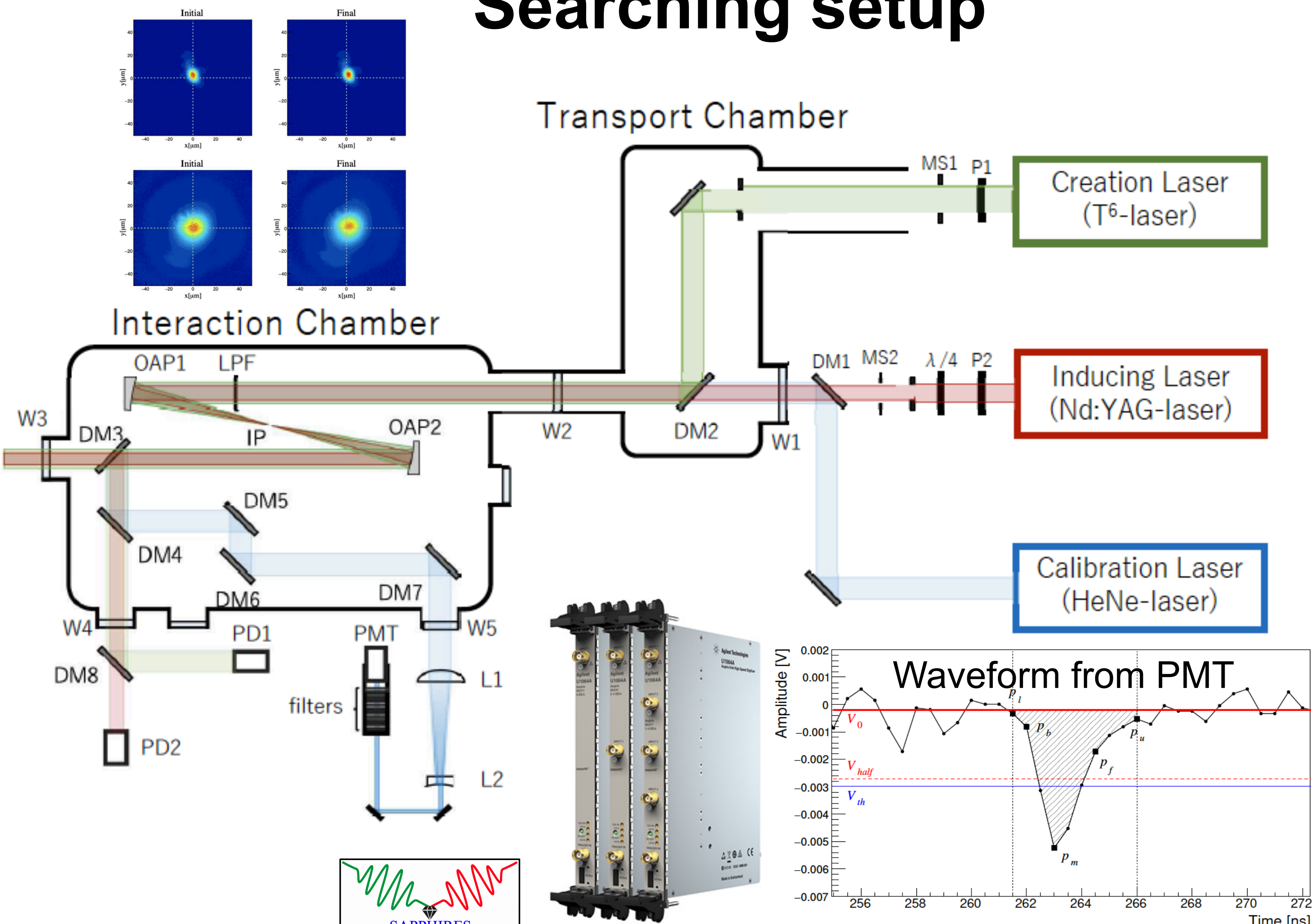
Searching setup



SAPPHIRES

arXiv: 2105.01224
The SAPPHIRES collaboration

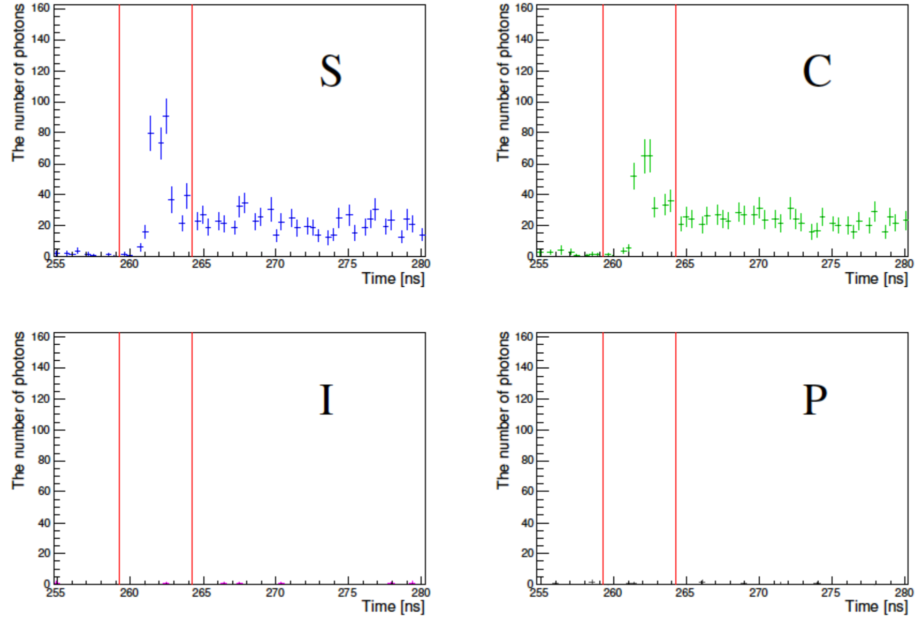
Pressure dependence of atomic four-wave mixing signals

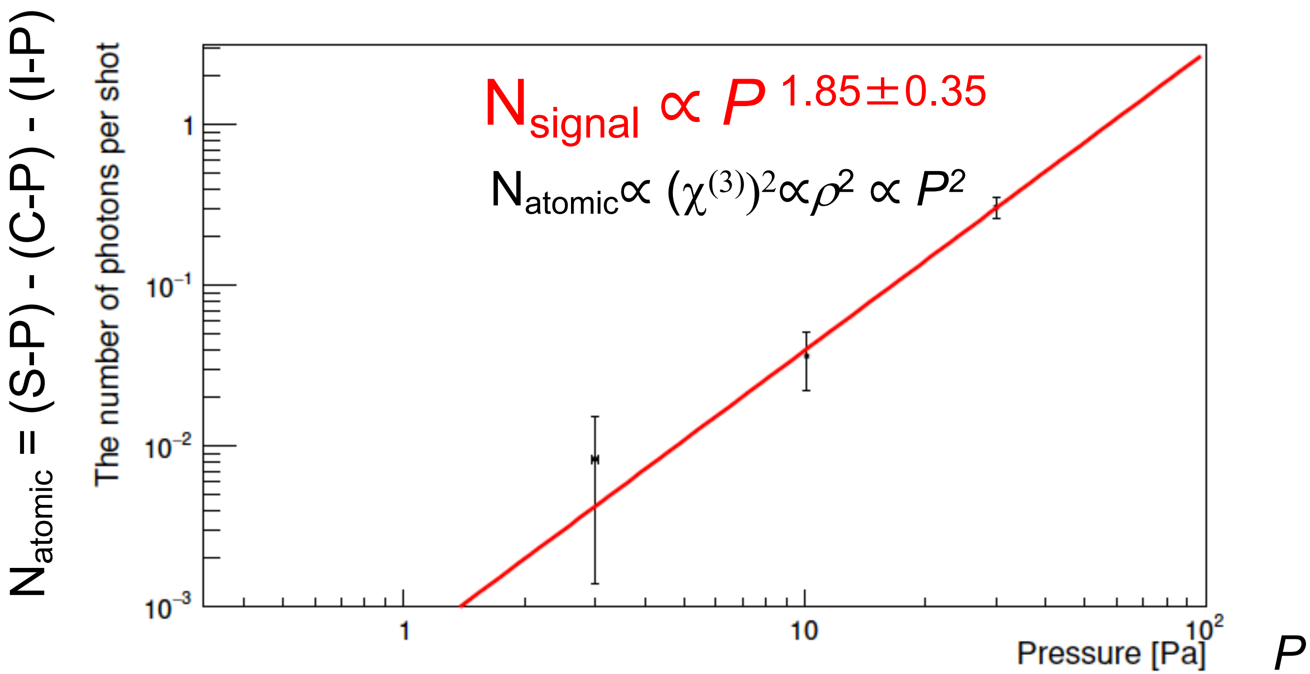
Creation + Inducing lasers

Creation laser

Inducing lasers

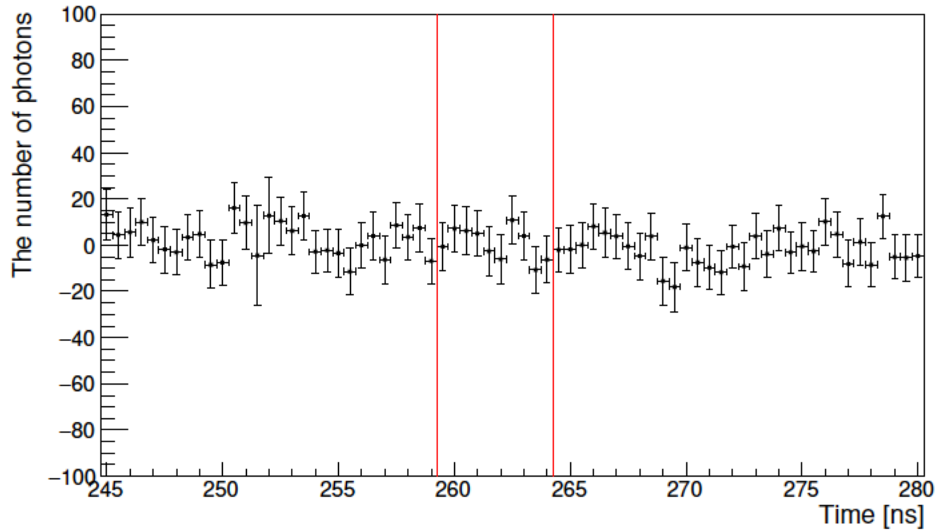
Pedestal





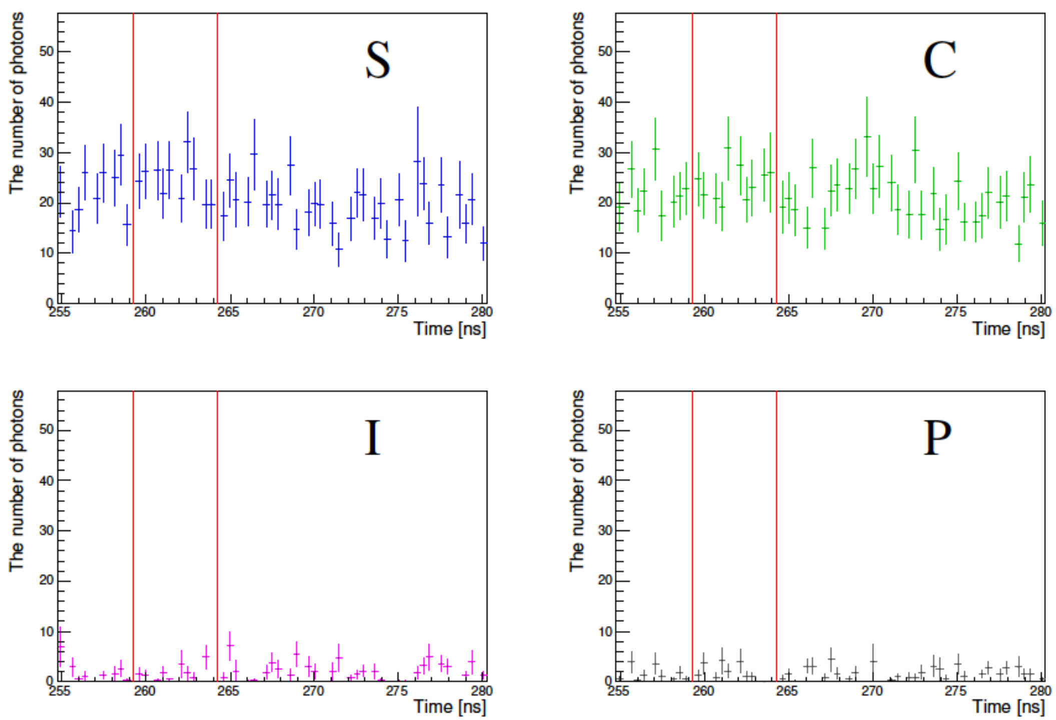
Search result at 2.6 x 10^{-5} Pa

$N_{signal} = (S\text{-}P) - (C\text{-}P) - (I\text{-}P)$



Background N_{atomic}
$O(10^{-8})$ photons

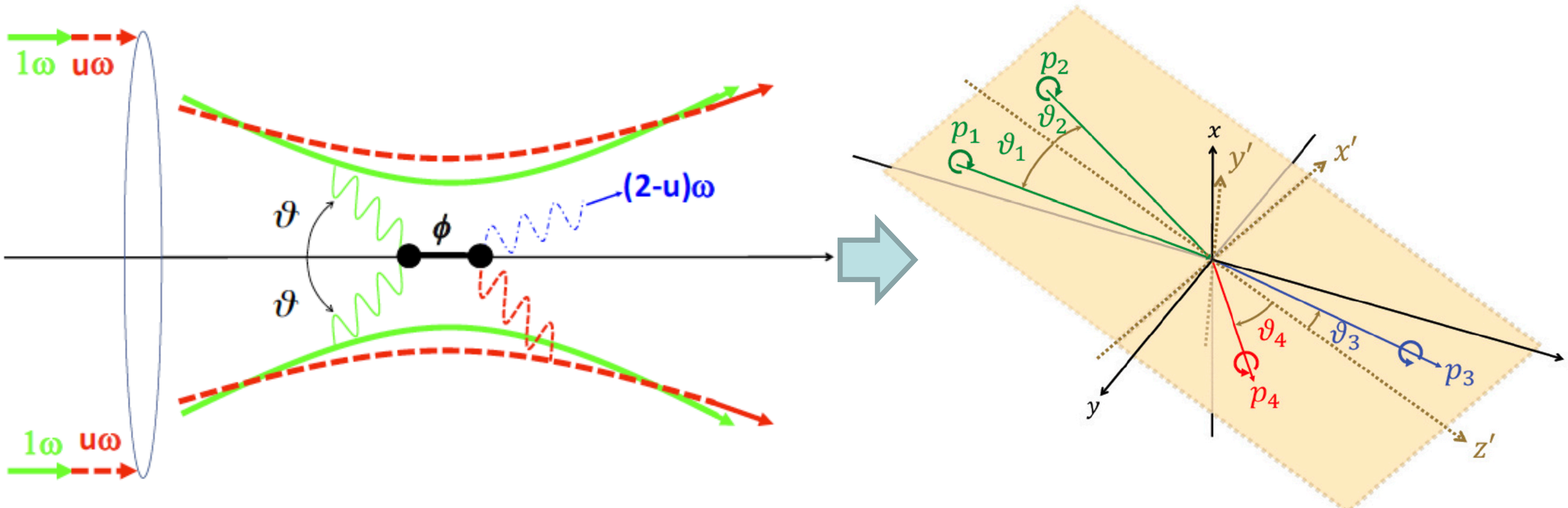
$N_{signal} = 4.9 \pm 22.8(\text{stat.}) \pm 22.8(\text{sys.I}) \pm 3.8(\text{sys.II}) \pm 3.7(\text{sys.III})$



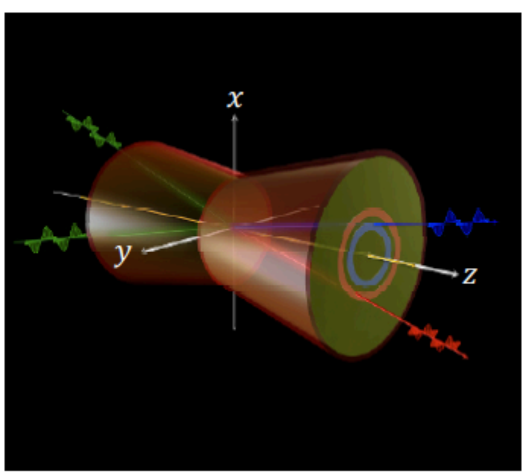
Extension to asymmetric-incident and non-coaxial collisions from symmetric geometry

KH and Y. Kirita,
Stimulated radar collider for probing gravitationally weak coupling pseudo Nambu-Goldstone bosons , JHEP 09 95 (2020)

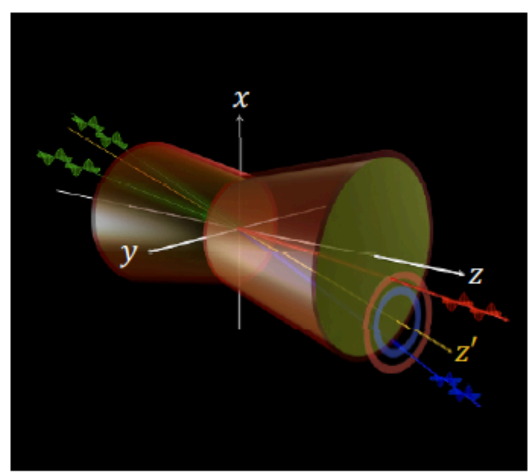
(a)



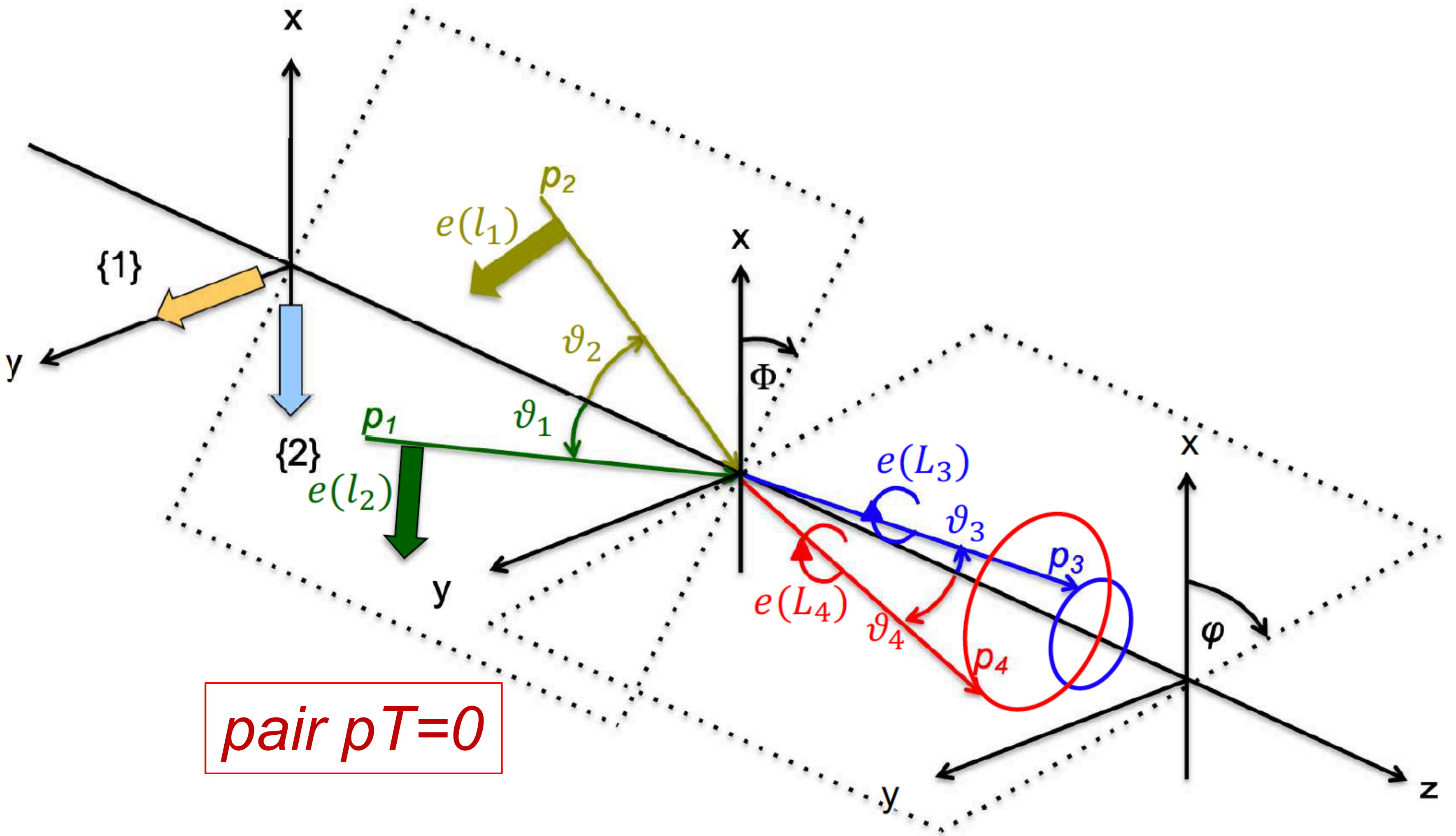
(b)



(c)



Linear polarization (creation) + Circular polarization (inducing)



pair pT=0

Exclusion region

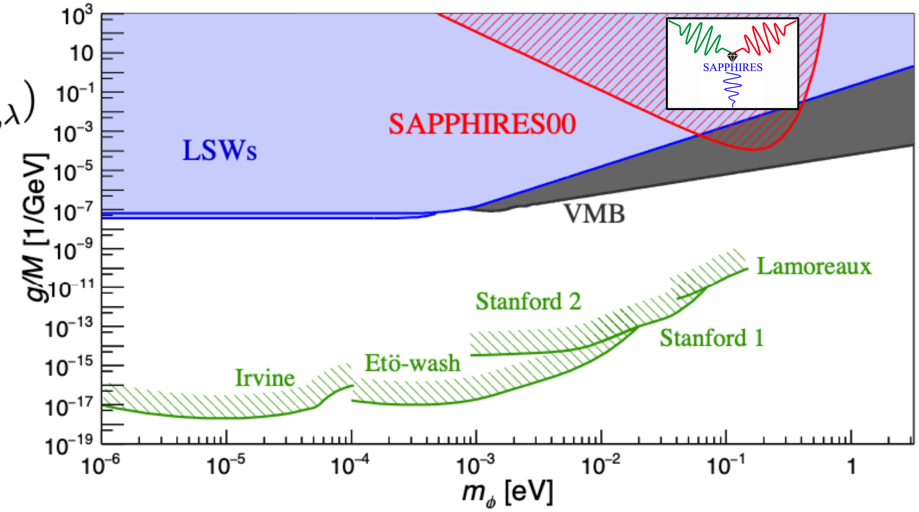
$$\mathcal{M}_S = \frac{1}{4}\left(\frac{g}{M}\right)^2 \frac{\boxed{\text{Vertex Factors}}}{m^2 - (p_1 + p_2)^2}$$

$$F^{\mu\nu} \equiv (-i)\int \frac{d^3\boldsymbol{p}}{(2\pi)^3 2p^0} \Sigma_{\lambda=1,2}(P^{\mu\nu}e^{-ipx}a_{\boldsymbol{p},\lambda} + \hat{P}^{\mu\nu}e^{ipx}a^\dagger_{\boldsymbol{p},\lambda})$$

$$P^{\mu\nu} \equiv p^\mu e^\nu(p,\lambda) - e^\mu(p,\lambda)p^\nu,$$

$$\hat{P}^{\mu\nu} \equiv e^{*\mu}(p,\lambda)p^\nu - p^\mu e^{*\nu}(p,\lambda)$$

$$\text{Scalar-type}: (P_1(l_1)P_2(l_2))(\hat{P}_3(L)\hat{P}_4(L))$$



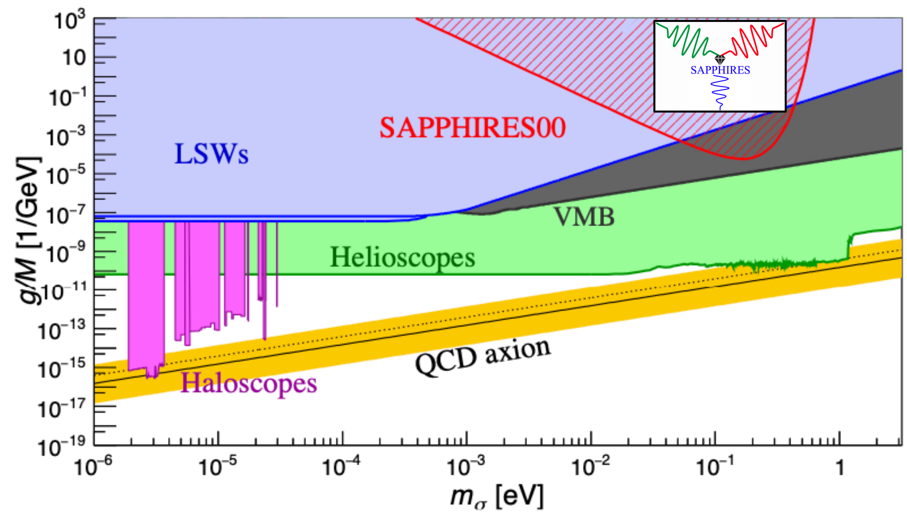
arXiv:2105.01224 (accepted by JHEP 2021)

$$\tilde{F}^{\mu\nu} \equiv \epsilon^{\mu\nu\alpha\beta}F_{\alpha\beta} = (-i)\int \frac{d^3\boldsymbol{p}}{(2\pi)^3 2p^0} \Sigma_{\lambda=1,2}(\tilde{P}^{\mu\nu}e^{-ipx}a_{\boldsymbol{p},\lambda} + \hat{\tilde{P}}^{\mu\nu}e^{ipx}a^\dagger_{\boldsymbol{p},\lambda})$$

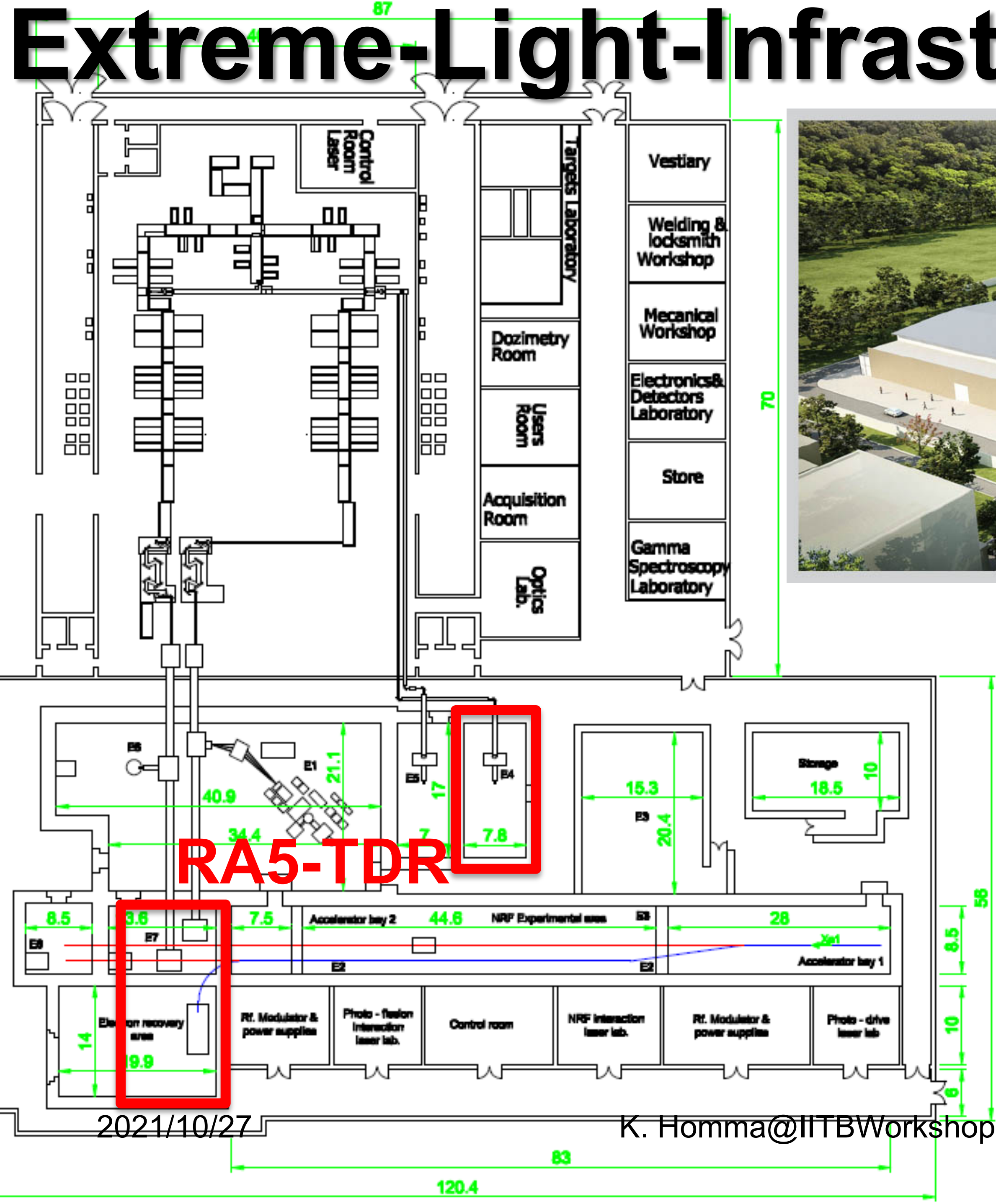
$$\tilde{P}^{\mu\nu} \equiv \varepsilon^{\mu\nu\alpha\beta}(p_\alpha e_\beta(p,\lambda) - e_\alpha(p,\lambda)p_\beta)$$

$$\hat{\tilde{P}}^{\mu\nu} \equiv \varepsilon^{\mu\nu\alpha\beta}(p_\alpha e^*_\beta(p,\lambda) - e^*_\alpha(p,\lambda)p_\beta)$$

$$\text{Pseudoscalar-type}: (P_1(l_1)\tilde{P}_2(l_2))(\hat{P}_3(L)\hat{\tilde{P}}_4(L))$$



Extreme-Light-Infrastructure (ELI)



ELI-NP facility

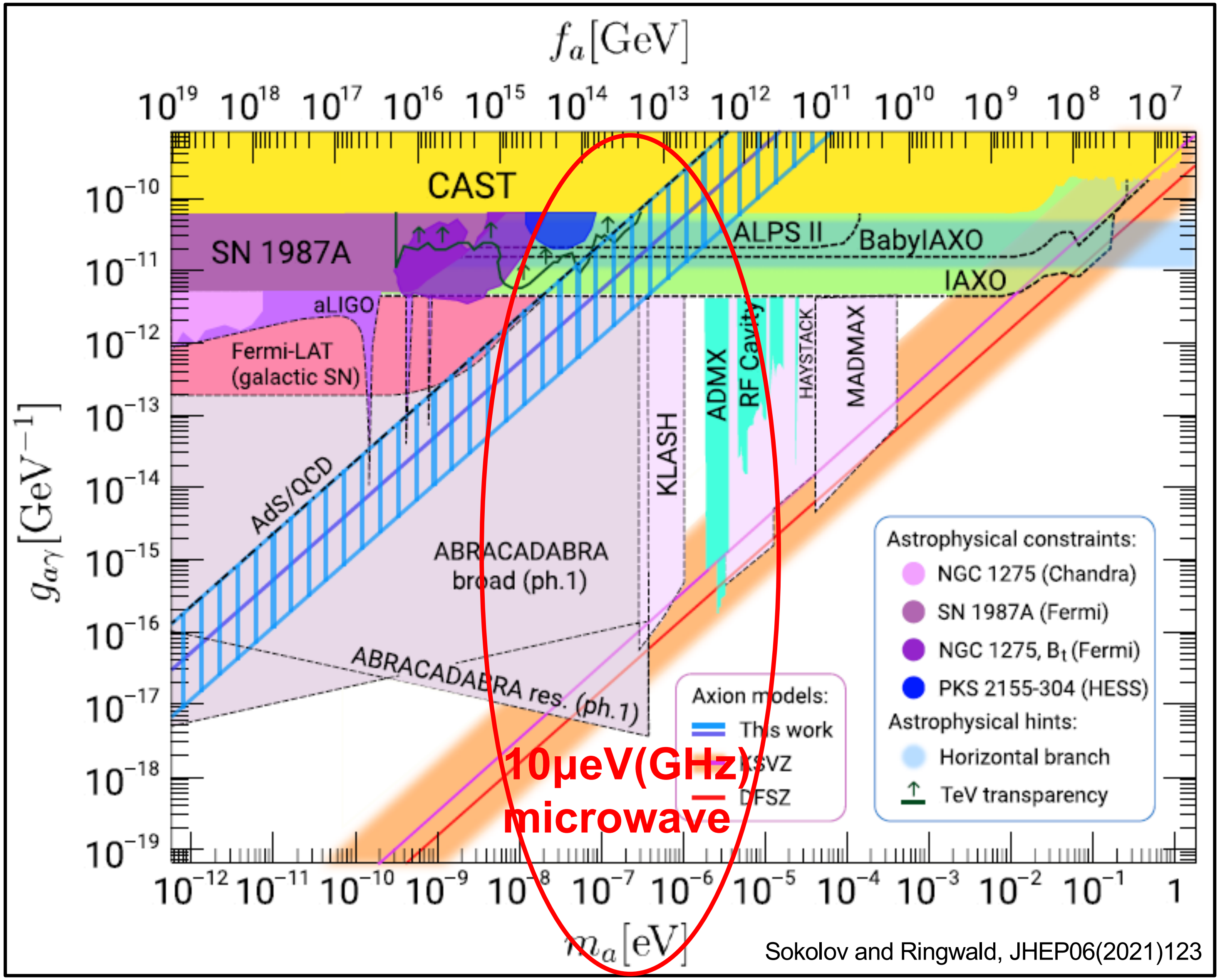
2 x 10PW

2 x 1 PW

2 x 0.1 PW

0.2-19.5 MeV gamma beam produced by ~700 MeV e- + laser

Target mass-coupling domains



Dream of dilaton detection

Progress of Theoretical Physics, Vol. 126, No. 3, September 2011

An Approach toward the Laboratory Search for the Scalar Field as a Candidate of Dark Energy

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[2] *Graduate School of Science, Hiroshima University, Higashi-Hiroshima 739-8526, Japan*
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(Received March 10, 2011; Revised July 18, 2011)

The observed accelerating universe indicates the presence of Dark Energy which is probably interpreted in terms of an extremely light gravitational scalar field. We suggest a way to probe this scalar field which contributes to optical light-by-light scattering through the resonance in the quasi-parallel collision geometry. As we find, the frequency-shifted photons with the specifically chosen polarization state can be a distinct signature of the scalar-field-exchange process in spite of the extremely narrow width due to the gravitationally weak coupling to photons. Main emphasis will be placed in formulating a prototype theoretical approach, then showing how the weak signals from the gravitational coupling are enhanced by other non-gravitational effects at work in laser experiments.

dilaton as a candidate of dark energy

Conformal (dilatation) transform

$$g_{\mu\nu} \rightarrow g_{*\mu\nu} = \Omega^2(x) g_{\mu\nu}$$

Jordan Frame (JF)

$$\xi\phi^2 = (8\pi G_{eff})^{-1}$$

$$\phi = \hat{\xi}^{-1/2}\Omega, \quad \text{with} \quad \Omega = \exp(\hat{\zeta}\sigma)$$

$$\hat{\xi} = \xi M_{\mathrm{P}}^{-2}, \quad \hat{\zeta} = \zeta M_{\mathrm{P}}^{-1}$$

$$\sqrt{-g}\left(\tfrac{1}{2}\xi\phi^2 R - \tfrac{1}{2}\epsilon g^{\mu\nu}\partial_\mu\phi\partial_\mu\phi + L_{\mathrm{matter}} - \Lambda\right)$$

Einstein Frame (EF)

Decaying $\Lambda \propto 1 / t^2$

$$\sqrt{-g_*}\left(\tfrac{1}{2}R_* - \tfrac{1}{2}g_*^{\mu\nu}\partial_\mu\sigma\partial_\mu\sigma + L_{*\mathrm{matter}} - \Lambda\exp(-4\hat{\zeta}\sigma)\right)$$

$t=10^{60}$ in Planckian units

$\Lambda=10^{-120}$, $a(t) \propto t^{1/2}$

Coupling to Higgs field to realize constant mass

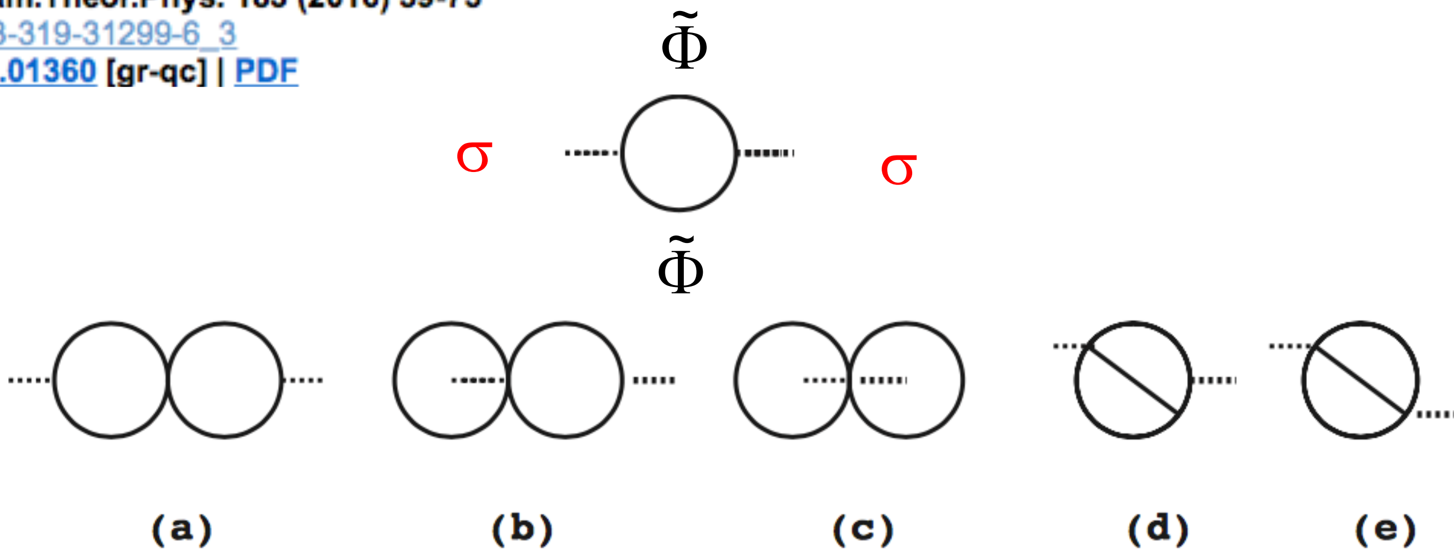
JF **EF**

$$-\mathcal{L}_H = \sqrt{-g}\left(\frac{1}{2}h\phi^2\Phi^2 + \frac{\lambda}{4!}\Phi^4\right) = \sqrt{-g_*}\Omega^{D-4}\left(\frac{1}{2}\tilde{m}^2\Phi_*^2 + \frac{\lambda}{4!}\Phi_*^4\right)$$

$$\tilde{m}^2 = h\hat{\xi}^{-1}$$

pseudo-dilaton mass and coupling

. **A new estimate of the mass of the gravitational scalar field for Dark Energy**
Yasunori Fujii (Waseda U., RISE). Dec 4, 2015. 17 pp.
Published in **Fundam.Theor.Phys. 183 (2016) 59-75**
DOI: 10.1007/978-3-319-31299-6_3
e-Print: **arXiv:1512.01360** [gr-qc] | PDF

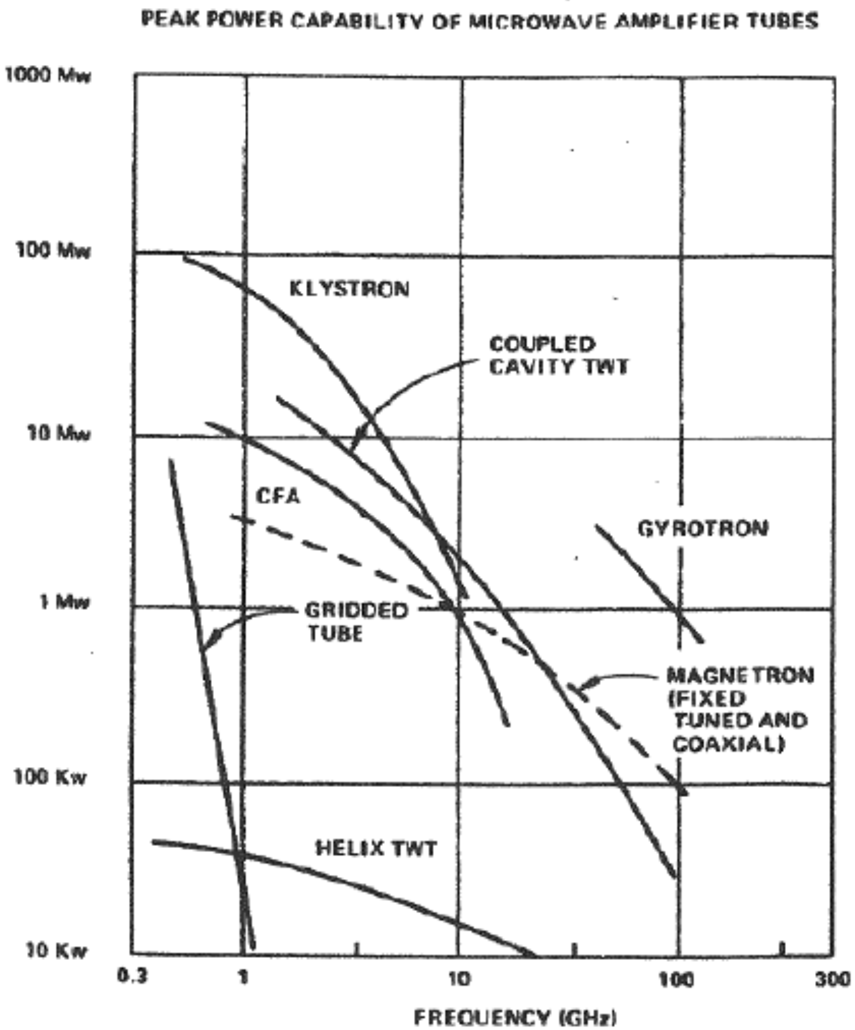


dilaton mass $m_\sigma = 0.15 \sim 0.59\ \mu\text{eV}$ @ $m_{Higgs} = 126$ GeV

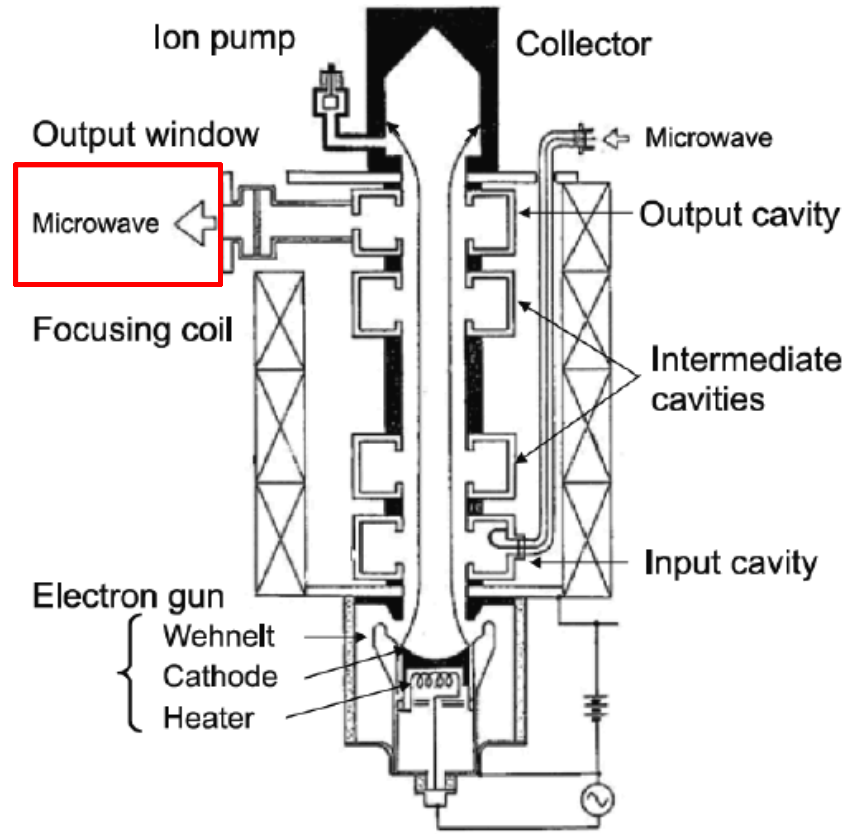
$$-L = \frac{1}{4}\frac{g}{M} F^{\mu\nu} F_{\mu\nu}\sigma$$

dilaton-photon coupling $g/M = (0.5 \sim 2) / (3\pi)\ (\alpha_{qed} / M_p)$

Klystron as a 10^{-5} eV photon source

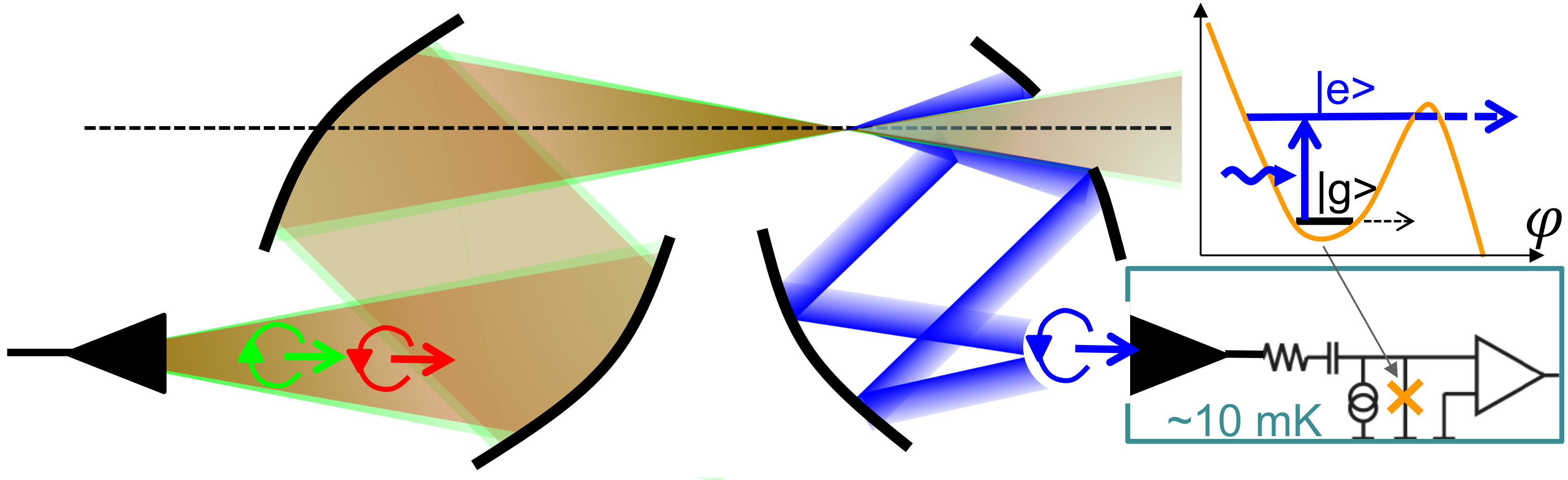


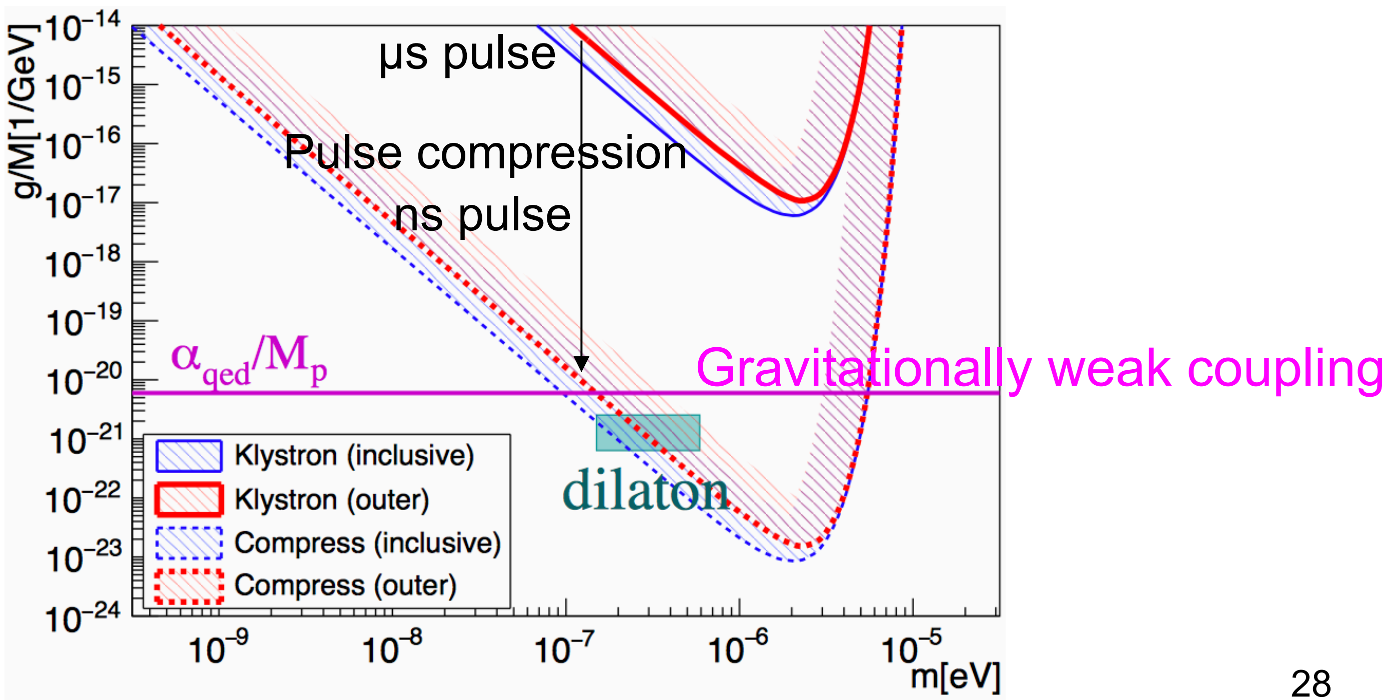
[3] Microwaves made simple: principles and applications/ the staff of the Microwave Training Institute, ed. By W. S. Cheung and F. H. Levin, Artech House, Boston 1985.



J.Plasma Fusion Res. Vol.86 (2010)

Focused radar collider





Comparison with charged particle colliders

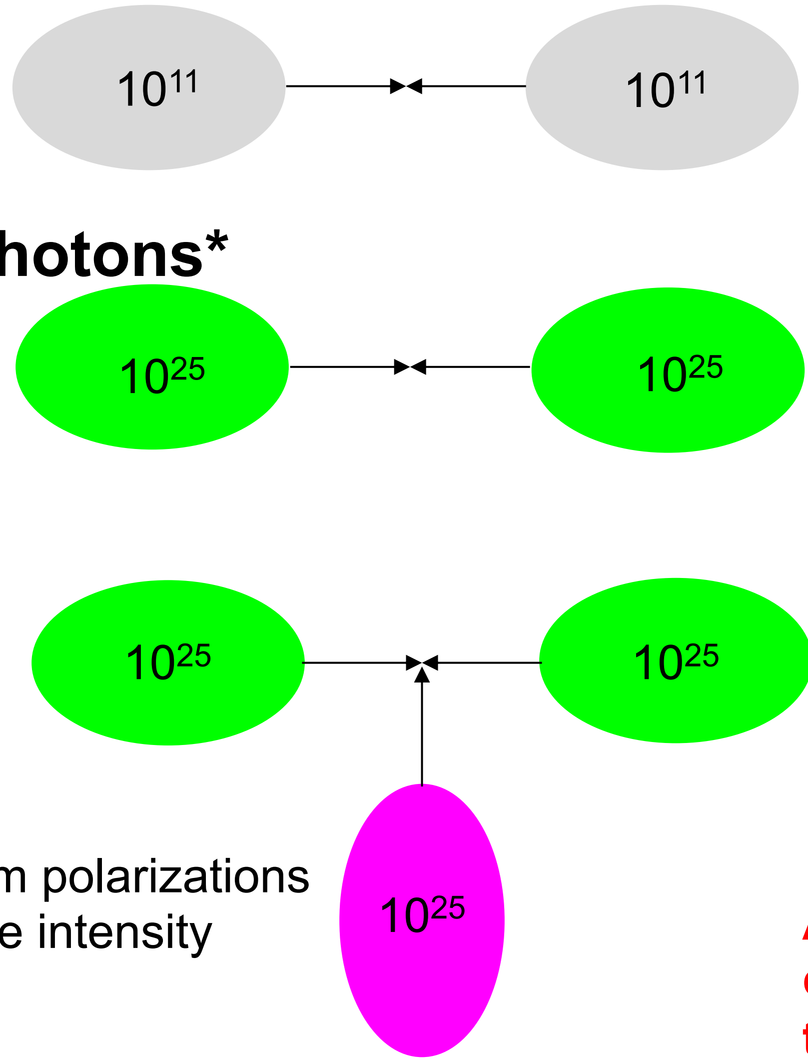
Space-charge limitation exits

$(10^{11})^2$

No limit on # of photons*

10^{25} ~ 100J@GHz

$(10^{25})^2$



Inducement

$(10^{25})^3$

Accessibility to coupling even weaker than that of gravity

* Threshold for real vacuum polarizations far beyond the cutting-edge intensity

Summary

Stimulated resonant photon-photon colliders can extend the present horizon of particle physics and cosmology

huge gap in coupling

force	nuclear	strong	electro magnetic	weak	gravitational
strength	10	0.1	1/137	10^{-5}	10^{-38}
distance (cm)	10^{-13}	10^{-13}	∞	10^{-16}	∞
potential	exp(-mr) / r	a / r + b r	1 / r	exp(-mr) / r	1 / r
gauge boson	pion	gluon	photon	W / Z	graviton
theory	**Yukawa**	QCD	QED	Electroweak	Relativity