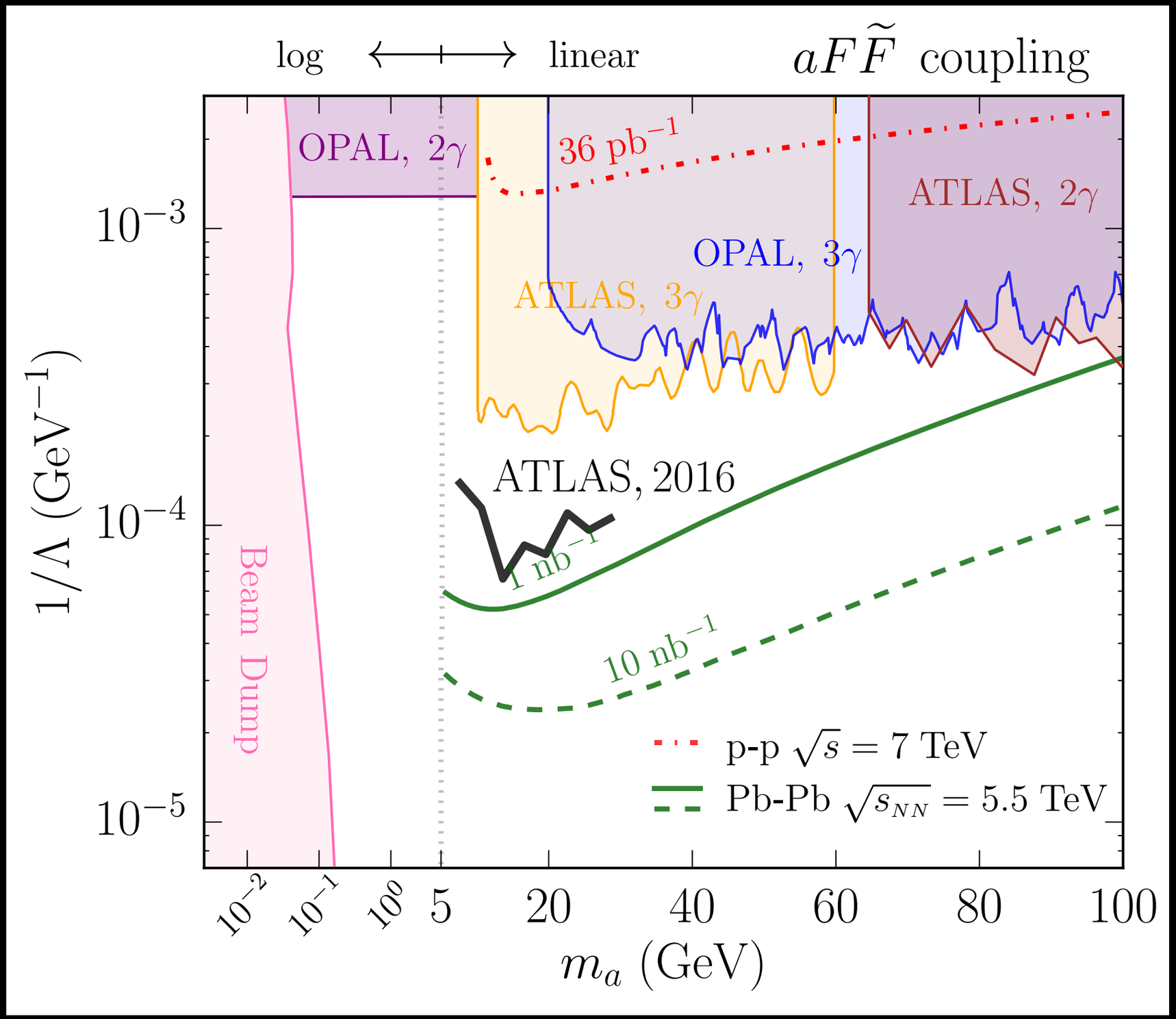


New limit set



Recasting **ATLAS-CONF-2016-111**

As far as we are aware, only place heavy ions can trump the p-p program for BSM



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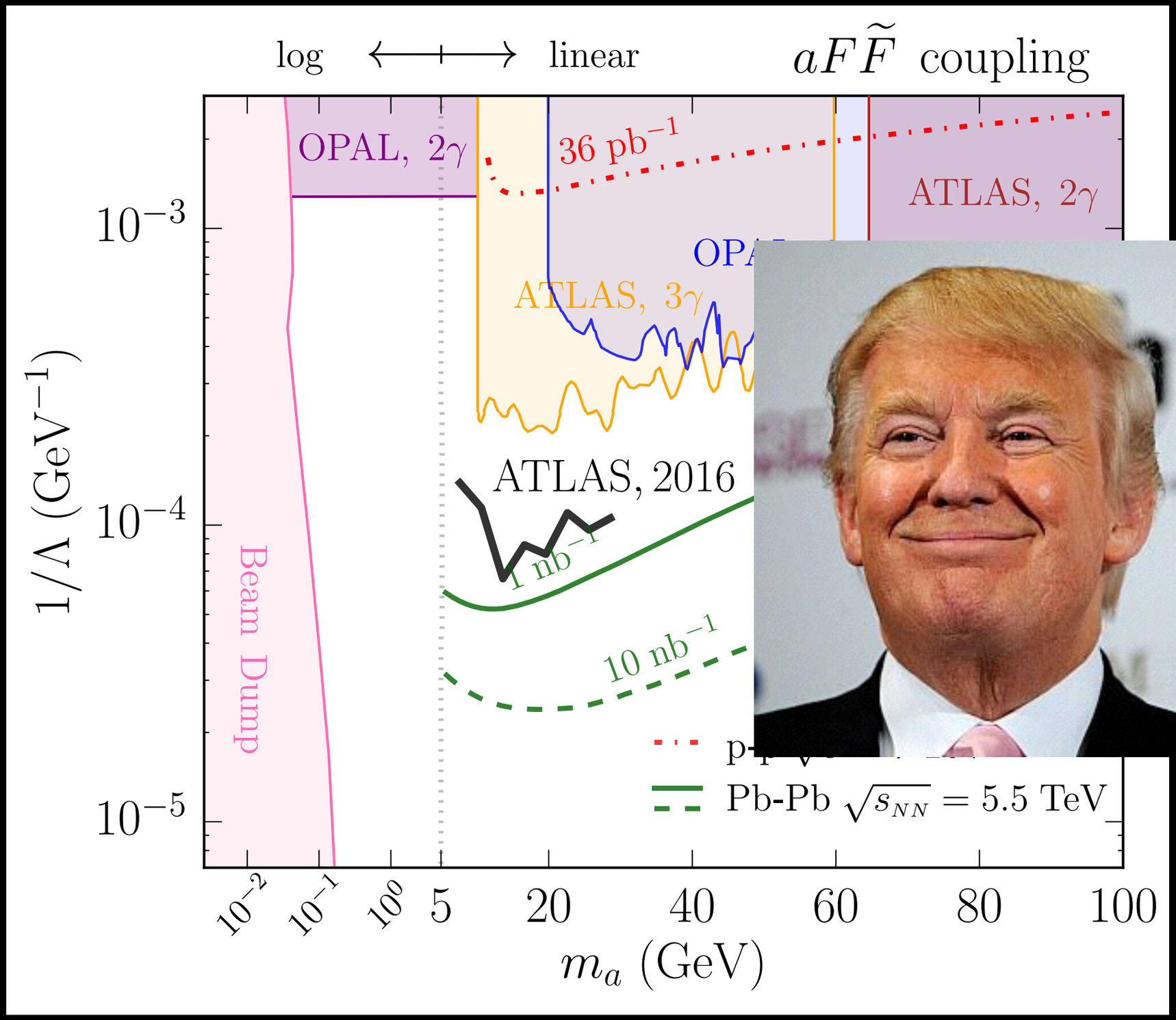

Thanks for listening!