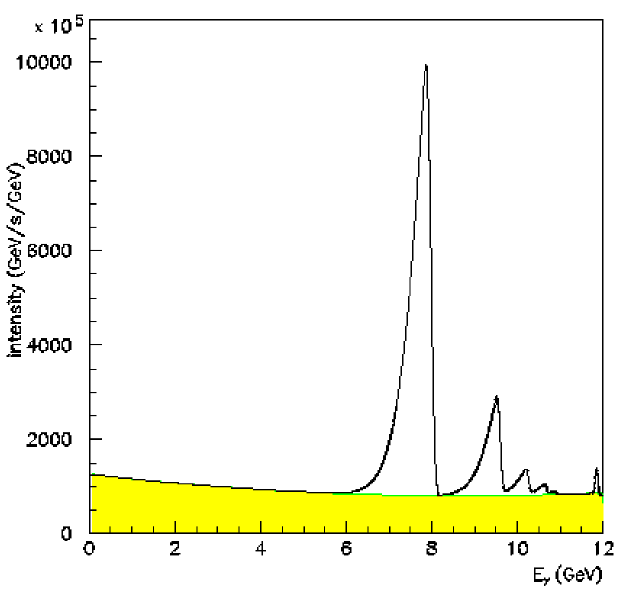
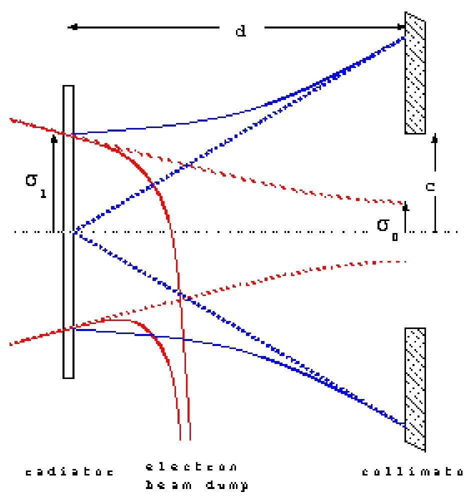
Hall D Review
TJNAF, Dec. 6, 1999

Photon Beam Line and Tagger

Richard Jones

- Method of coherent bremsstrahlung
- Polarization and collimation
- Electron beam properties
- Tagging spectrometer
- Development projects

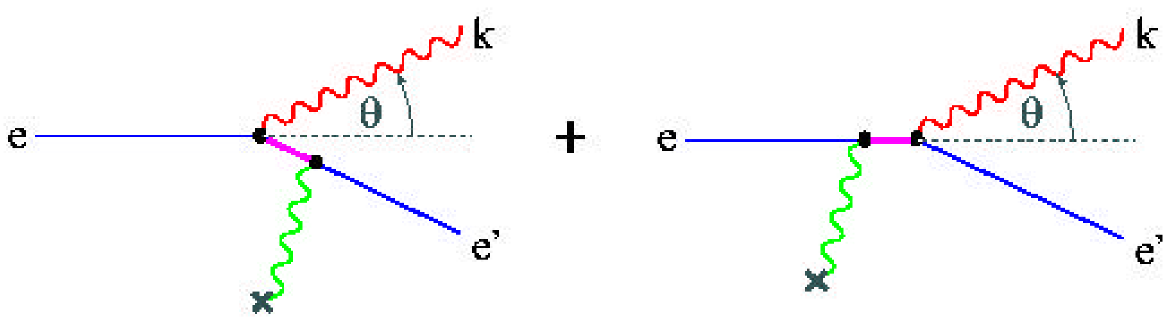




Criteria for Photon Source

1. high energy — $E_\gamma = 8\text{–}10$ GeV
2. polarization — P_O , $P_| = 0.5$
3. high flux — $N_\gamma = 10^8\ s^{-1}$
4. energy resolution — $\sigma_E = 10$ MeV
5. low backgrounds

The generic photon source



Techniques:

A. **Compton backscatter**
B. **Bremsstrahlung**
C. **Coherent bremsstrahlung**

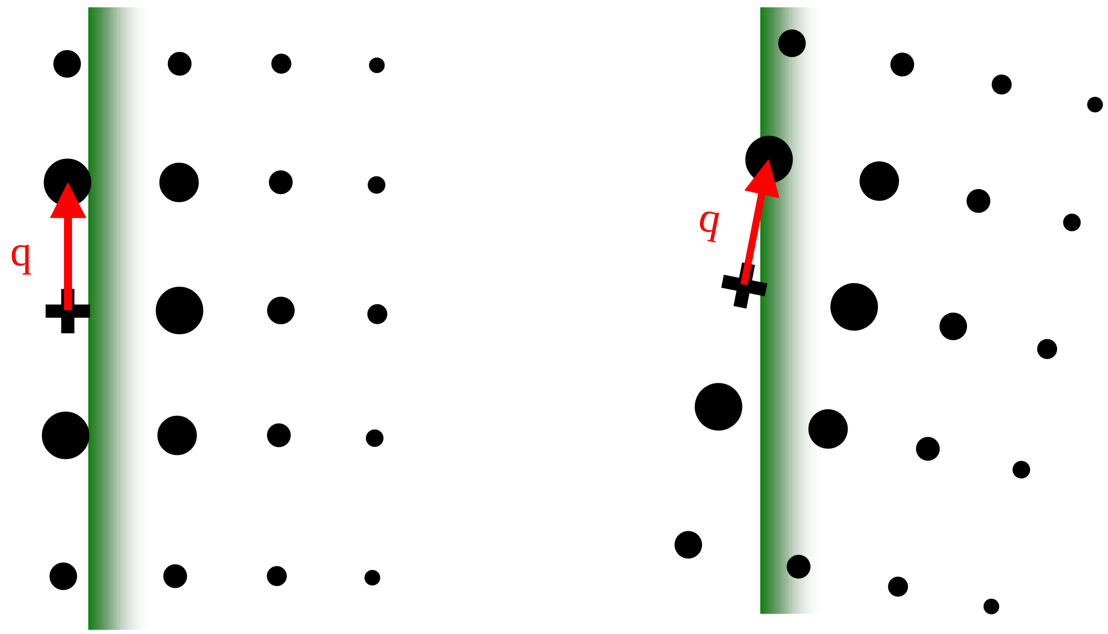
	A	B	C
1. energy	✖	★★★	★★
2. polarization	★★★	✖	★★
3. rate	✖	★★★	★★★
4. resolution	(†)	(†)	(†)
5. background	★★★	★	★★

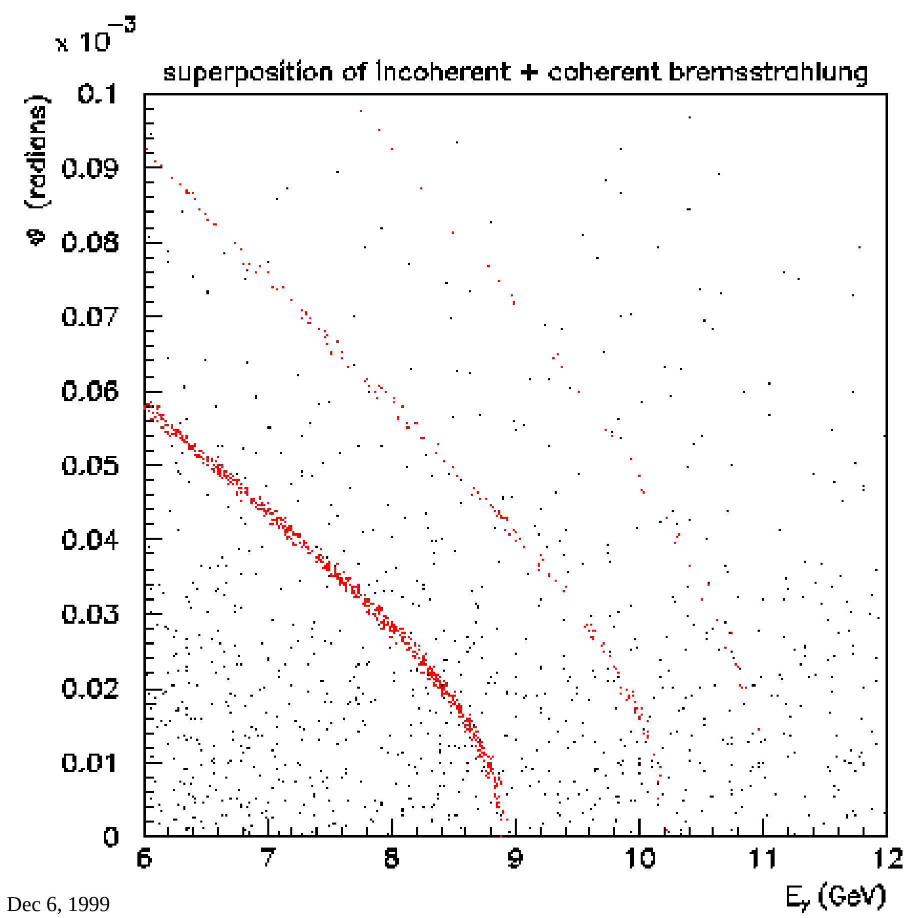
(†) with tagging

B. Incoherent *vs* coherent bremsstrahlung

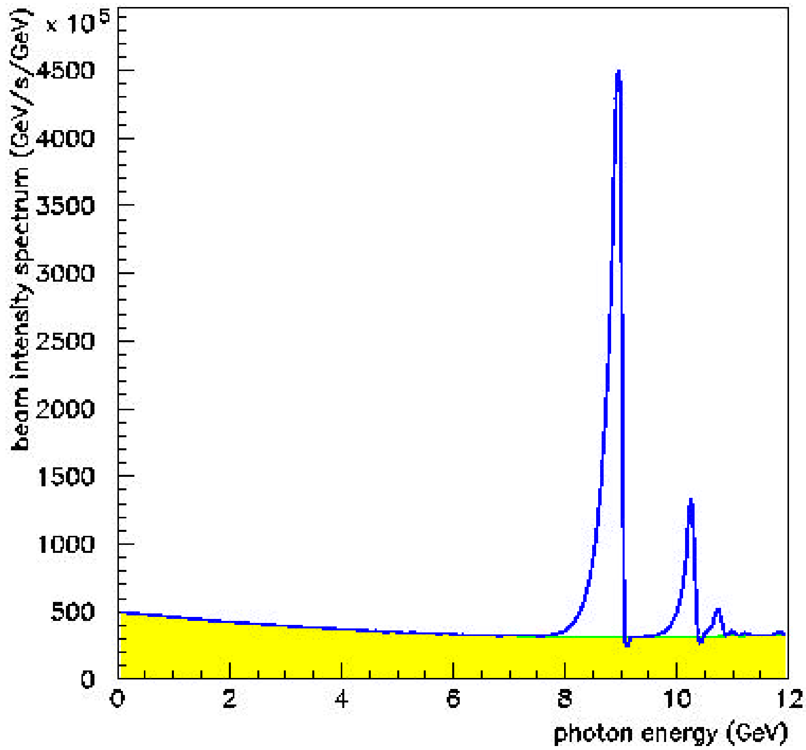
Consider the electromagnetic form-factor of the target in q-space

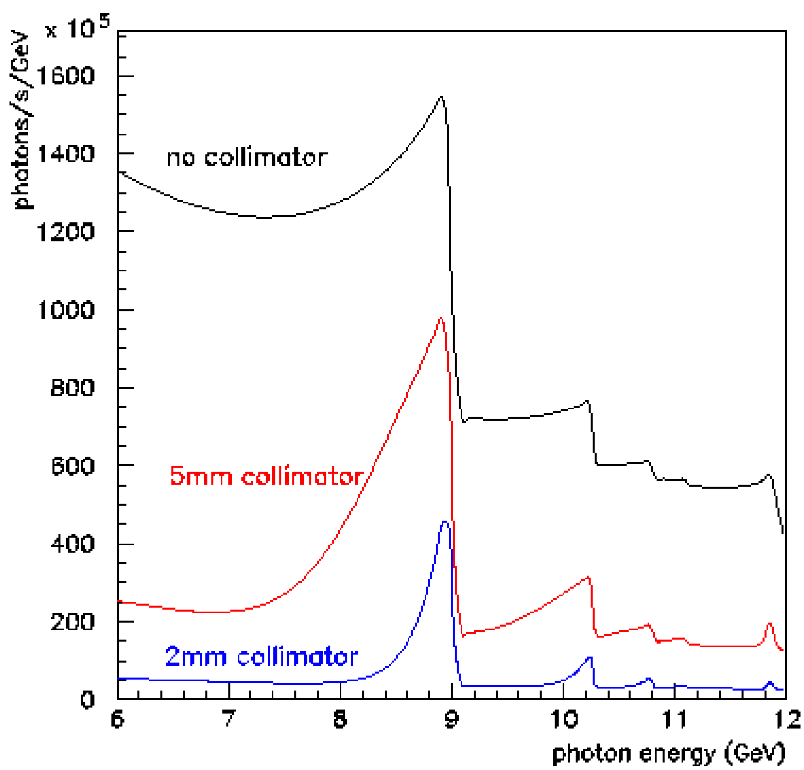
no enhancement strong enhancement



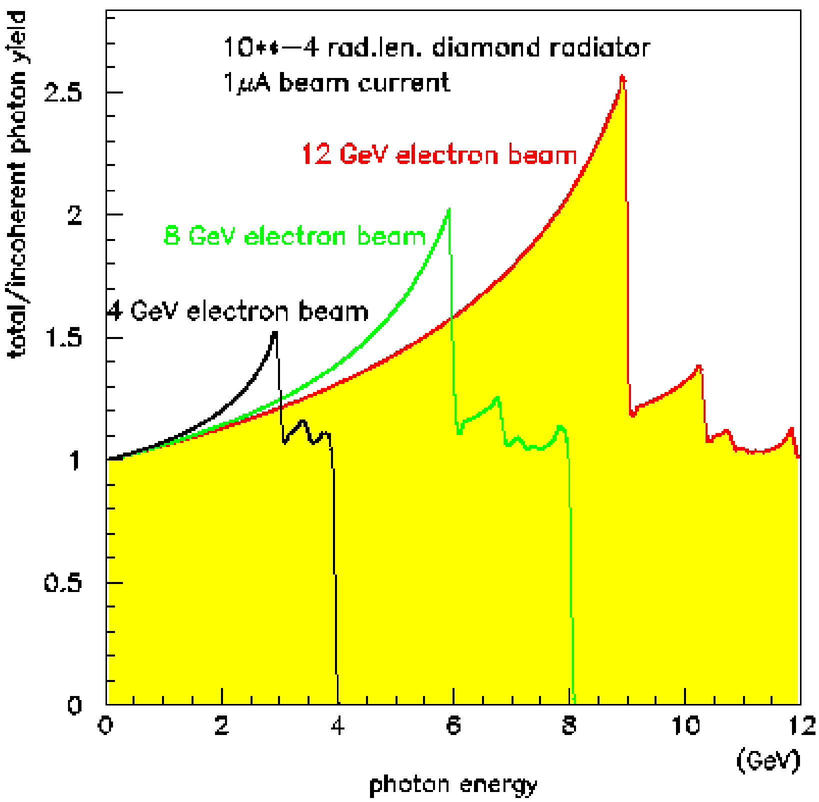


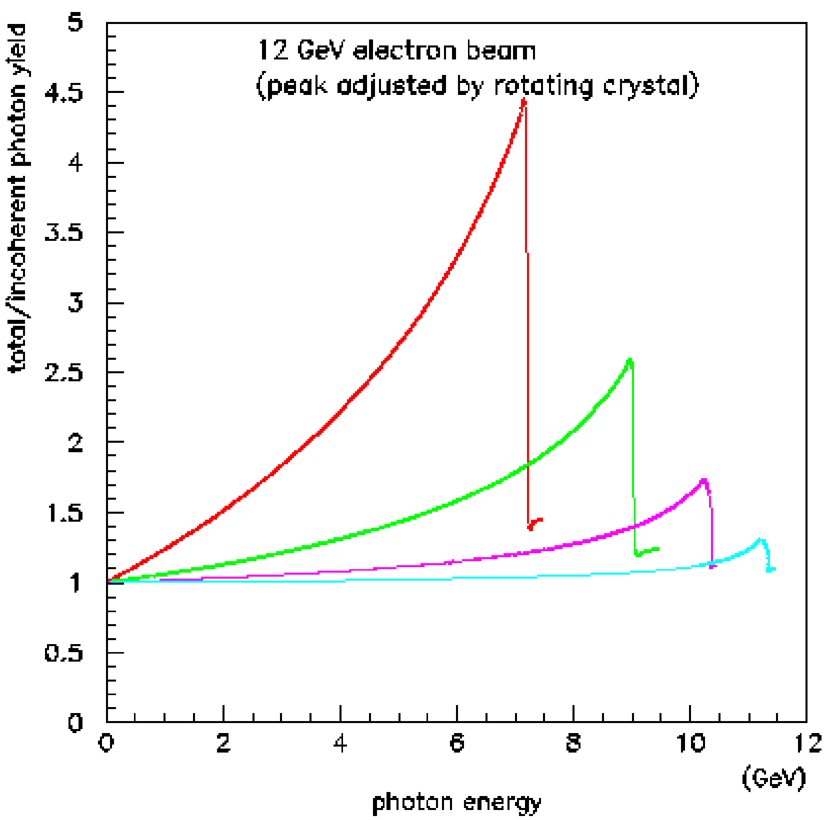
C. Coherent bremsstrahlung





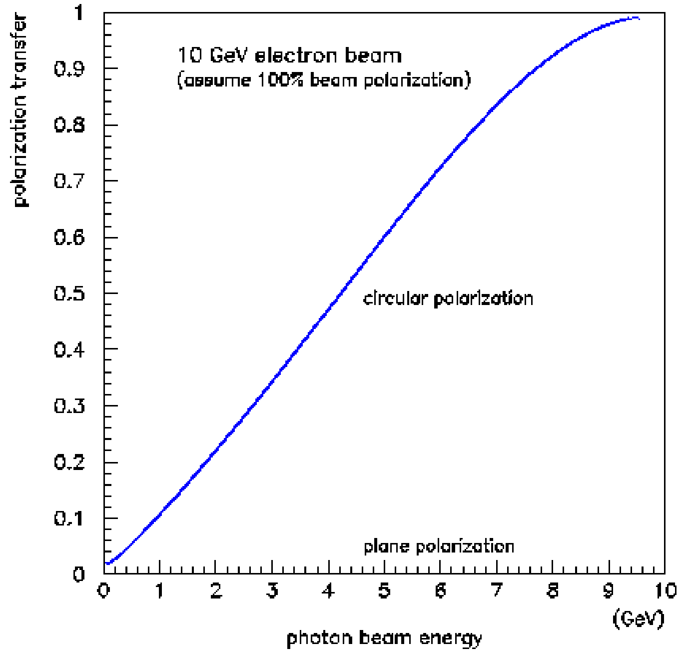
Coherent gain





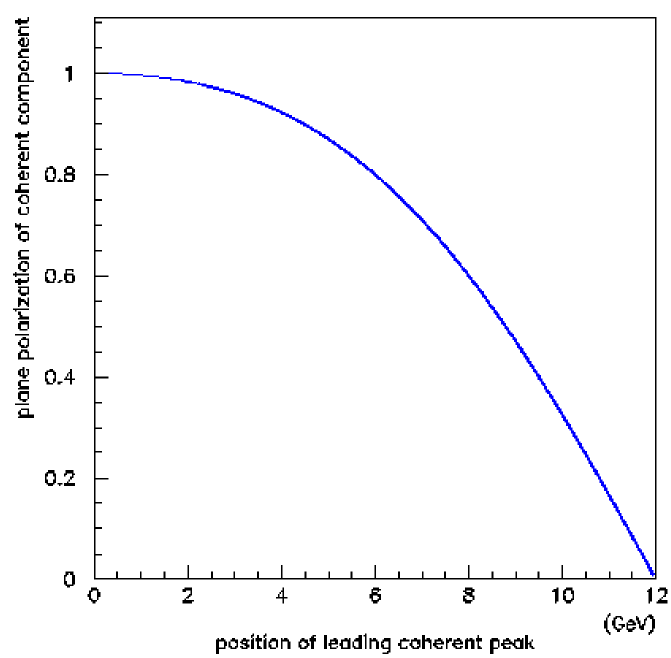
Circular polarization

- ✓ available by transfer from electron beam
- ✓ 100% transfer at endpoint
- ✓ independent of coherent process

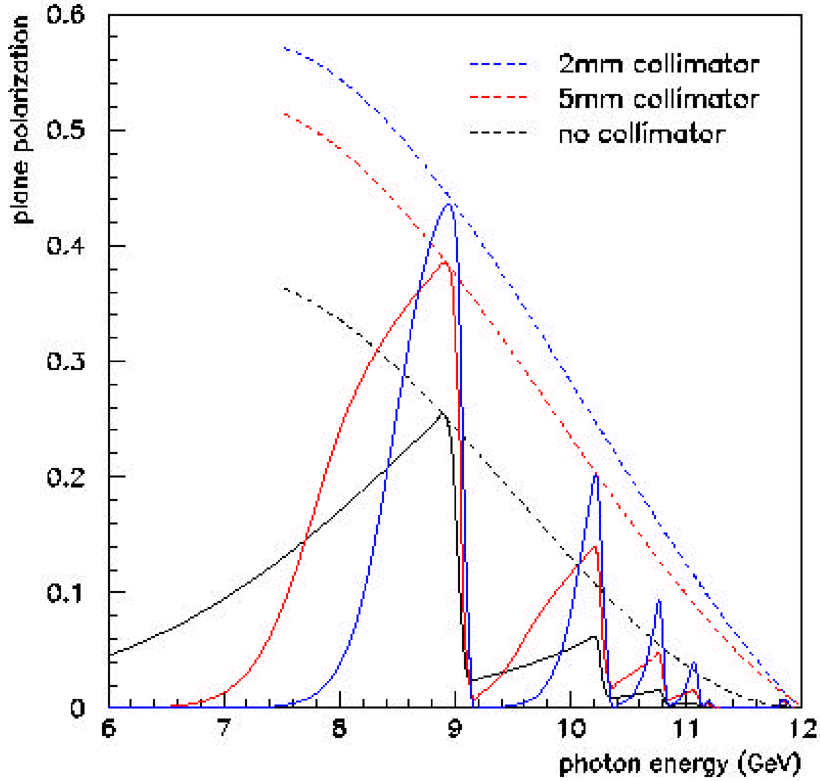


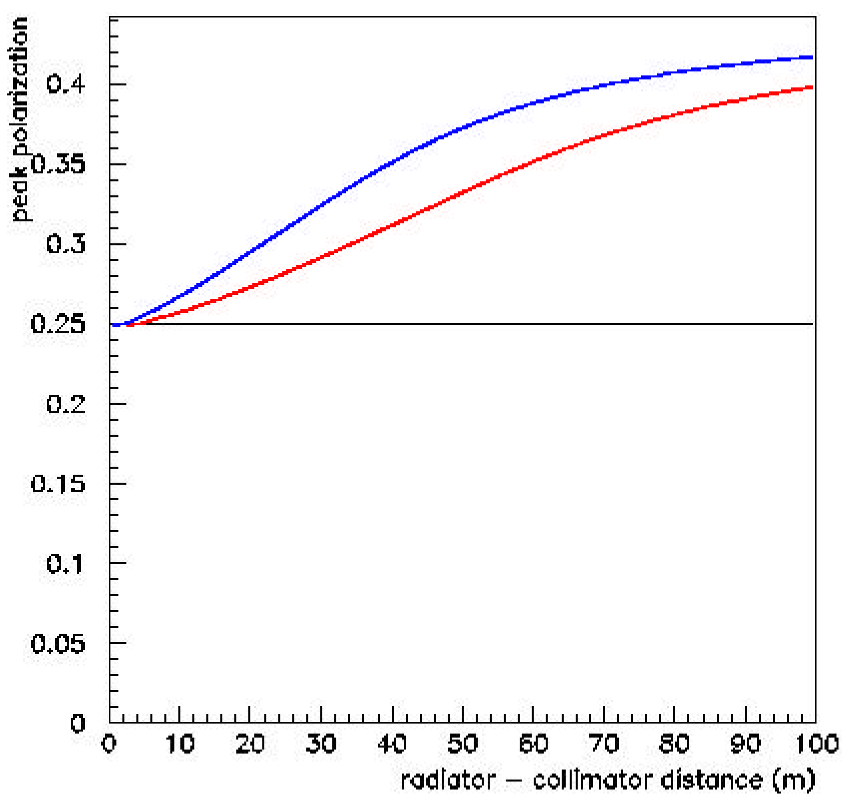
Plane polarization

- ✓ independent of electron polarization
- ✓ goes to zero at endpoint
- ✓ requires coherent process
- ✓ enhanced by collimation

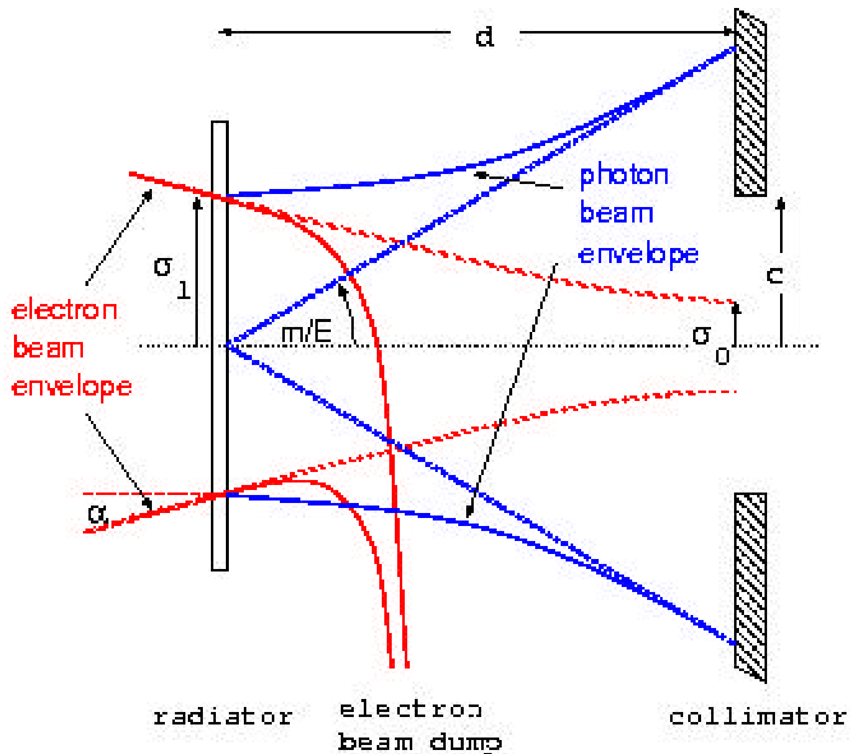


Collimation





Collimator geometry



Rough estimate for minimum d:

$\frac{c}{d} = \frac{1}{2}\frac{m_e}{E_0}$	collimation condition	let $\varepsilon_x = 1.0 \times 10^{-8}$ m.r
$\sigma_0 \leq \frac{c}{3}$	high efficiency at 0°	$\sigma_0 = 0.5$ mm $\sigma_1 = 1.7$ mm
$\alpha \leq 20\ \mu r$	small divergence spread	
$\alpha\sigma_0 = \varepsilon$	definition of emittance	

$$d = 2c\frac{E_0}{m_e} \geq \frac{6\sigma_0 E_0}{m_e} = \frac{6\varepsilon E_0}{\alpha m_e}$$

$d \geq 70$ m

$2c = 3.4$ mm

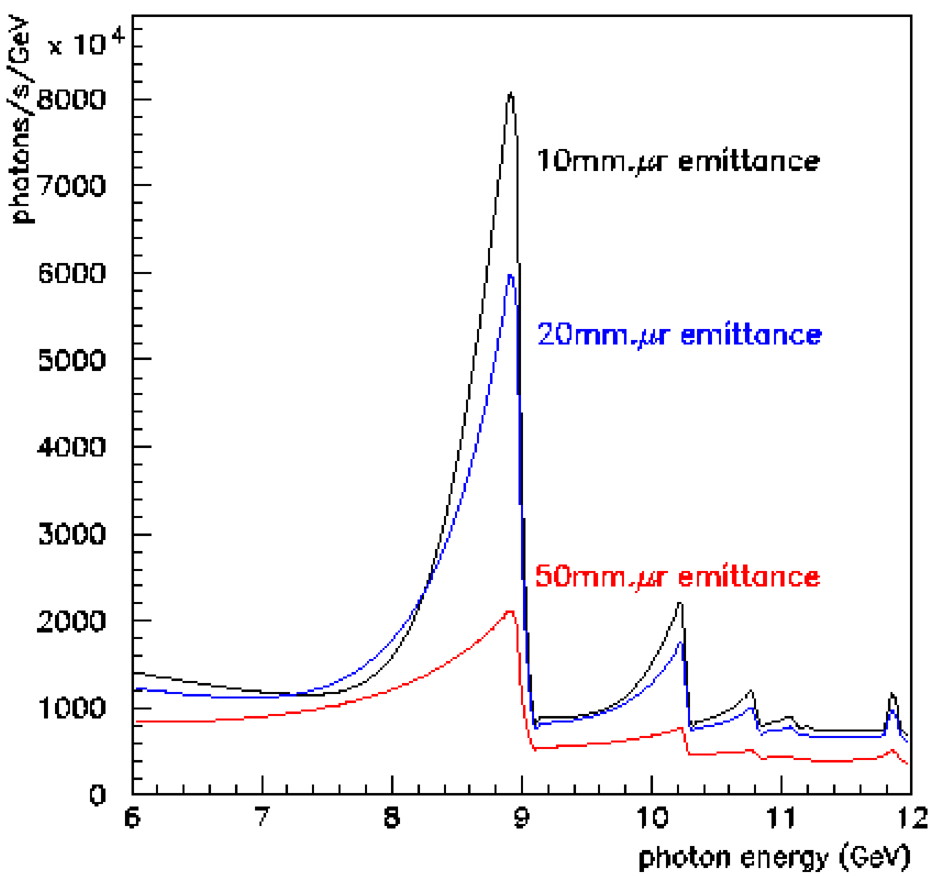
Allow some margin for error:

$\boxed{\text{80m from radiator to collimator}}$

Electron beam

Electron beam properties for Hall D

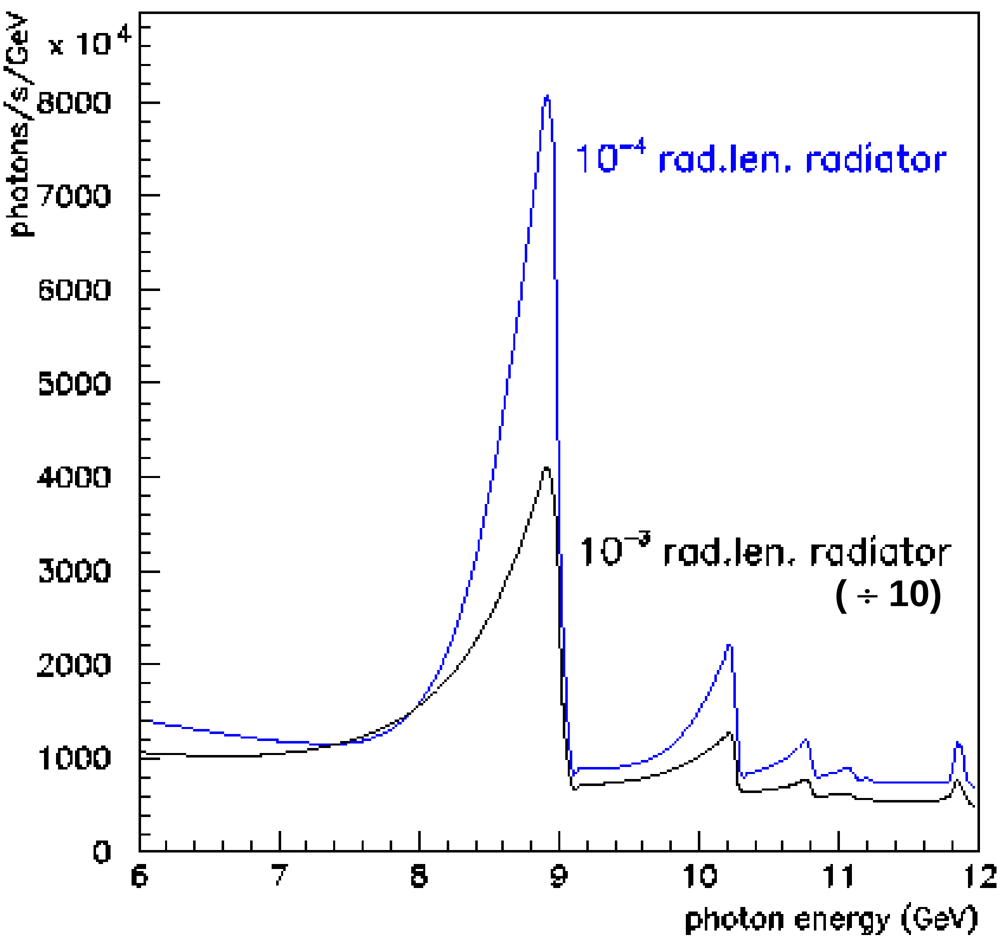
energy	12 GeV
r.m.s. energy spread	<10 MeV
transverse x emittance	10 mm µr
transverse y emittance	2.5 mm µr
electron polarization	longitudinal
minimum current	100 pA
maximum current	3 µA
x spot size at radiator	1.7 mm r.m.s.
y spot size at radiator	0.7 mm r.m.s.
x spot size at collimator	0.5 mm r.m.s.
y spot size at collimator	0.5 mm r.m.s.
position stability	±200 µm



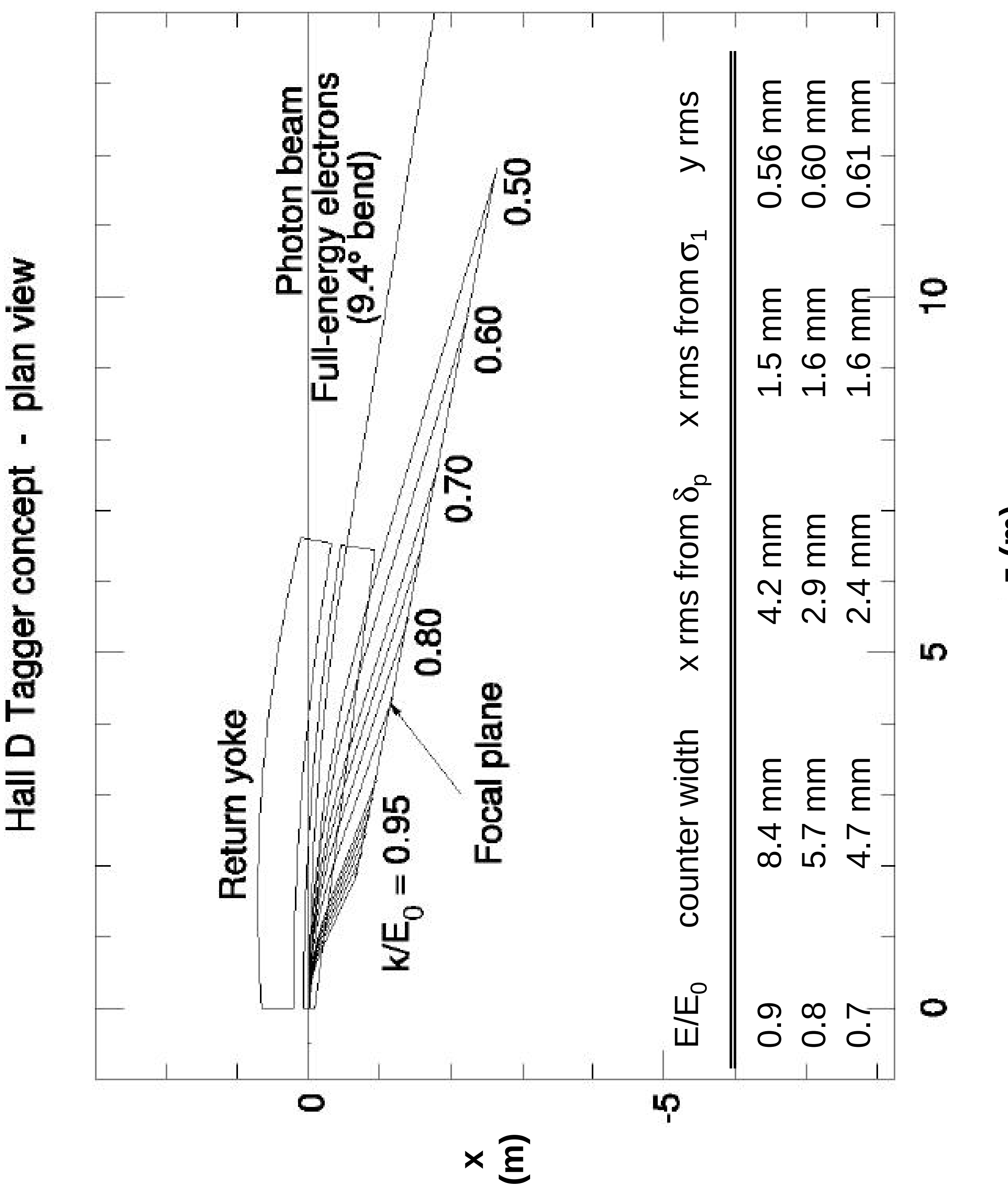
Crystals

crystal	best reciprocal vector	figure of merit
diamond	2,-2,0	1.00
beryllium	0,0,2	0.86
boron	2,0,8	0.38
silicon	2,-2,0	0.19
Be_2C	2,2,0	1.10

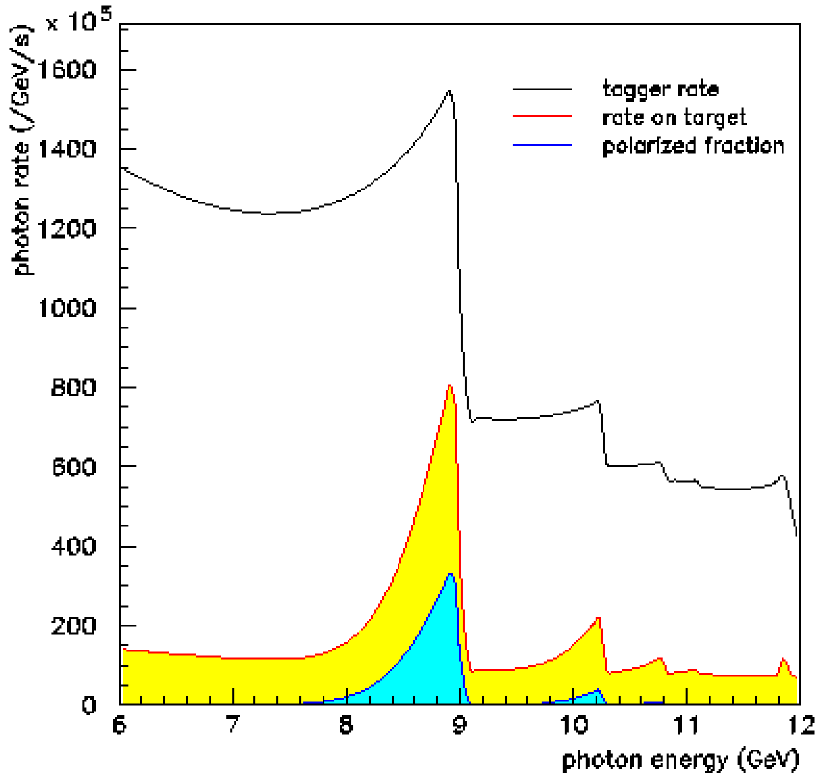
Diamond: effect of crystal thickness

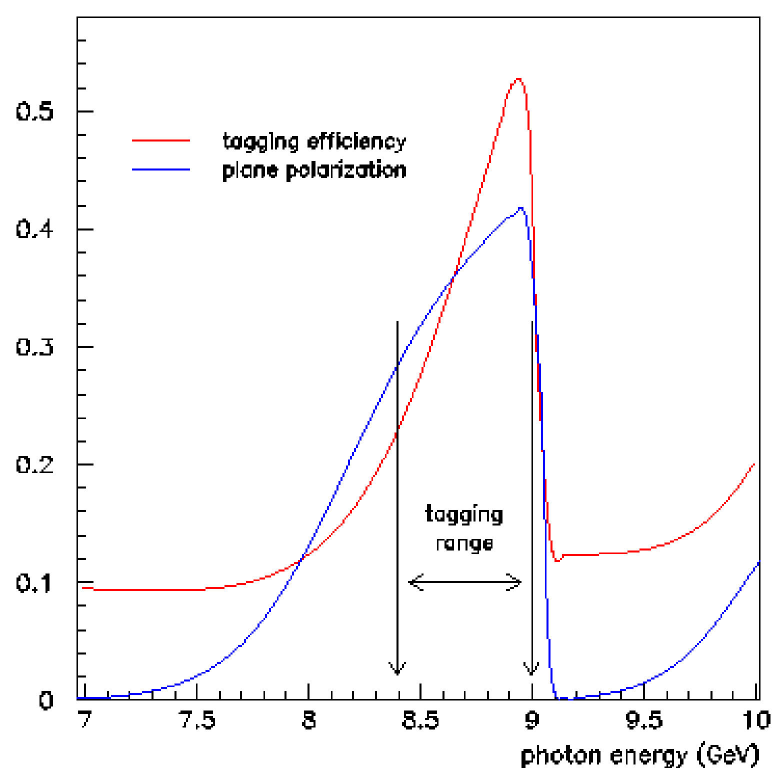


Tagging spectrometer



Tagging efficiency





Backgrounds

Choice of collimator diameter allows trade-off between optimum polarization and high tagging efficiency.

For constant photon flux in the peak:

collimator diameter ↓ peak polarization ↑ tagging efficiency ↓ beam current ↑

But total hadronic rate is very nearly constant

Example:

peak energy	**8 GeV**	**9 GeV**	**10 GeV**	**11 GeV**
N_γ in peak	185 M/s	100 M/s	45 M/s	15 M/s
peak polarization (f.w.h.m.)	0.54 (1140 MeV)	0.41 (900 MeV)	0.27 (600 MeV)	0.11 (240 MeV)
peak tagging eff. (f.w.h.m.)	0.55 (720 MeV)	0.50 (600 MeV)	0.45 (420 MeV)	0.29 (300 MeV)
total hadronic rate (in tagged peak)	385 K/s (26 K/s)	365 K/s (14 K/s)	350 K/s (6.3 K/s)	345 K/s (2.1 K/s)

Assumptions:

• beam energy	12 GeV
• beam current	1 μA
• collimator diameter	3.4 mm
• collimator distance	80 m
• crystal radiator	diamond (2,-2,0)
• crystal thickness	15 μm (10^{-4} rad.len.)
• target thickness	30 cm (liq. H_2)

R & D

★ **Crystals:** *thin crystals are required for optimum polarization*

- natural diamonds vs. synthetic
  - Can natural diamonds be thinned in a controlled manner?
  - Are synthetic diamond monocrystals competitive?
- robustness of thin monocrystals
  - What is the thickness limit from heat load?
  - What are the mounting and handling properties?
  - What is the most effective recovery procedure from radiation damage?

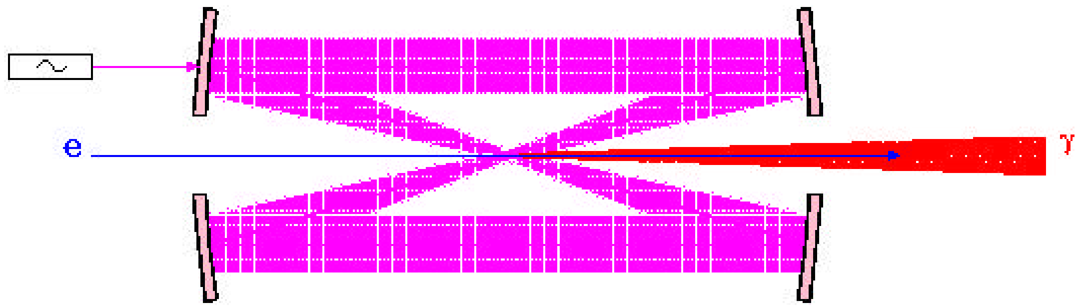
★ **Active collimator:** *requires long-term stability, linearity*

- immune to long-term drifts
- compatible with high-radiation environment
- low maintenance

★ **2D tagger readout**: *enhance polarization, tagging efficiency*

- readout of vertical coordinate on focal plane
- second plane of fast micro-strips in front of scintillators
- takes advantage of low y-emittance, natural amplification in θ_y

A. Backscatter source



	light energy	peak power	rep. rate	cavity gain	crossing angle	neck radius	pulse length
(a)	2.4eV	10kW	100MHz	10000	2°	10μm	2ps
(b)	4.8eV	10kW	100MHz	250	2°	10μm	2ps
(c)	20eV	1kW	500MHz	1	0.5°	10μm	1ps