A Gamma-ray Beam Line at ALBA for Nuclear Physics Experiments and Applications: Design Status

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http://ific.uv.es/gamma

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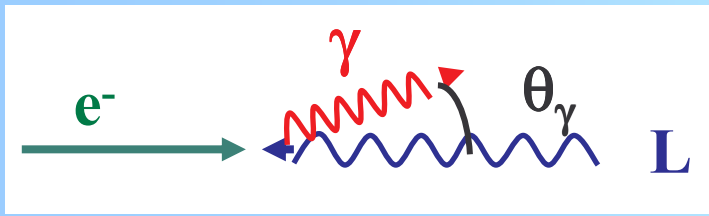
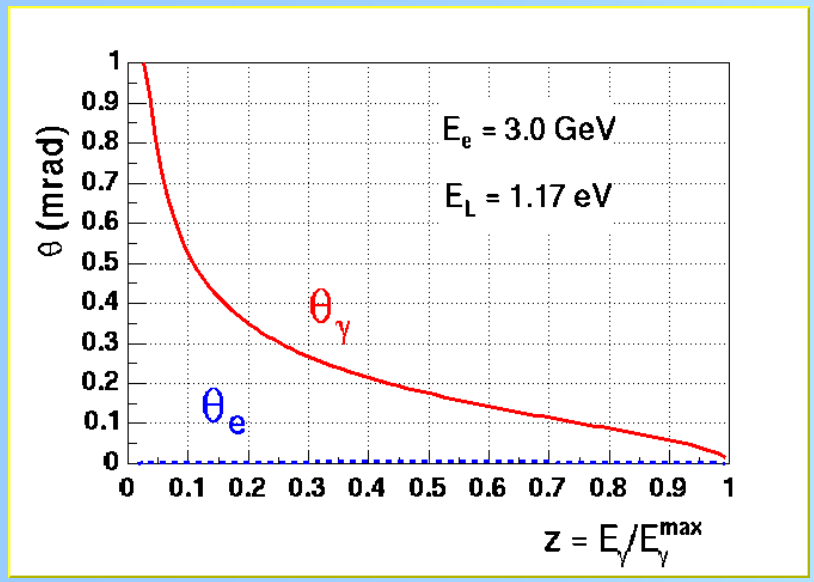
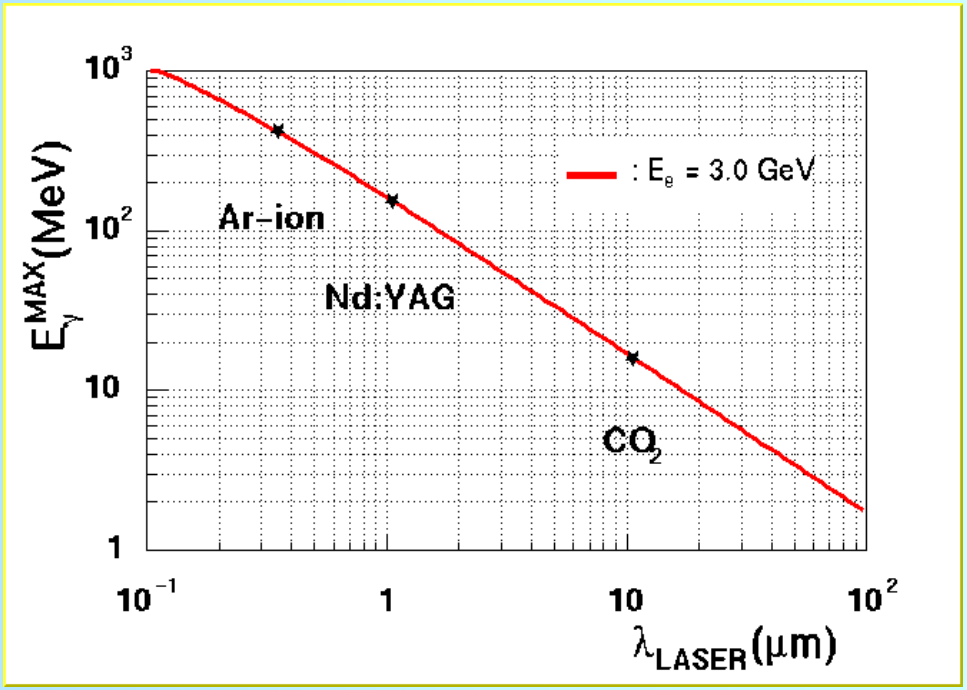
Compton backscattering of Laser light on energetic e⁻



$$E_\gamma = \frac{(1+\beta)E_L}{1+\frac{E_L}{E_e}+\left(\frac{E_L}{E_e}-\beta\right)\cos\theta_\gamma}$$





E_e : 3 GeV	CO_2 0.117 eV	Nd:YAG 1.17 eV	Nd-YAG SH 2.34 eV	Nd-YAG TH 3.51 eV	Nd:YAG FH 4.68 eV
E_γ^{max} (MeV)	16.0	153.1	291.3	416.7	531.0

Gamma-ray energy and polarization distribution

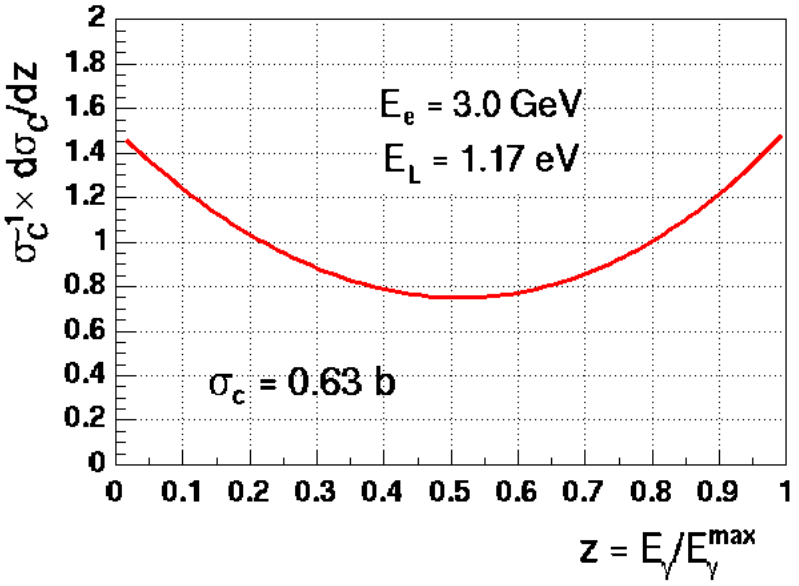
$$\frac{d\sigma_C}{dz} = \frac{1}{2(1+x)} C_{00} = \frac{1}{2(1+x)}\left(1 - y + \frac{1}{1-y} - \frac{4y}{x(1-y)} + \frac{4y^2}{x^2(1-y)^2}\right)$$

$$P_\gamma^{\,L} = \frac{2y^2}{x^2(1-y)^2}\frac{1}{C_{00}}$$

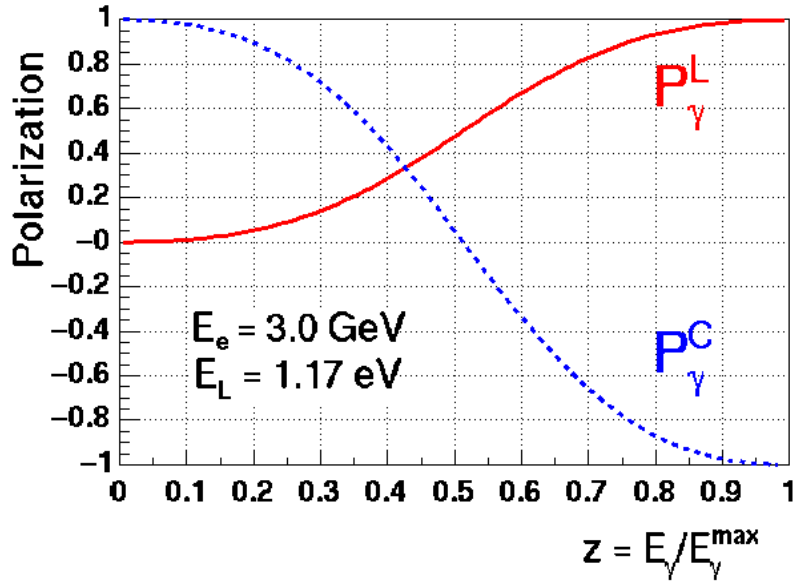
$$x = 4\frac{E_e E_L}{m_e^{\,2} c^4} \quad , \quad y = \frac{E_\gamma}{E_e} \quad , \quad z = \frac{E_\gamma}{E_\gamma^{\,max}}$$

$$P_\gamma^{\,C} = -\left(\frac{2y}{x(1-y)} - 1\right)\left(1 - y + \frac{1}{1-y}\right)\frac{1}{C_{00}}$$

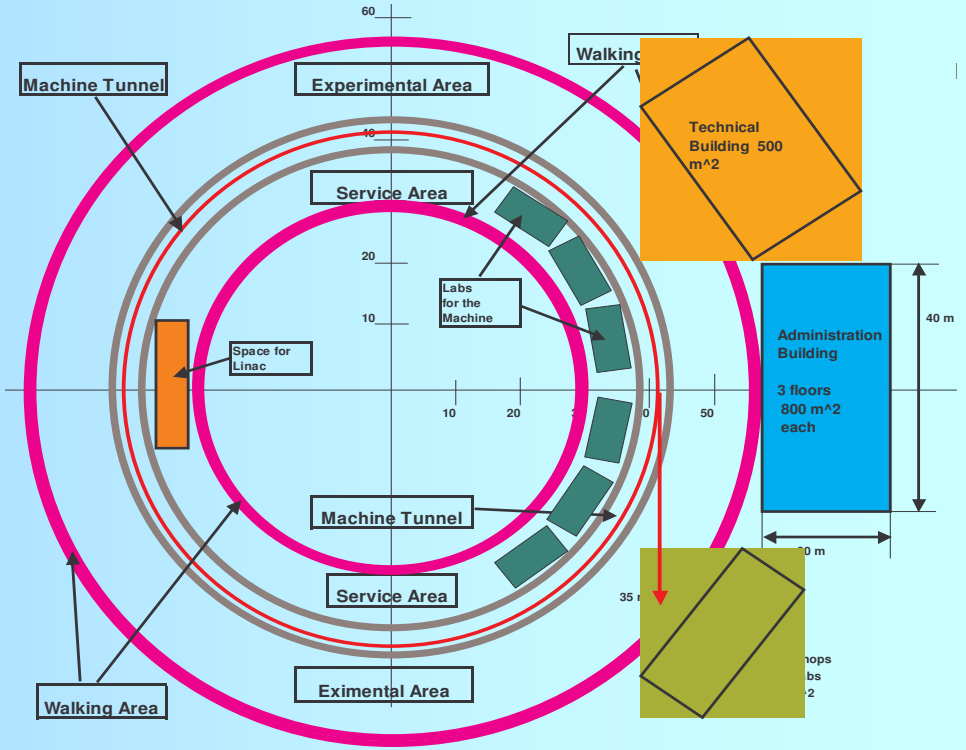
Energy distribution

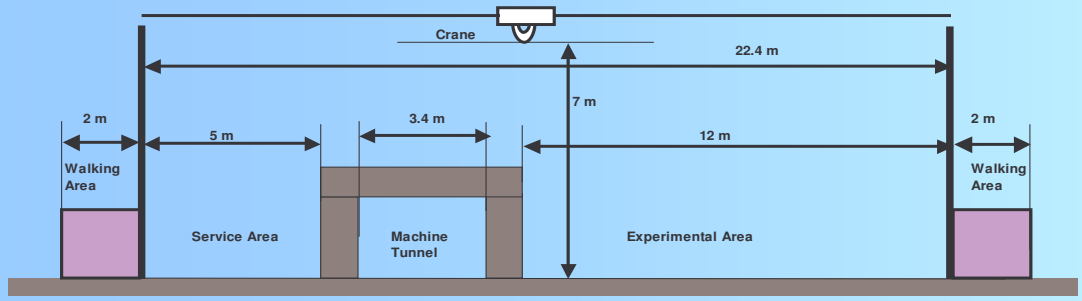


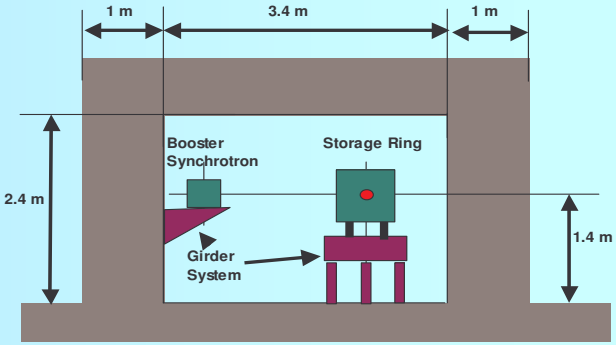
Linear and circular polarization



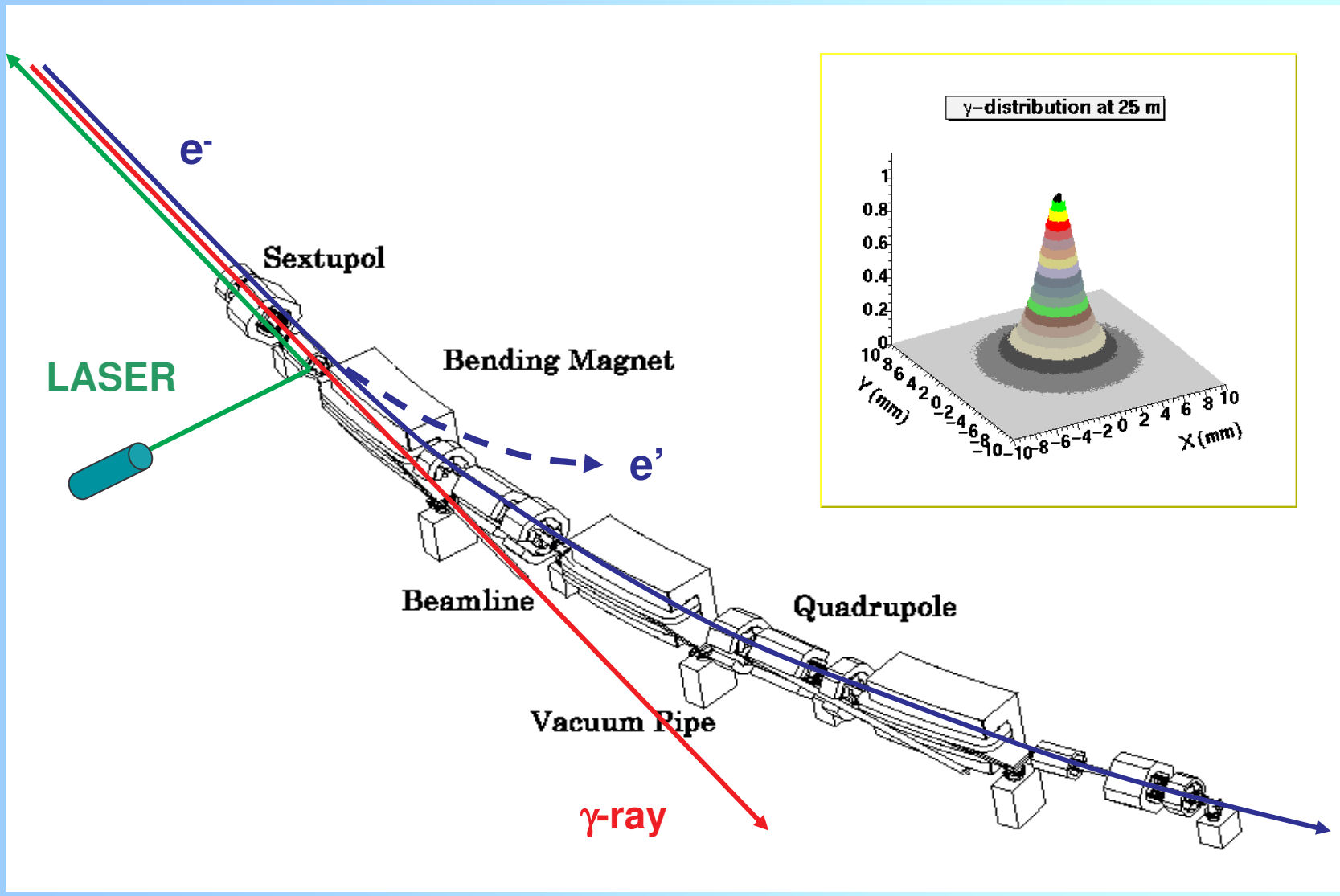
The Synchrotron ALBA



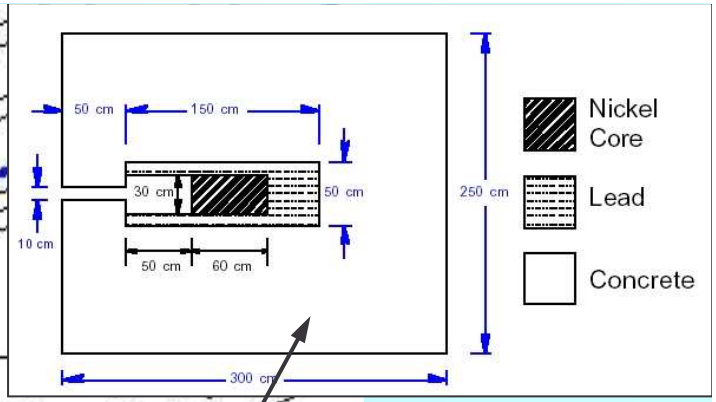




Gamma-ray beam line



(LEPS@Spring8)



BL33LEP

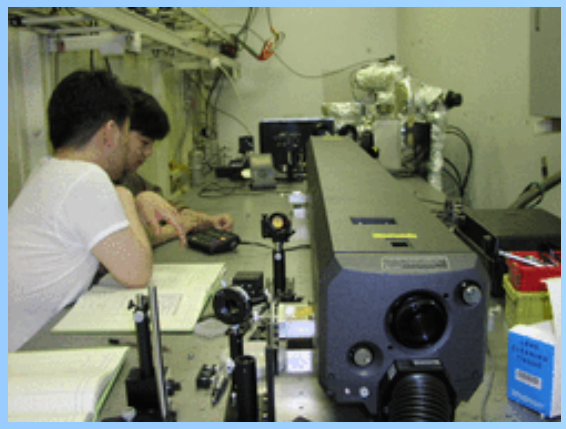
Beam-dump

Laser Hutch

Detector

Experimental Hutch

0 10 20m



ALBA lattice and parameters (provisional)

E_e = 3.0 GeV

$\sigma_E/E_e = 1\times10^{-3}$

I_e = 250 mA (topping-up filling)

DBA lattice structure:

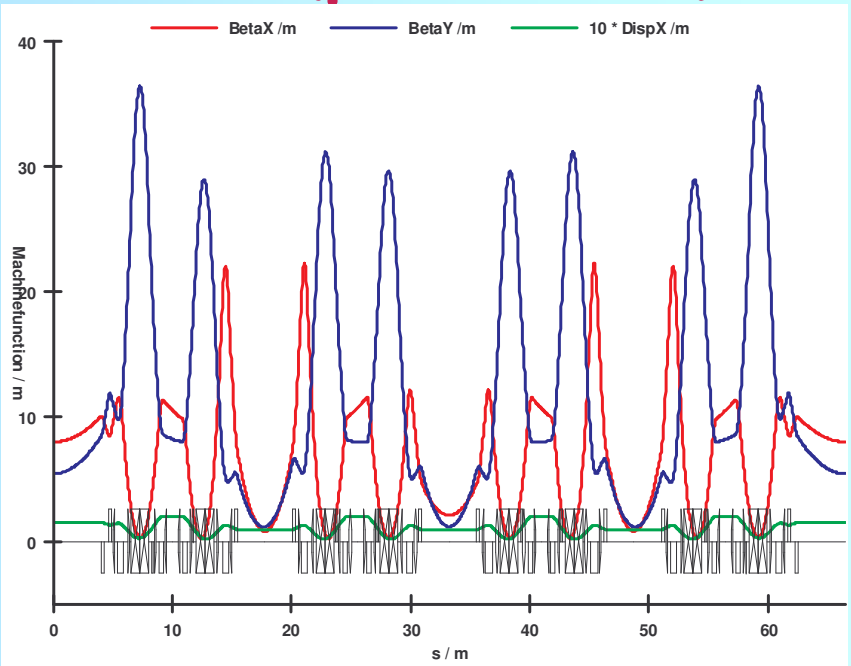
Emittance hor. ε_X = 3.6 nm.rad

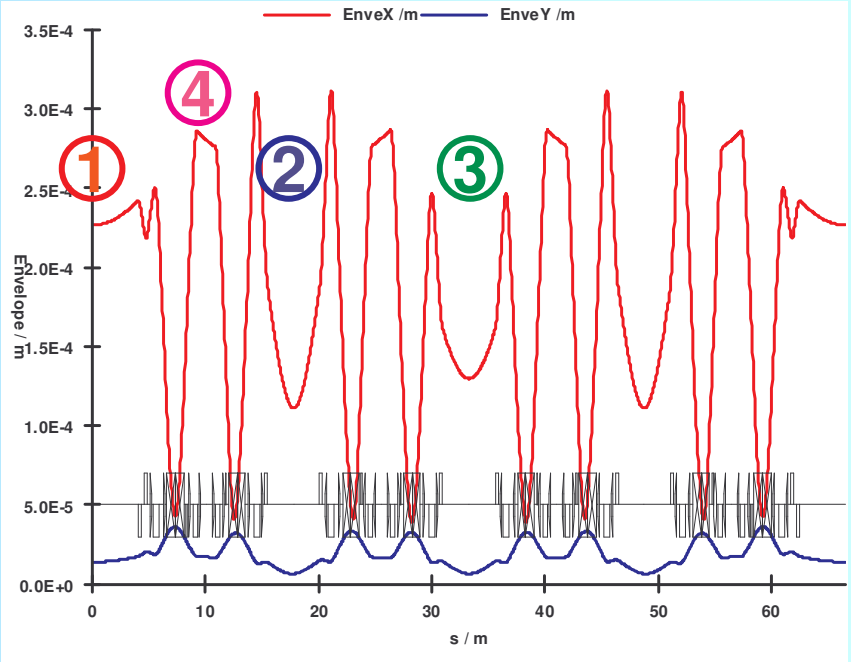
ver. ε_Y = 0.036 nm.rad

Acceptance $\Delta p/p_0 = 0.03$

Straight sections:

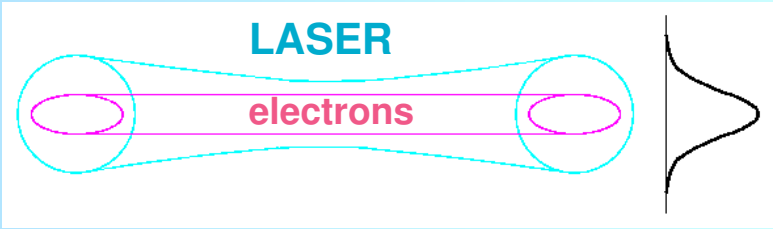
	①	②	③	④
L (m)	13.2	8.6	8.6	4.0
σ_x (μm)	228	113	131	280
$\sigma_{x'}$ (μrad)	21	66	41	21
σ_y (μm)	14	6.5	6.5	17
$\sigma_{y'}$ (μrad)	2.6	5.5	5.5	2.2

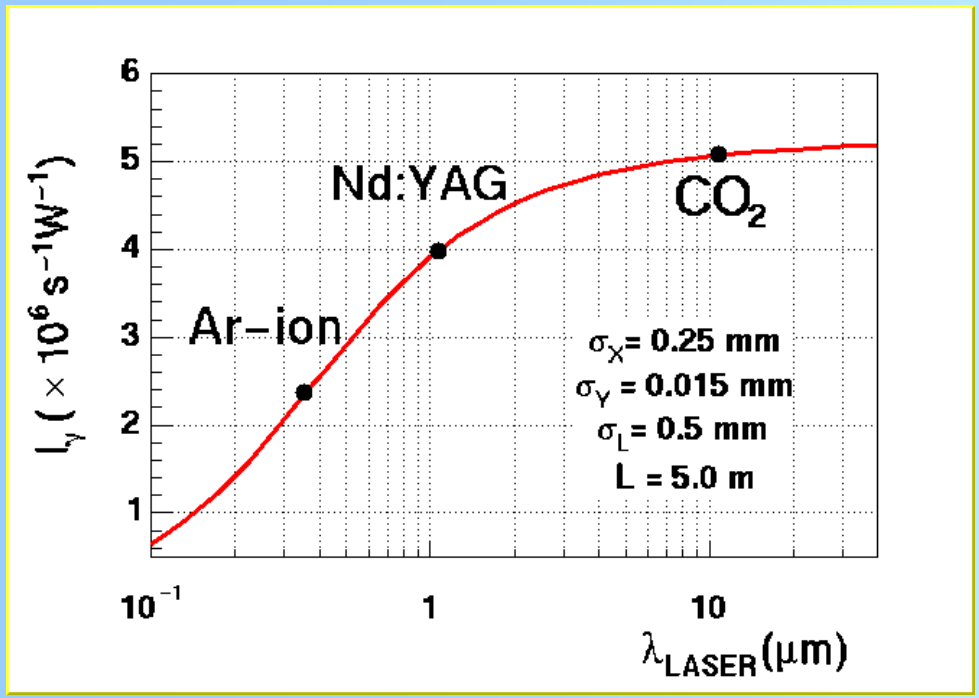




Gamma-ray beam intensity

$$I_\gamma = \frac{2\sigma_C P_L I_e}{ceE_L} \int p_e p_L dV$$





Ring acceptance:

$\Delta p/p_0 = 0.03$

E_γ < 90 MeV: I_γ limited by laser power

E_γ > 90 MeV: I_γ limited by laser power, electron depletion, tagging technique

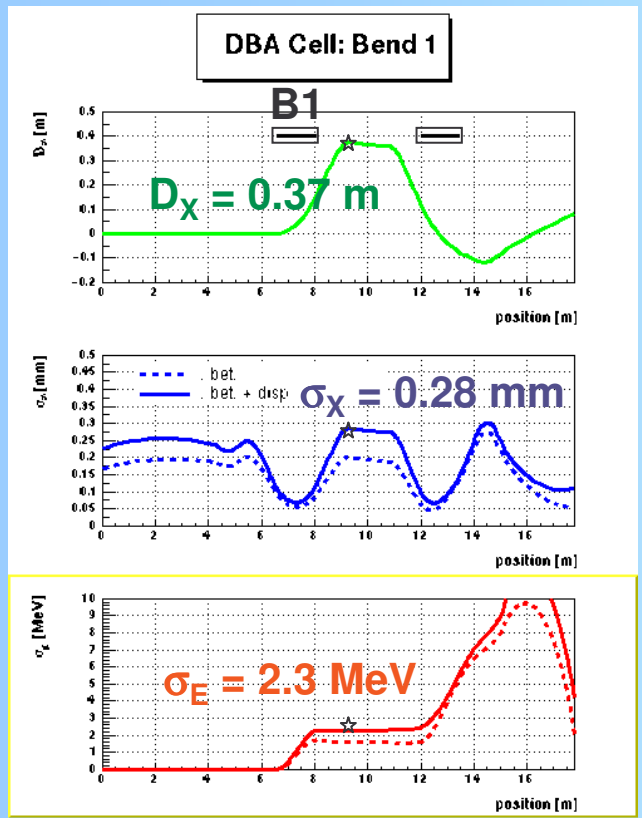
Gamma-ray beam energy and energy resolution (I)

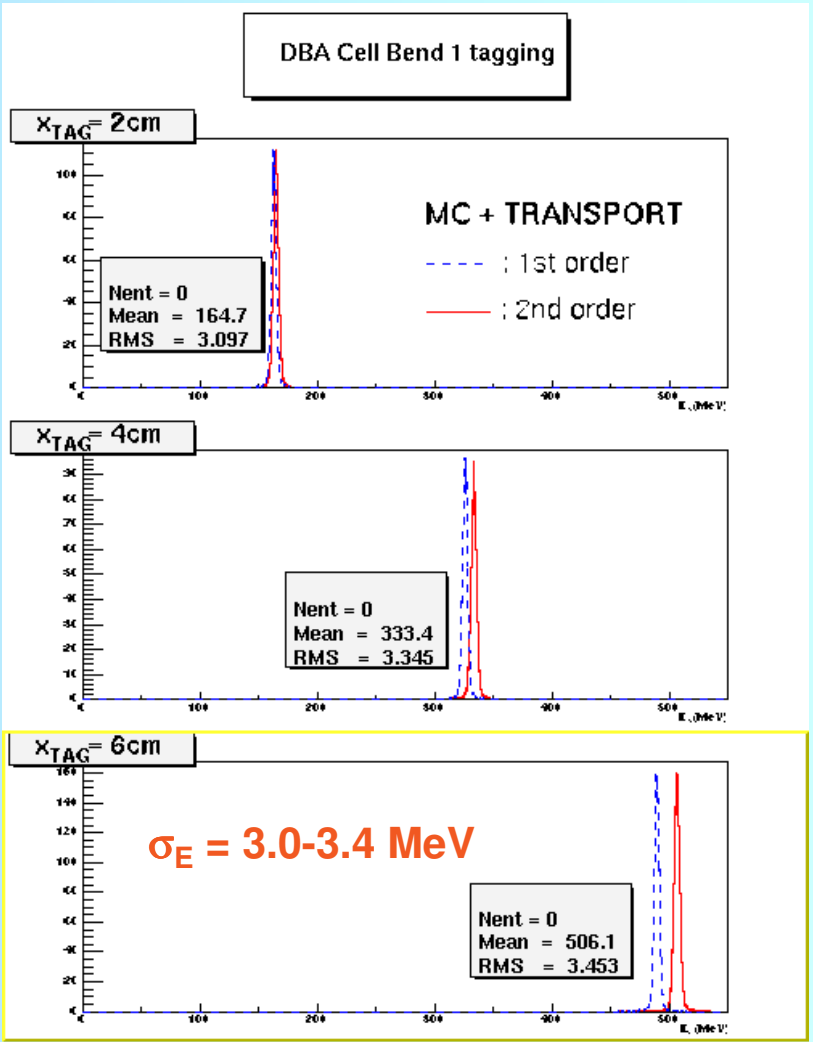
Internal Tagging:

measuring scattered electron energy with Si-microstrip detector after bending magnet

$$\sigma_{E_\gamma} = \frac{1}{D_x}\sqrt{\varepsilon_x \beta_x E_e^2 + \eta_x^2 \sigma_{E_e}^2}$$

- Minimum tagged energy: ~150 MeV
- Resolution limited by e^- beam resolution or optics





Gamma-ray beam energy and energy resolution (II)

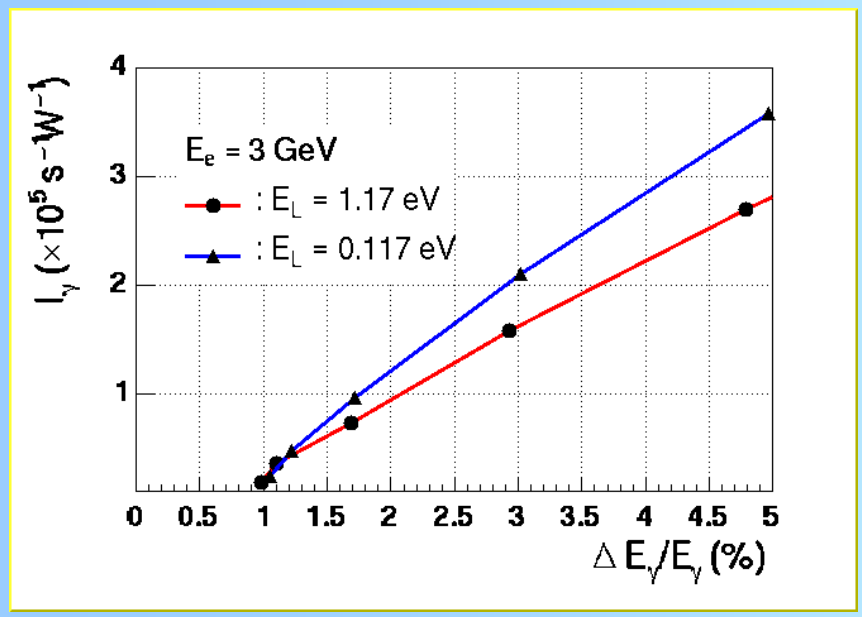
Collimation:

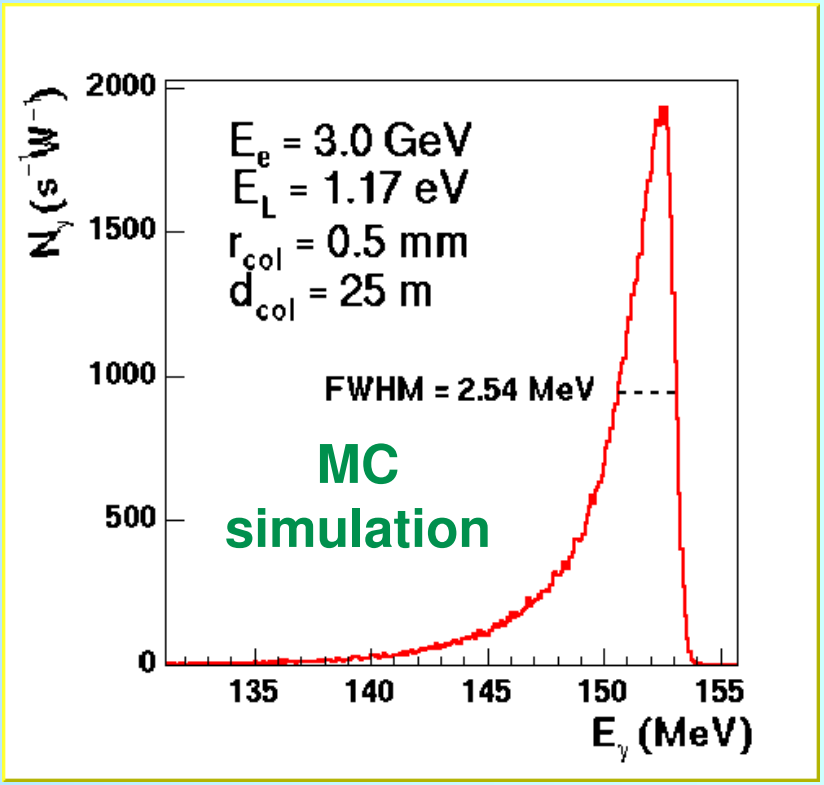
(measuring γ-ray angle)

$$\frac{\sigma_{E_\gamma}}{E_\gamma} = \frac{2\theta_\gamma \sigma_{\theta_\gamma}}{\frac{4E_L}{E_\gamma^{max}} + \theta_\gamma^2}$$

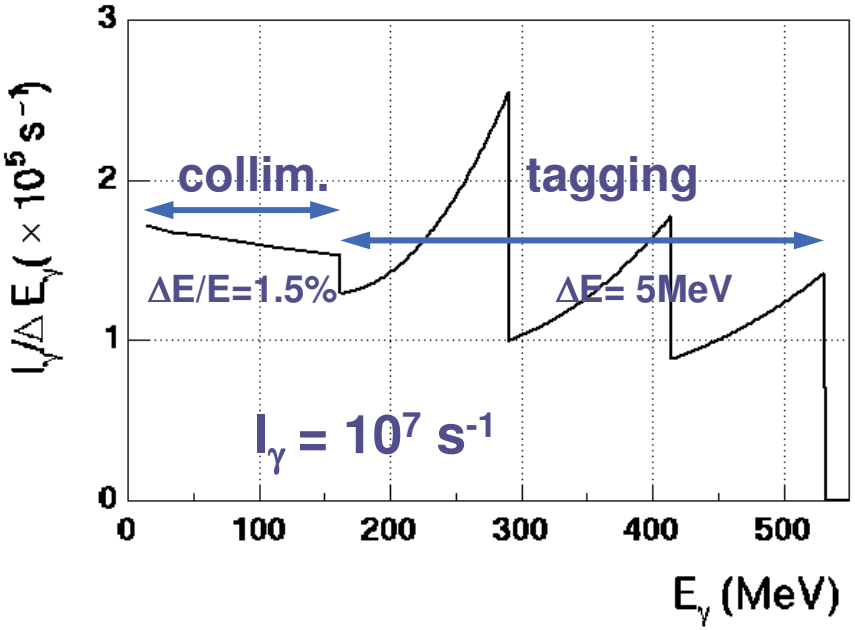
$\Rightarrow$ Only adequate at $\theta_\gamma = 0^o$

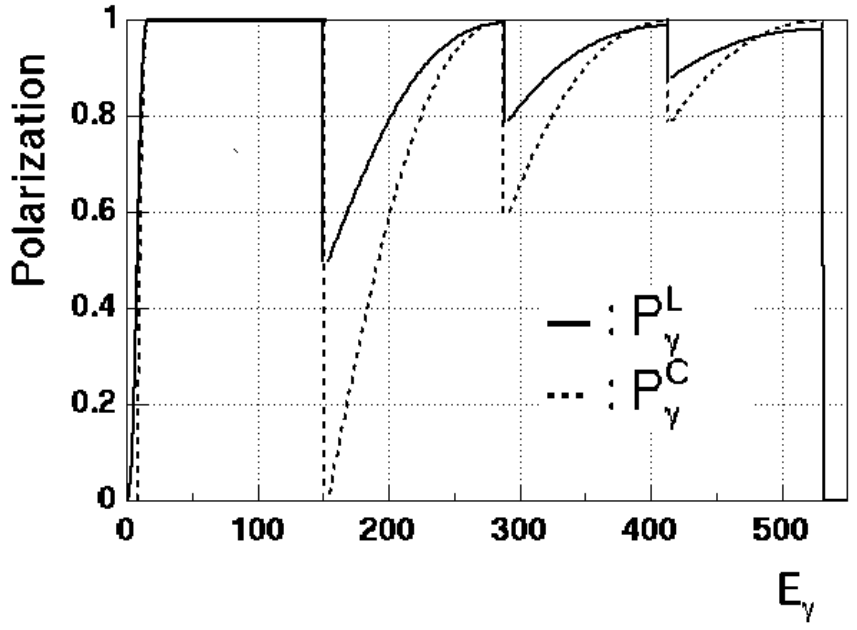
- Needs variable E_e or E_L
- Resolution limited by e^- beam divergence





Gamma-ray beam intensity/resolution and polarization in the range E_γ ~ 15-530 MeV at ALBA (provisional)

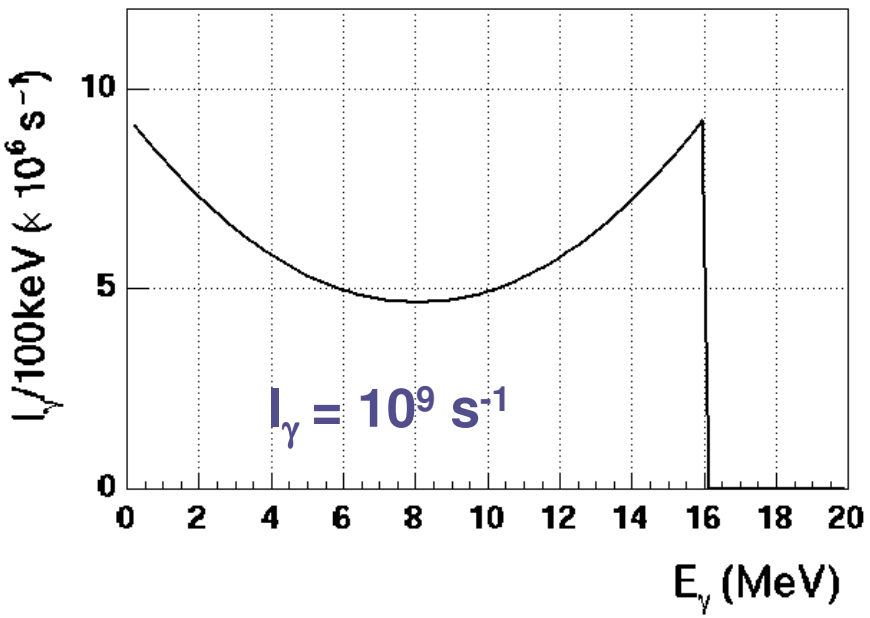


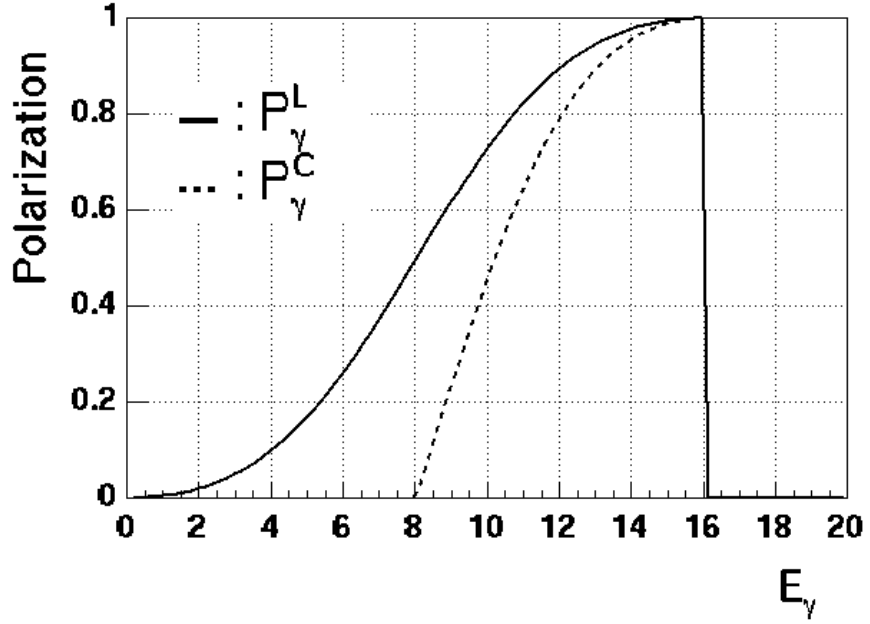


Laser system:

- **100W Nd:YAG: SH(40%),TH(25%),FH(5%)**
- **5W OPO (1-12μm) (Nd:YAG pump)**

Gamma-ray beam intensity and polarization below E_γ ~ 16 MeV at ALBA (provisional)



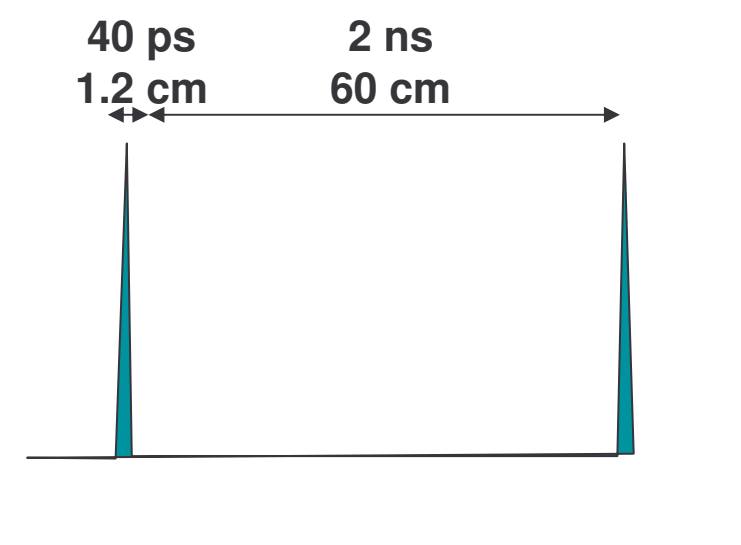


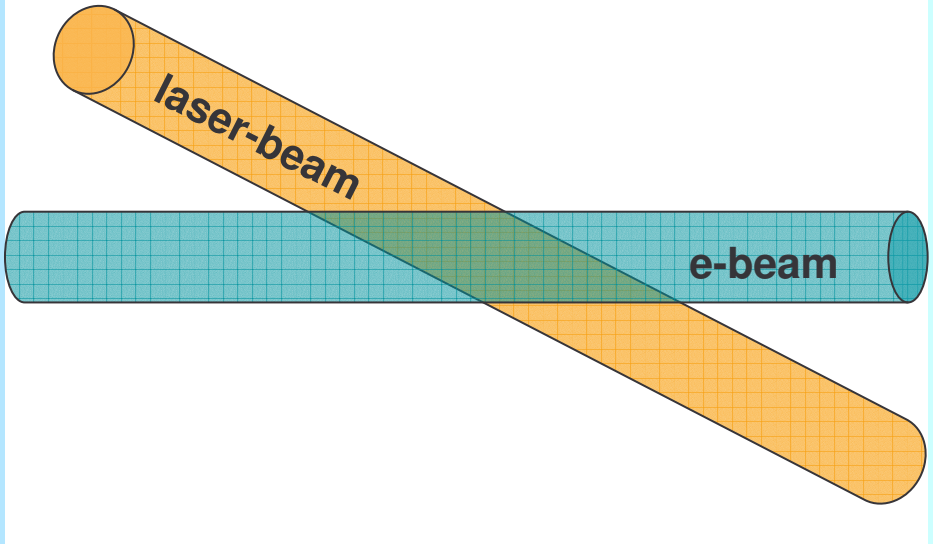
Laser system:

- **1kW CO2**

Gamma-ray beam time structure (TOF measurements)

e^--beam time structure:





best time-resolution (collinear pulsed laser):

13 ns – 44 ns

depending on length of interaction

Time resolution through angle crossing?

Summary:

Realistic gamma-ray beam intensity, polarization and energy resolution have been estimated for a GRL at ALBA by MC simulations with consideration of:

- Laser system
- Collimation system
- Tagging system

Also, feasibility of Si-microstrip + Scintillator tagger has been studied

Remains, study of shielding and beam dump and of the e-beam energy resolution degradation

Laser backscattering facilities in the world

Name	E_e (GeV)	I_e (mA)	E_L (eV)	E_γ (MeV)	ΔE_γ (MeV)	I_γ (s^{-1})	Year
ETL-LCS Tsukuba	0.2 – 0.8	400	1.17 - 4.68	1 - 40	-	10^3 - 10^5	1991
NewSUBARU Himeji	1 – 1.5	500	1.17 FEL?	1 - 40	0.3	10^5	2003
HIGS Durham	1.3	100	FEL: 2 - 12.5	1-220	0.2 – 1.2	10^9	1996
LEGS Brookhaven	2.5	200	2.41 – 3.53	110 - 330	6	10^6	1987
ROKK-1M Nobosivirsk	1 - 6	80	1.17 – 4.68	100 - 1600	1 - 20	$< 10^6$	1993
GRAAL Grenoble	6	100	3.53	400 – 1500	15	10^7	1996
LEPS Harima	8	200	2.41 – 4.68	1500 – 3500	15	10^6	1999

Proposals: APS (Argonne), PLS (Pohang)