Results for the proposed $\gamma\gamma$ – Collider at TESLA

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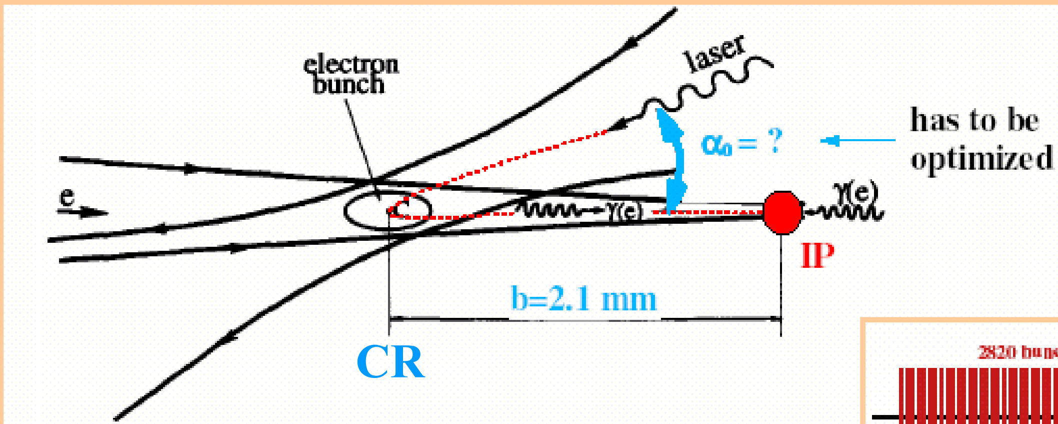
DESY – Zeuthen

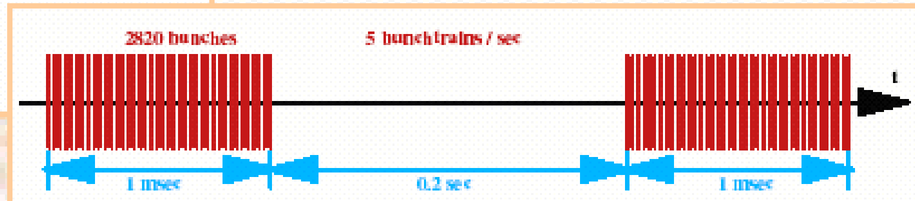
TESLA - Group

- **Optics**
- **Luminosity optimization**
- **$\gamma\gamma$ – background**
- **Neutron background**

Scheme of γe- and $\gamma\gamma$- Collider



TESLA bunch-structure
2820 bunches/train
337 ns spacing
5 Hz repetition rate



Laser requirements :

Laser pulses of

≈ 5 J	pulse energy
≈ 1 -3 ps	pulse duration (FWHM)
≈ 14 µm	spotsize ($1/e^2$)
≈ 1 µm	laser wavelenght
2.5° - 4°	crossing angle α_0

$$w_{1/e^2} = \sqrt{2} \cdot w_{r.m.s}$$

Requires :

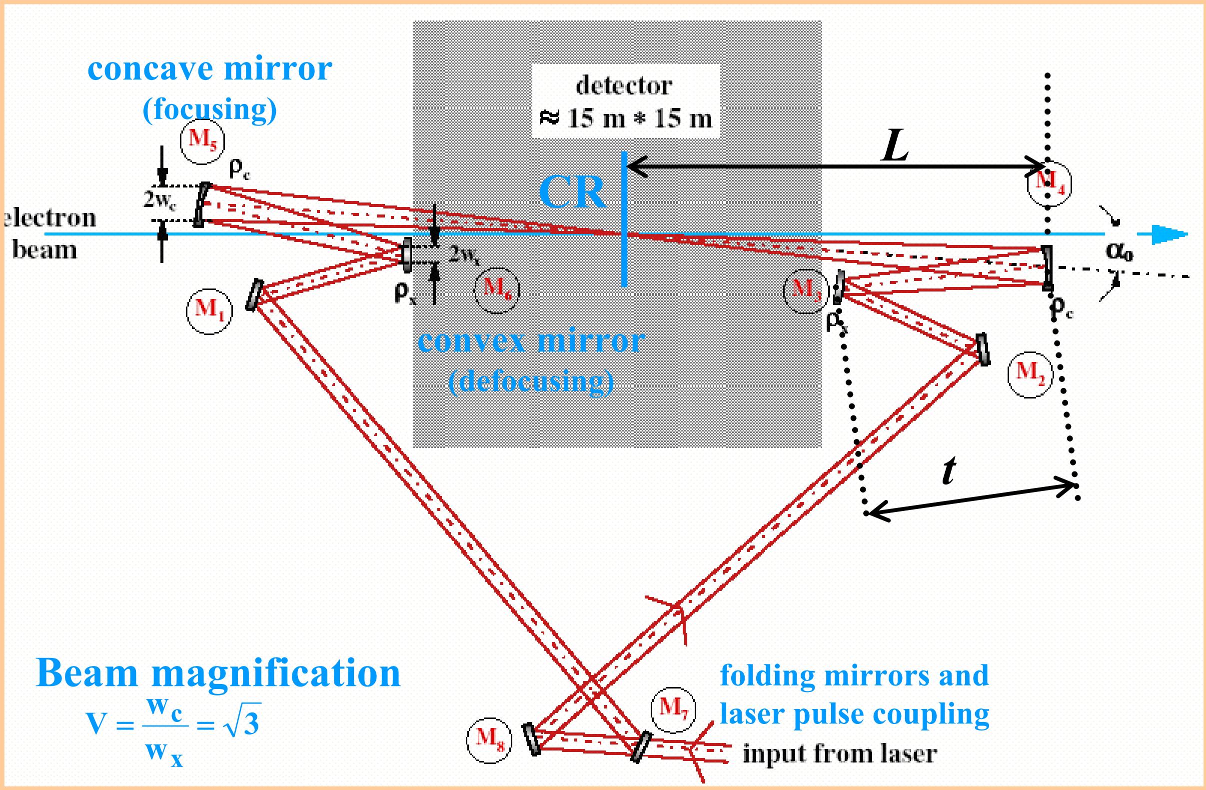
- High peak power (≈ 2 TW)
- High average power (≈ 70 kW)
- Precise timing, low jitter (1 ps)

Present geometry of passive , resonant cavity

SOLUTION →

pulsed laser with the correct timestructure and reduced power requirements feeds a resonant cavity for enhancement of power

Telescopic active or passive ring resonator with 101 m circumference



Distances :

Focal lengths

Convex mirror, f_X= - 10.0 m

Concave mirror, f_C=8.10 m

Telescope length, t = 7.32 m

L (IP - M_4) ≈ 15.21 m

L (M_3, M_4) = t = 7.32 m = L (M_6, M_5)

L (M_3, M_2) = 5.3 m = L (M_1, M_6)

L (M_2, M_8) = 20.84 m = L (M_7, M_1)

L (M_8, M_7) = 3.70 m

L (M_4, M_5) = 2·L ≈ 30.42

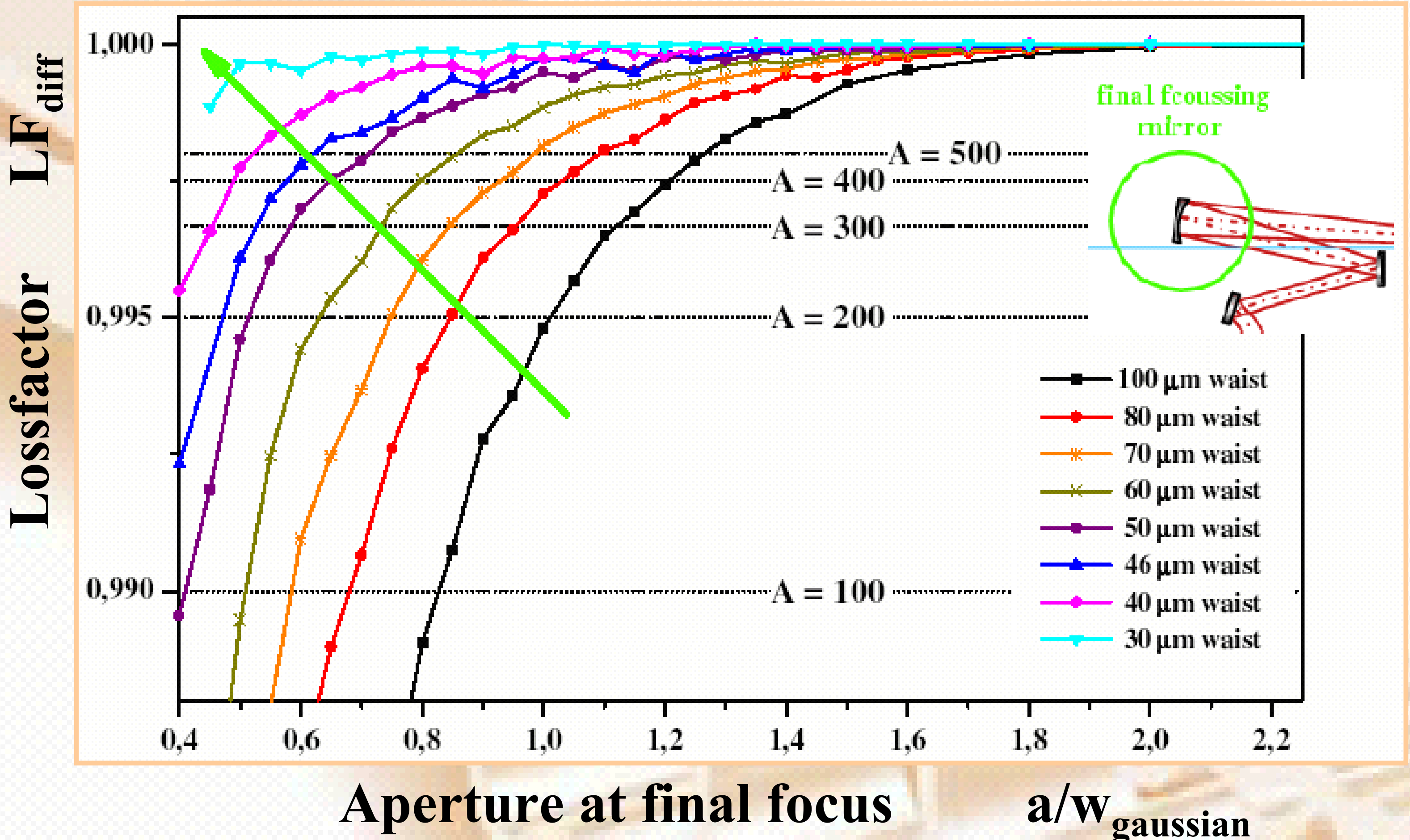
Folding angles :

$\gamma_{345} = 10^\circ$	$\gamma_{871} = \gamma_{287}$
$\gamma_{234} = 30^\circ$	$\gamma_{716} = \gamma_{287}$
$\gamma_{328} = 64.63^\circ$	$\gamma_{165} = \gamma_{234}$
$\gamma_{287} = 44.63^\circ$	$\gamma_{654} = \gamma_{345}$

Diffraction loss of resonant cavity

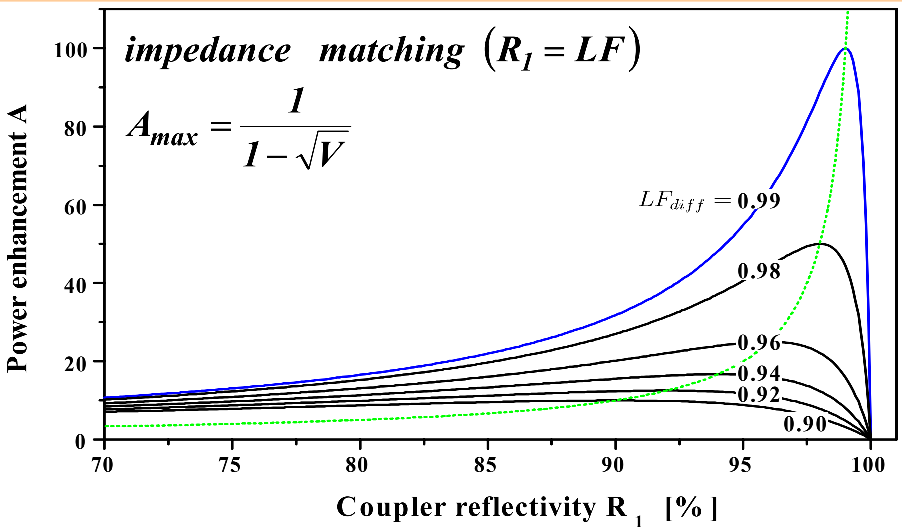
Final size of aperture, telescopic cavity, magnification $\sqrt{3}$

using GLAD



Power enhancement for a resonant cavity

… and limitations on mirror reflectivity



Desired enhancement factor

A = 100

R_1 – reflectivity of coupling mirror

LF_{diff} – diffraction loss factor for 1 round-trip

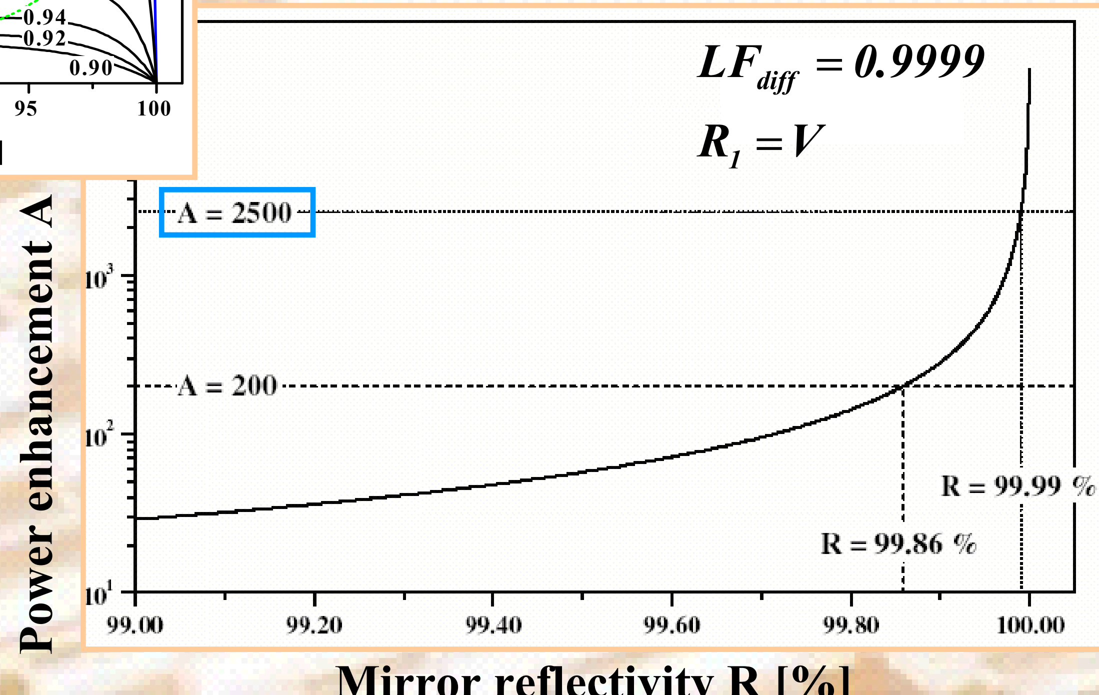
$$A = \frac{1-R_1}{\left(1-\sqrt{R_1 \cdot \ldots \cdot R_N \cdot LF_{diff} \cdot LF_{other}}\right)^2}$$

$$R_2 = \ldots = R_N = 1$$

$$LF_{other} = 1$$

$$A_{max} = \frac{1-R_1}{\left(1-\sqrt{R_1 \cdot \tilde{V}}\right)^2}$$

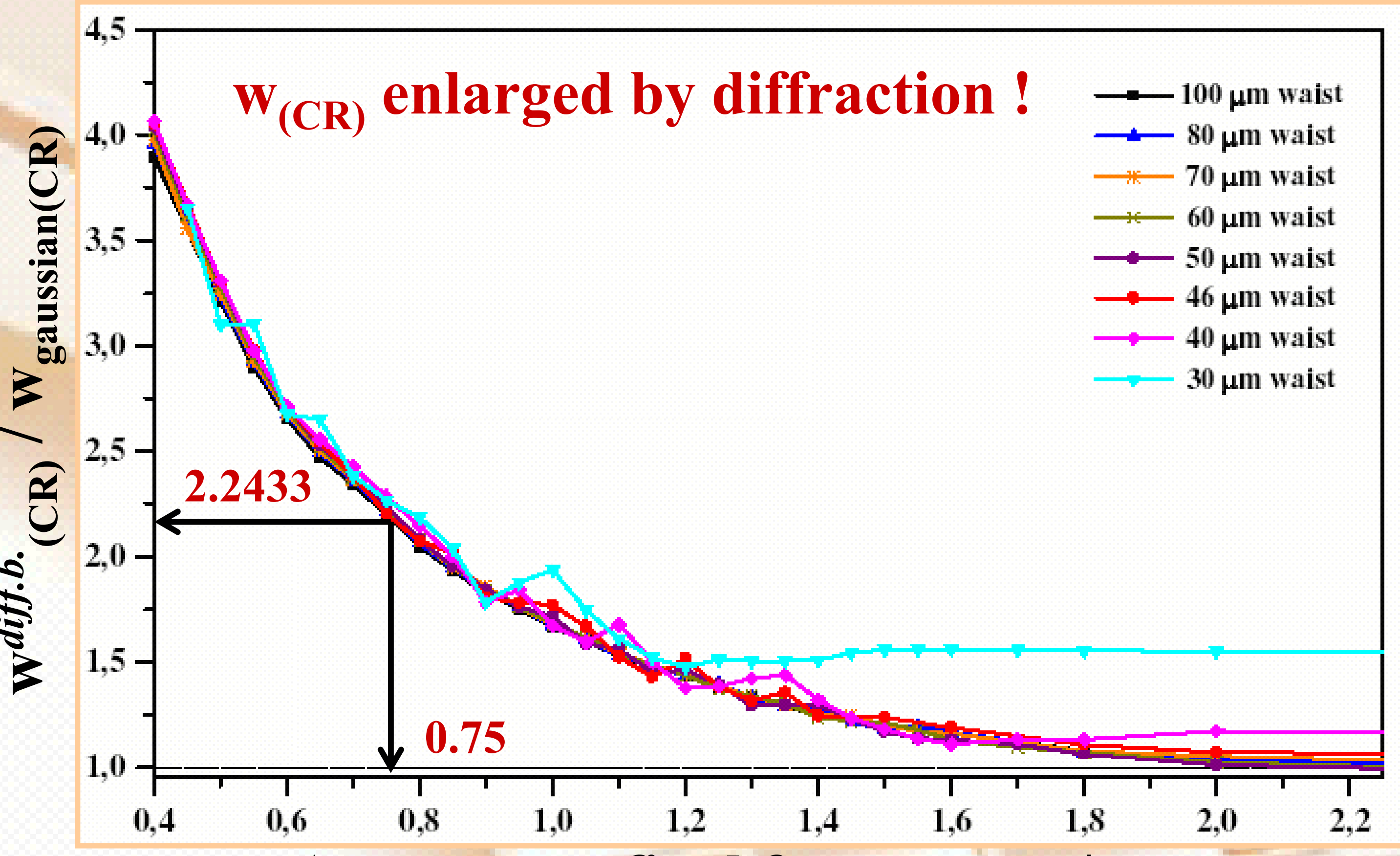
$$\tilde{V} = R_2 \cdot \ldots \cdot R_N \cdot LF_{diff}$$



Diffraction broadening of laser focus

Final size of aperture, telescopic cavity, magnification $\sqrt{3}$

for a → ∞ (infinite aperture), $w^{diff.b.}_{(CR)} \rightarrow w_{gaussian(CR)}$



Aperture at final focus $a/w_{gaussian}$

Photon – Electron beam crossing angle

required Gaussian beam waist at CR :

$$w_{gauss(CR)} = \sqrt{\frac{Z_R^{gauss} \cdot \lambda}{\pi}}$$

$$\frac{a}{w_{gauss}} = 0.75 \rightarrow w_{CR}^{diff.b.} \approx 2.2433 \cdot w_{gauss(CR)}$$

$$Z_R^{diff.b.} = (2.2433)^2 \cdot Z_R^{gauss}$$

… and γ-e crossing angle α_0 determination

α_0 determined by the tolerated diffraction broadening of the beam

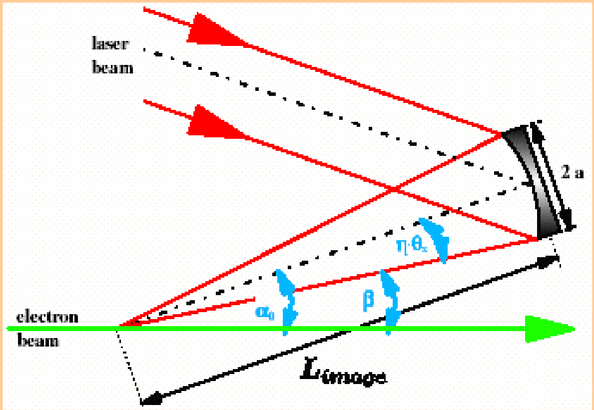
Diffraction broadening of $w_{(CR)}$ included **by changing Rayleigh length** $Z_R^{gauss} \rightarrow Z_R^{diff.b.}$

$$\alpha_0 = \eta \sqrt{\frac{\lambda}{\pi Z_R^{diff.b}}} + \frac{\alpha_C}{2}$$

$$\eta = 2 \cdot \frac{a}{w(L_{image})}$$

Maximum mirror size and crossing angle are related

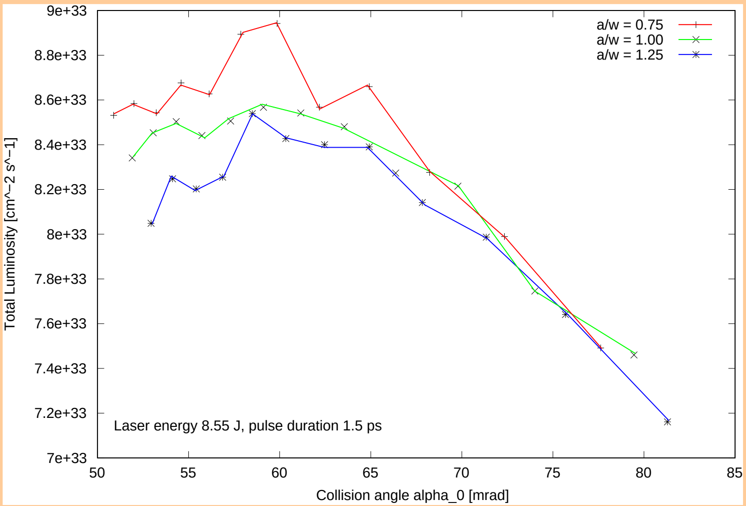
$$\alpha_0 = \eta \vartheta_{x,rms} + \beta \approx \frac{a}{L_{image}} + \beta$$



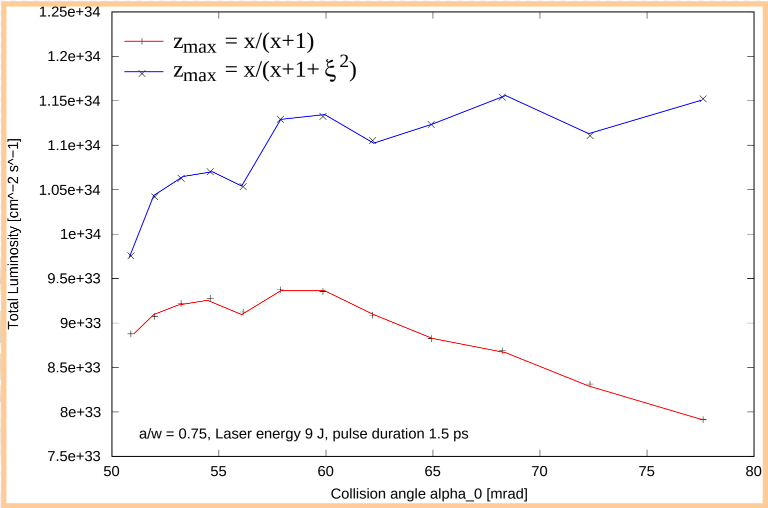
Luminosity optimization for TESLA PC

Several steps, optimizing one by one parameter using CAIN

Luminosity $[cm^{-2}s^{-1}]$



α_0 [mrad]



α_0 [mrad]

Laser parameters	TDR pt. VI	This study
Rayleigh length Z_R at Conversion point	0.35 mm	0.63 mm
Collision angle α_0		55.1 mrad
Laser energy A	5 J	9.0 J
pulse duration $\sigma_{L,z}$	1.5 ps	1.5 ps
nonlinearity parameter ξ^2	0.30	0.30
Total Luminosity $[10^{-34} cm^{-2} s^{-1}]$	1.10	1.05

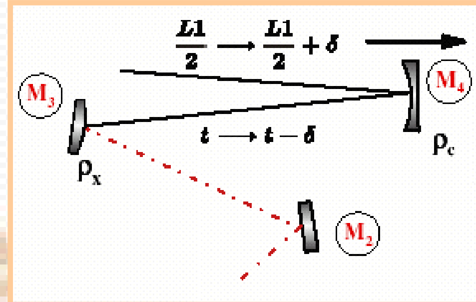
$w_{CR}^{diff.b.} \approx 14.9\ \mu m$

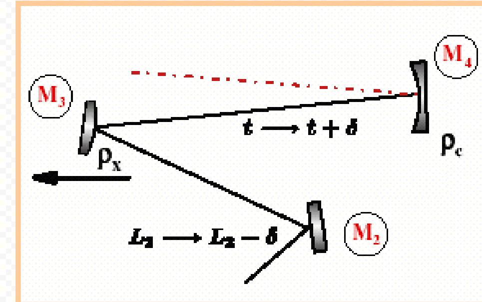
$w_{gaussian} \approx 6.5\ \mu m$

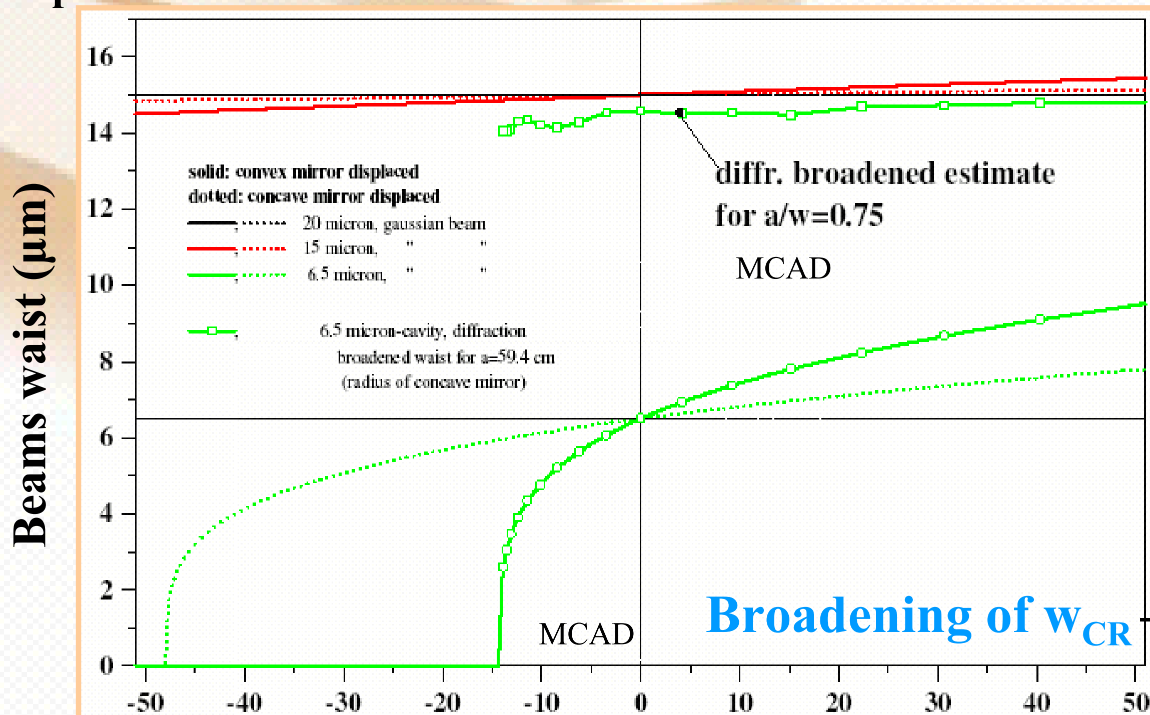
Possible misalignments of the cavity

❑ Axial shifts of the mirrors

telescopic cavity, estimation of diff. broadening at presence of finite concave mirror







Axial displacement of one mirror (nm)

Displacement of w_{CR}

Shift << Z_R → movement of beam waist is not critical

Broadening of w_{CR} – sensitive to the deviations

❑ Deviation of focal lengths from their respective design-values

Broadening of w_{CR} – sensitive to the deviations

Displacement of w_{CR}

Shift $\ll Z_R \rightarrow$ movement of beam waist is not critical

❑ Detuning of the cavity length

❑ Tilt errors of the mirrors

❑ Distorted mirror surfaces

Conclusions

- A > 100 seems possible
- Diff. broadening of focus is not non-negligible
- interdependences between a, α_0, τ and A exist
- misalignment sensitivity : ongoing
- 3D nesting of two cavities : ongoing

'To do' list

- Final cavity design
- misalignment sensitivity
- creating error-signals for feedback loops

Automatic alignment system has already been developed for interferometric detection of gravitational waves → $\gamma\gamma$ - collider can benefit from that

Control loops and ideas:

- Beam spot position, cavity length control, mirror tilt control

Background studies for $\gamma\gamma$- Collider

mask design in forward region – minimization of background in TPC and VTX

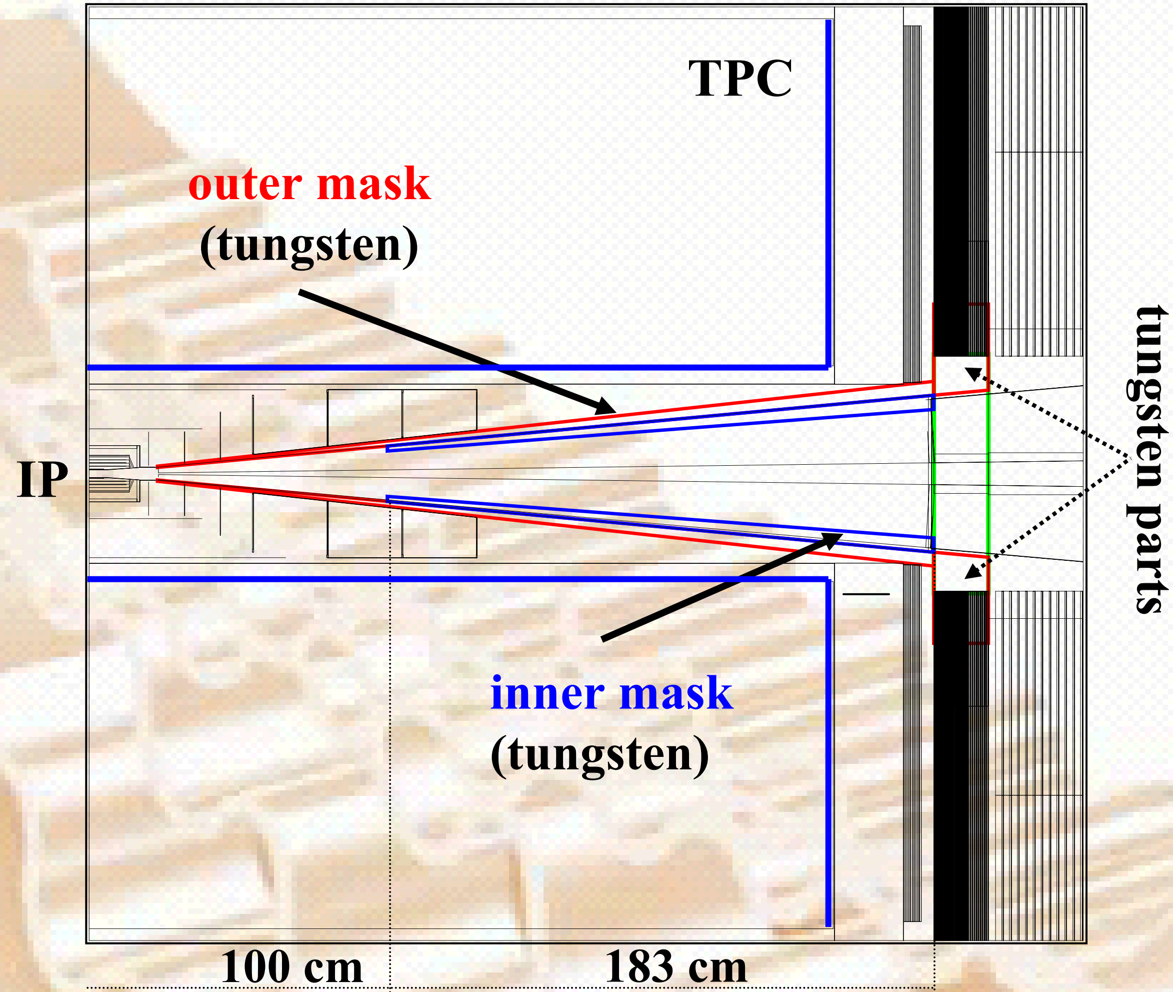
BACKGROUND :
(B –B interactions)
- **incoherent pairs**
- **coherent pairs**

(simulated by CAIN)

Amsterdam :

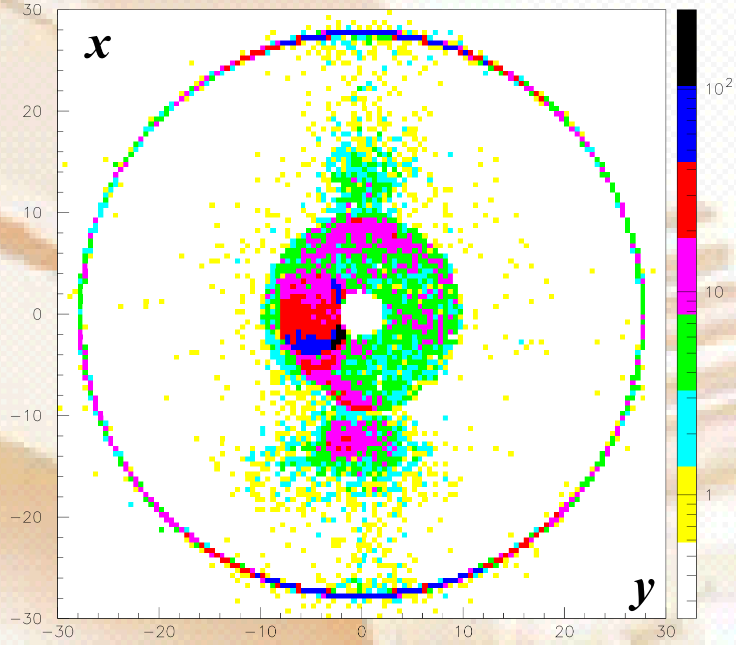
TPC
- **CP ~ 2440 γ/BX**
- **ICP ~ 927 γ/BX**

VTX
- **CP ~ 20 hits**
- **ICP ~ 368 hits**

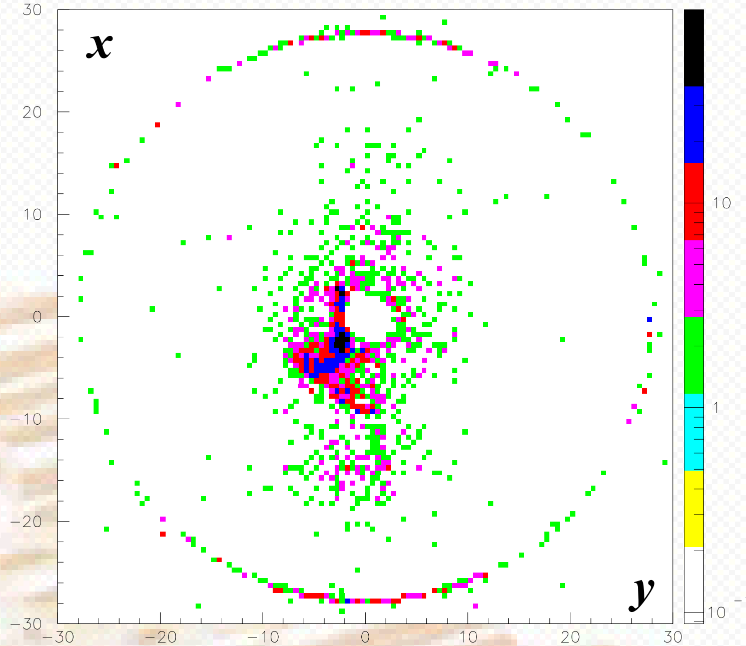


Background studies for $\gamma\gamma$ - Collider

Outgoing electron beam - pipes are made narrower



particles entering the outer mask/BX

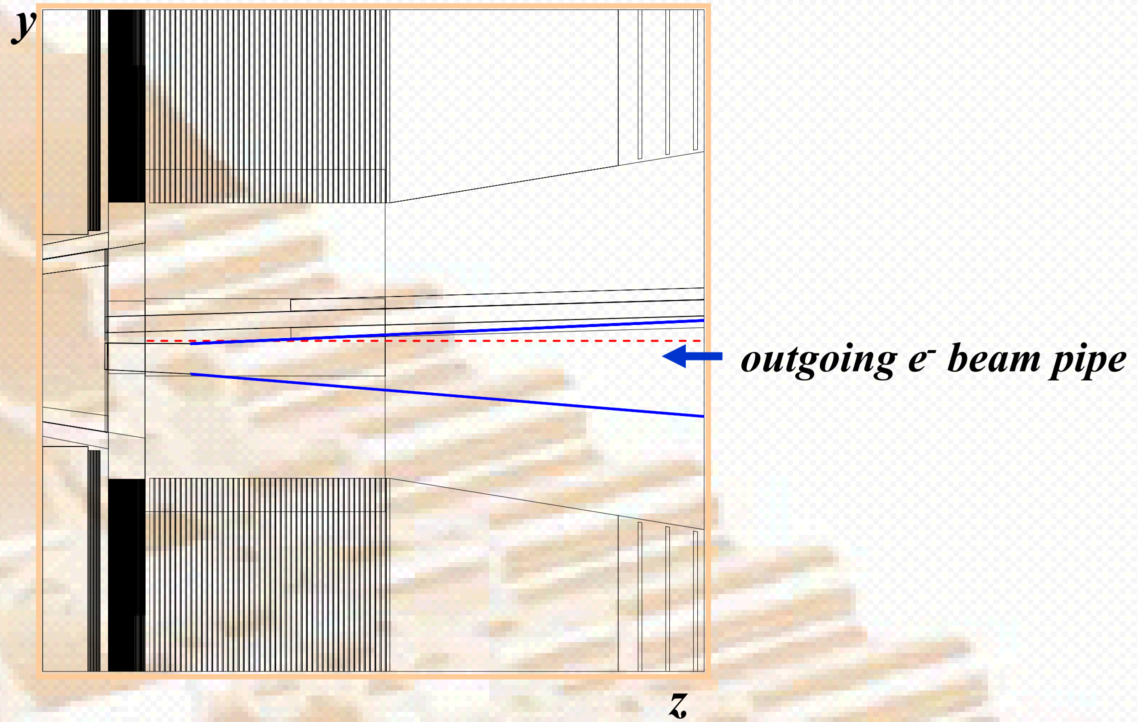


particles leaving the outer mask/BX

CP ~ 138955 γ/BX (94125)
ICP ~ 2099 γ/BX (1873)

CP ~ 13735 γ/BX (9800)
ICP ~ 1835 γ/BX (1809)

Background studies for $\gamma\gamma$ - Collider



TPC

- **actual mask design :** **- CP ~ 6310 γ/BX (~ 3 times larger)**
  - ICP ~ 1069 γ/BX

VTX

- **CP ~ 60 hits**
- **ICP ~ 272 hits**

Background studies for $\gamma\gamma$- Collider

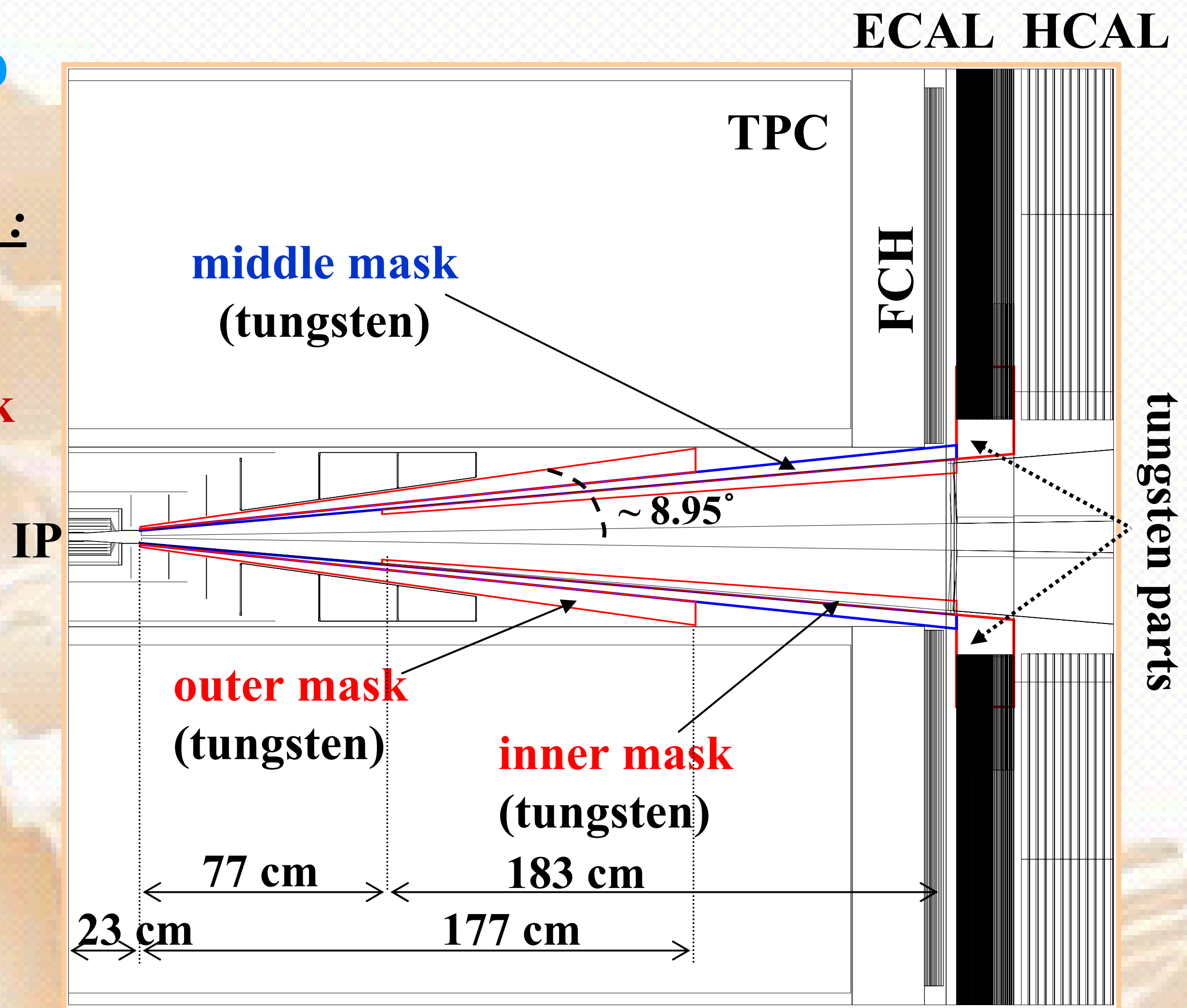
" GO BACK TO THE OLD BACKGROUND … "

Changes from last design :

third mask is added in order to minimize bck in TPC region
length – 177 cm

TPC
- CP ~ 2055 γ/BX
- ICP ~ 417 γ/BX

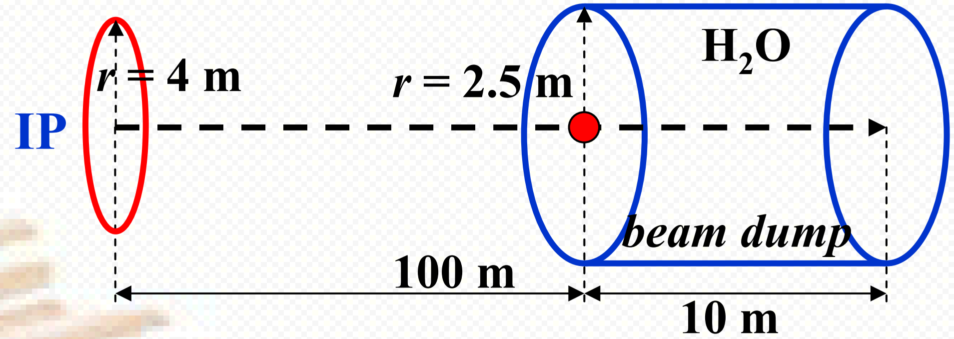
VTX
- CP - 220 hits
- ICP - 323 hits



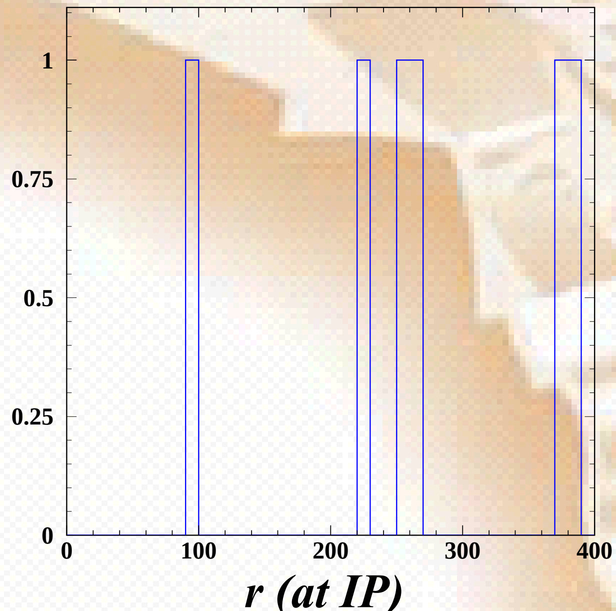
Neutron Background at $\gamma\gamma$ - Collider

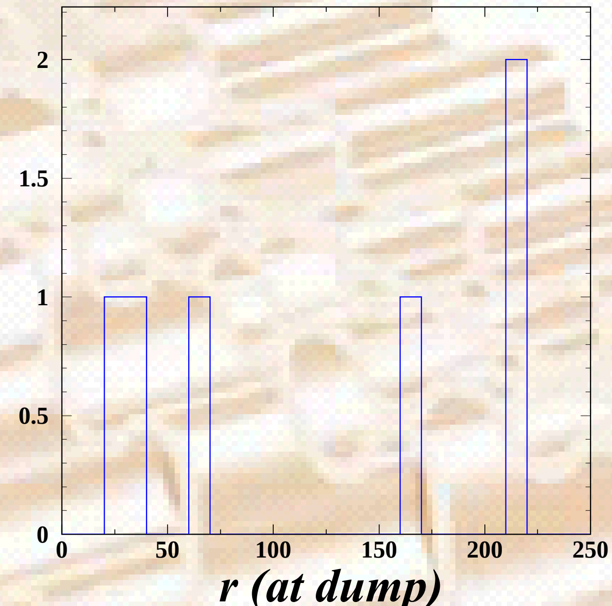
Neutrons and ***beam dump***
simulated by
GEANT4 (phys. list **QGSP_HP**)
(cross – check LHEP_GN)

- 150000 γ (250 GeV) shut in



RESULTS : 1 neutron/cm^{-2}/BX → 10^{11} neutrons/cm^{-2}/year





V. Telnov (Amsterdam) → more complicated shape of the dump to suppress the neutron background (for ***r*** > 1 m at dump)