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Photon Source and Tagger

presented by

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Photon Beam: coherent bremsstrahlung

- Criteria
  - **high energy** 8-9 GeV
  - **linear polarization** 0.5
  - **high flux** 10^8 s^{-1}
  - **energy resolution** 10 MeV r.m.s.
  - **low background**

- Design options
  A. laser backscatter
  B. synchrotron backscatter
  C. bremsstrahlung
  D. coherent bremsstrahlung

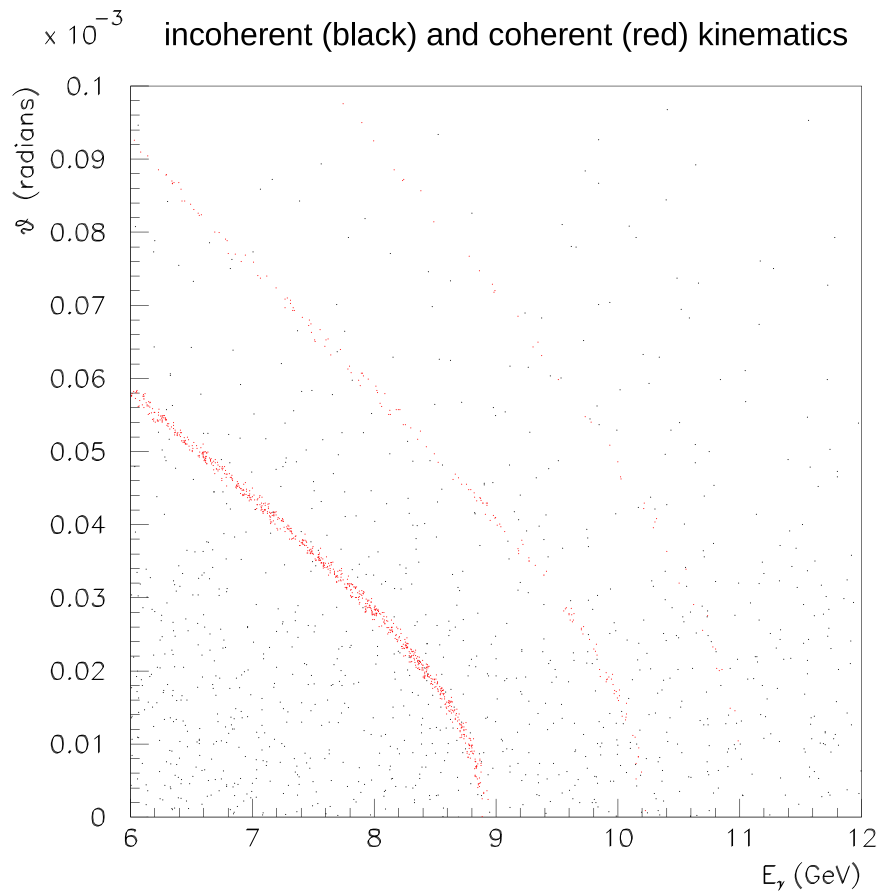
"figure of merit" = (rate in 8-9 GeV window) * $(\text{polarization})^2$ @ constant b.g.

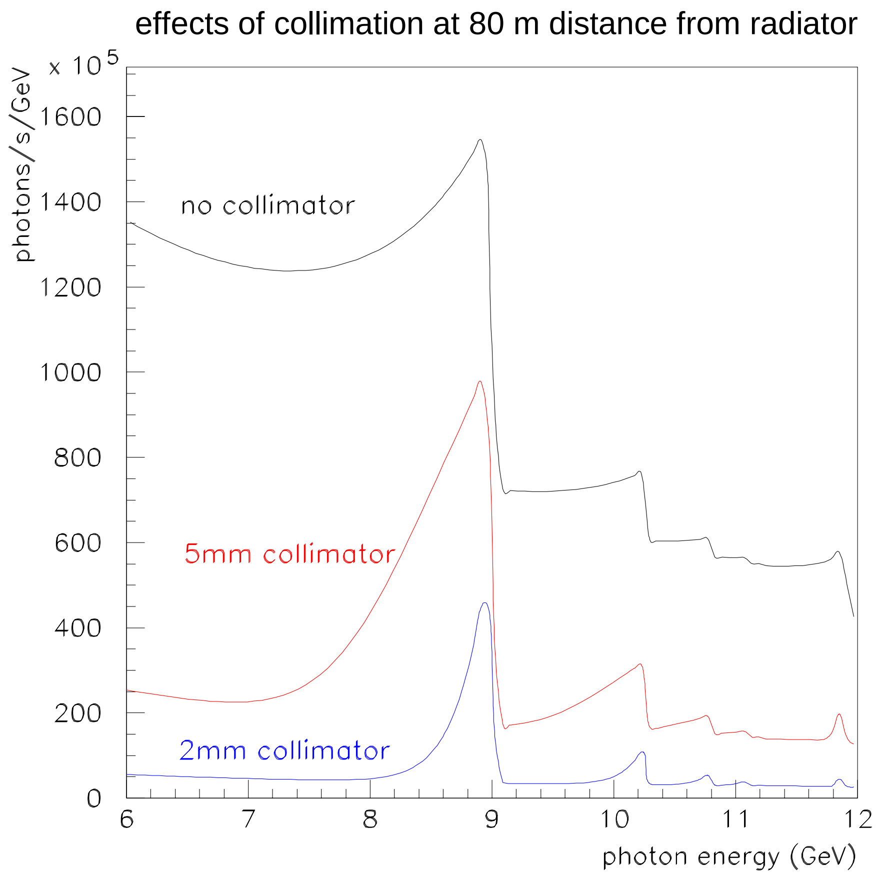
	A	B	C	D
energy	x	★★	★★★	★★
polarization	★★★	★★★	x	★★
flux	x	x	★★★	★★★
resolution	(†)	(†)	(†)	(†)
background	★★★	★★★	★	★★

(†) with tagging

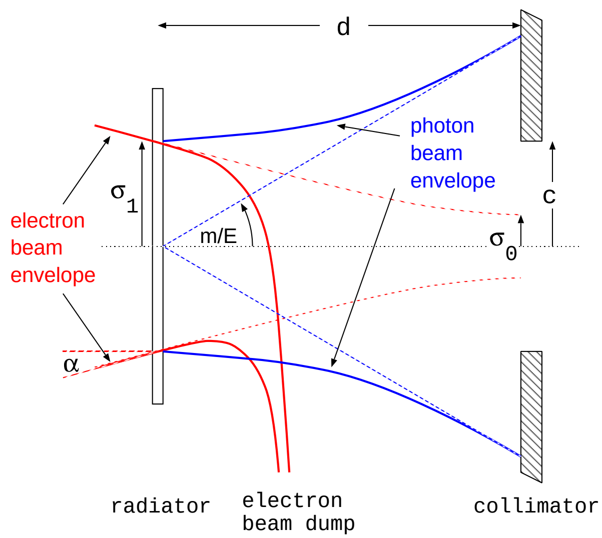
Photon Beam: energy spectrum

effects of collimation: **reduce low-energy background** and **increase polarization**





Photon Beam: collimation



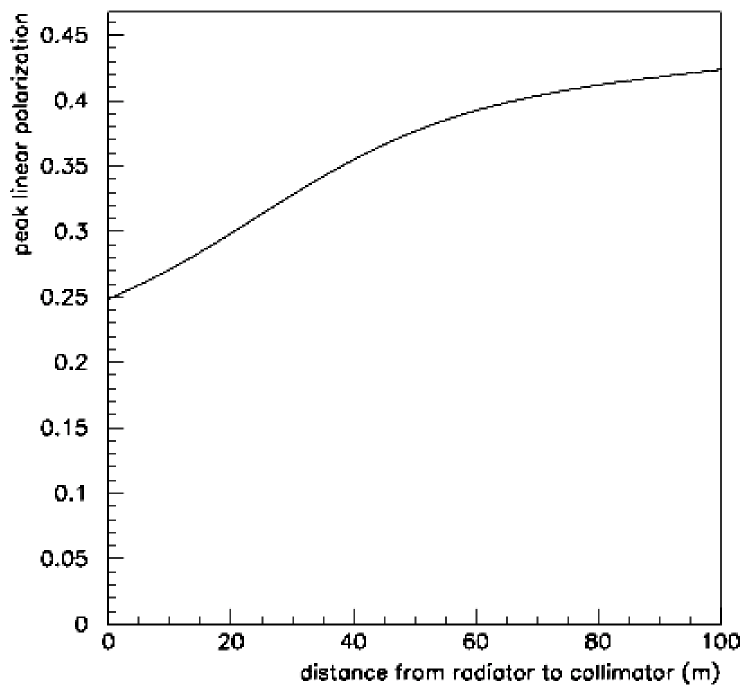
α < 20 μr

σ_0 < 1/3 c

d > 70 *m*

With increased collimator distance:

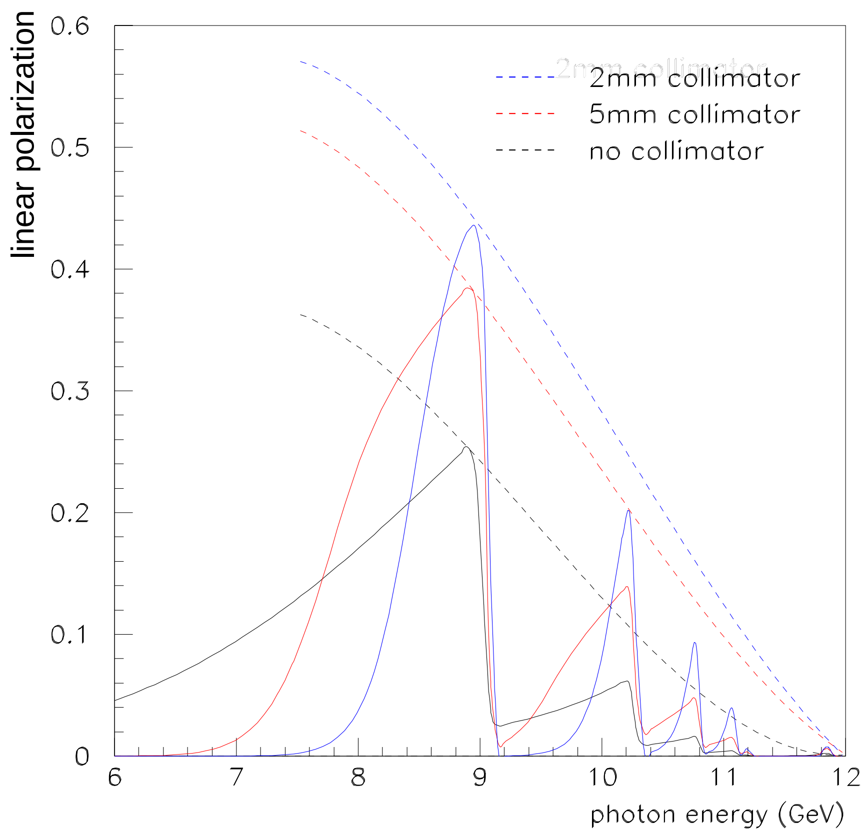
- polarization grows
- low-energy backgrounds shrink
- tagging efficiency drops off



Photon Beam: collimation

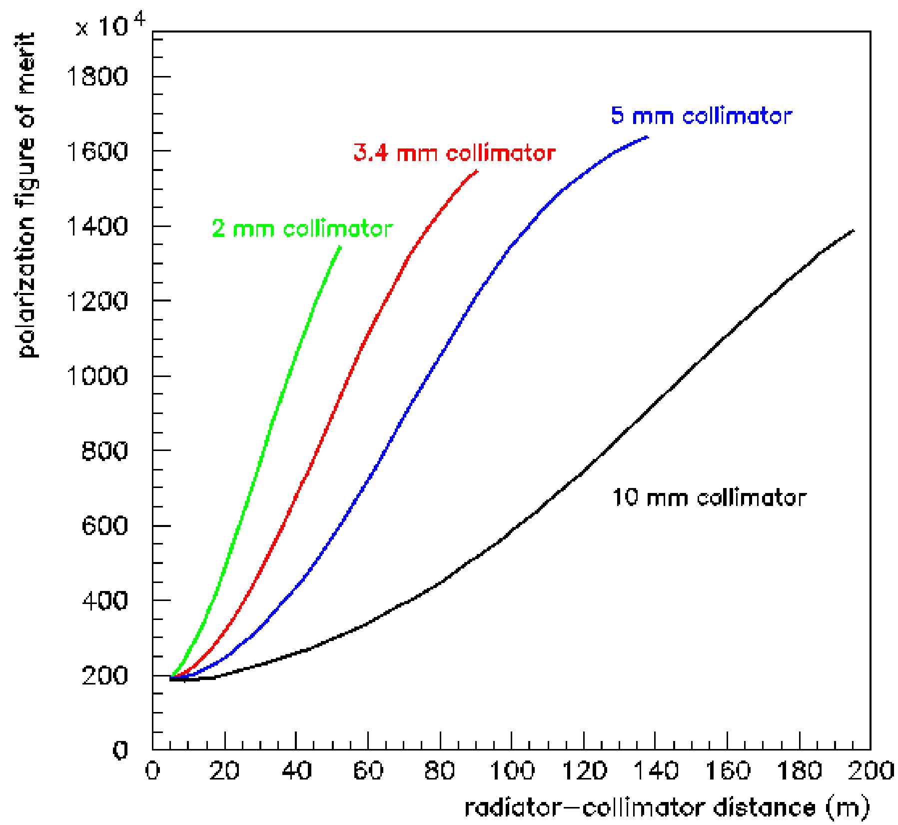
effects of collimation on polarization spectrum

collimator distance = 80 m



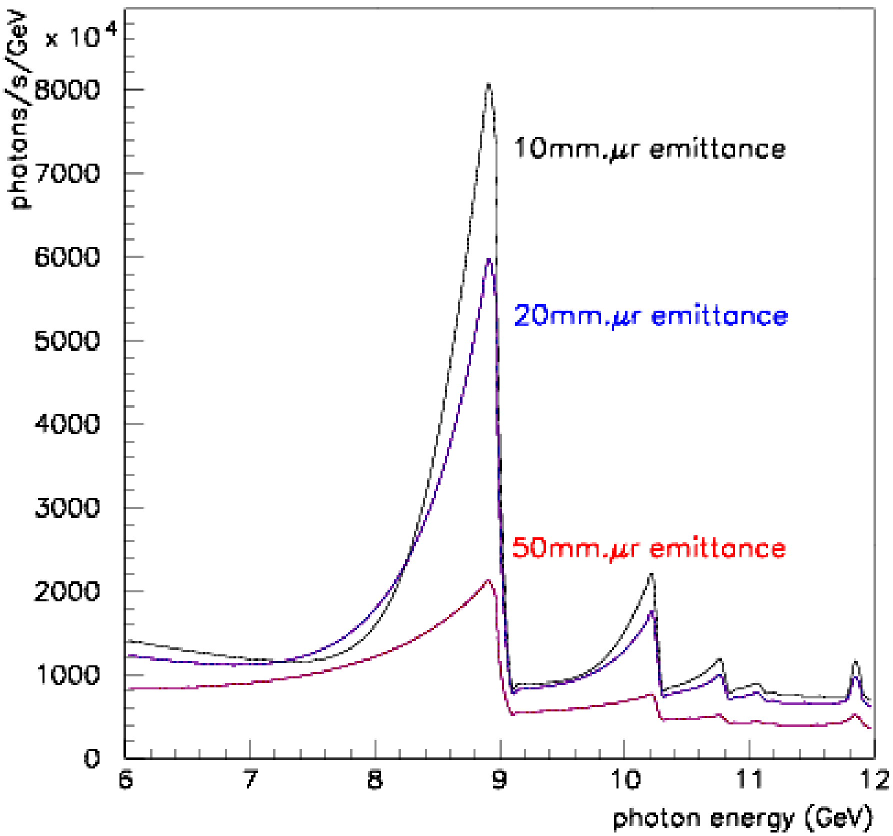
effects of collimation on figure of merit:

rate (8-9 GeV) * p² @ fixed hadronic rate



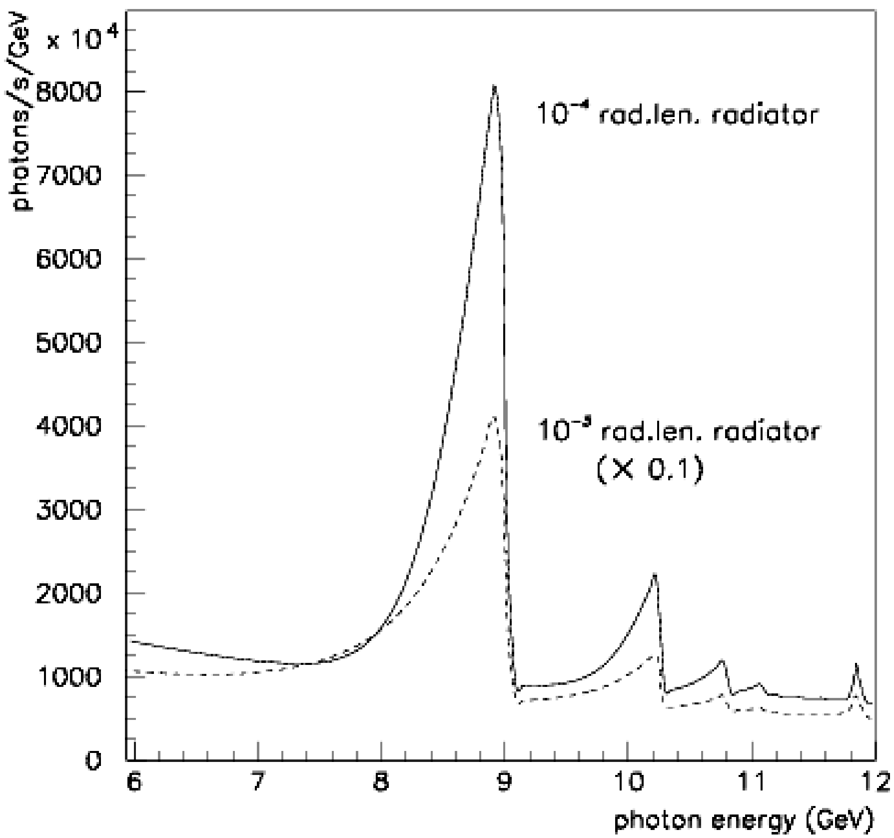
Electron Beam: properties

energy	12 GeV
r.m.s. energy spread	7 MeV
transverse x emittance	10 mm μr
transverse y emittance	2.5 mm μr
electron polarization	available
minimum current	100 pA
maximum current	5 μA
x spot size at radiator	1.6 mm r.m.s.
y spot size at radiator	0.6 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

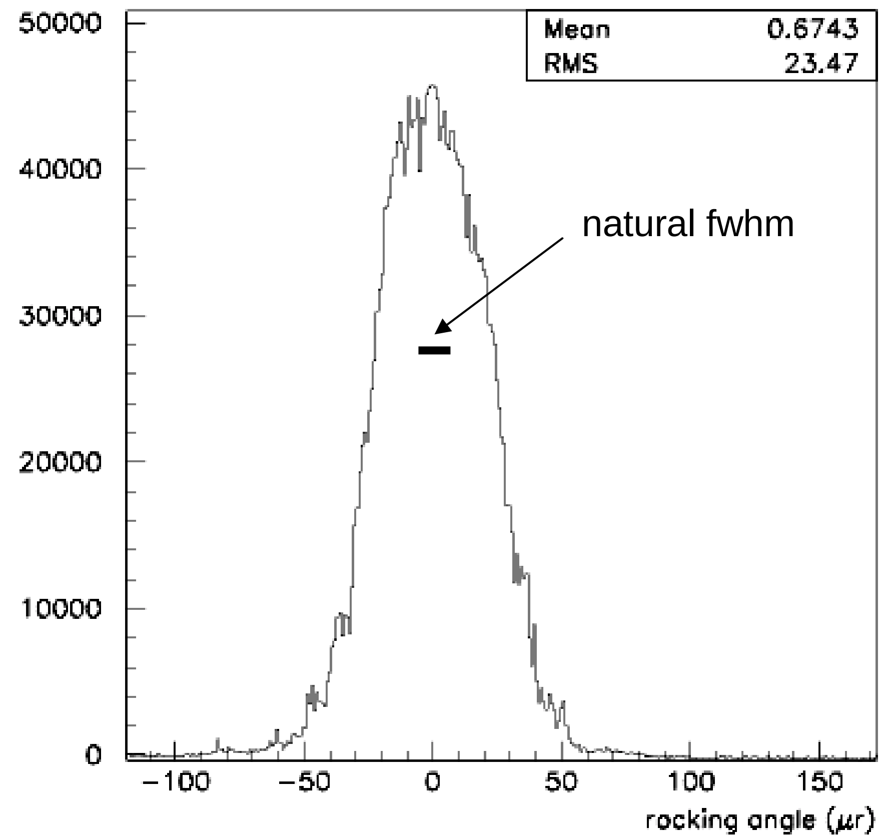


Diamond crystal: properties

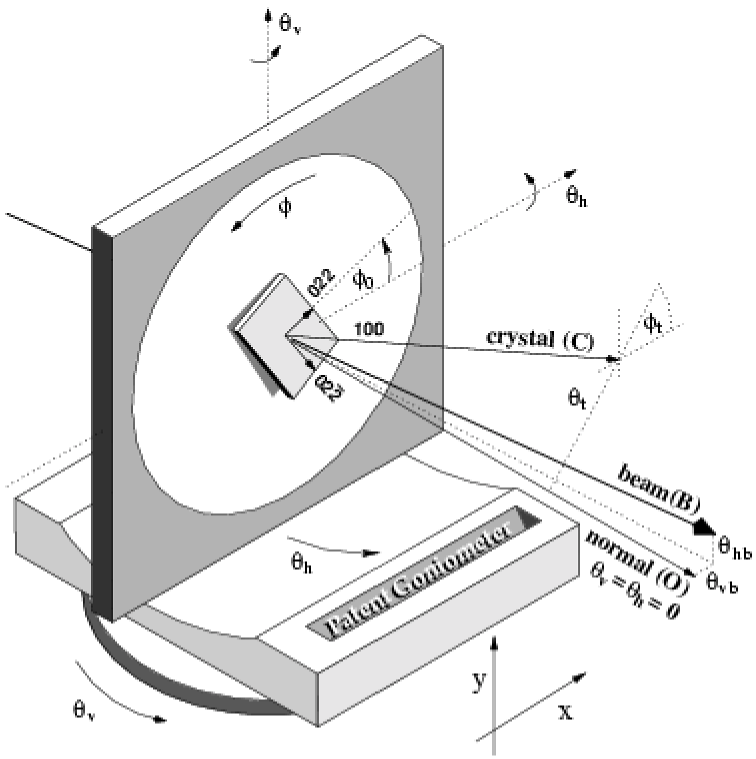
limits on thickness from multiple-scattering



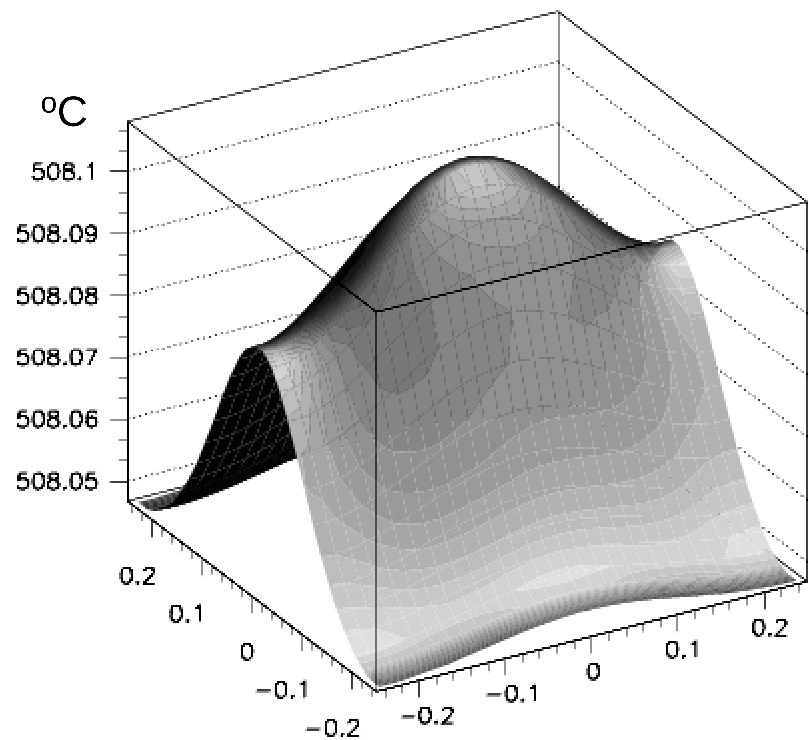
rocking curve from X-ray scattering



Diamond crystal: goniometer mount



temperature profile of crystal
at full operating intensity



Tagging spectrometer

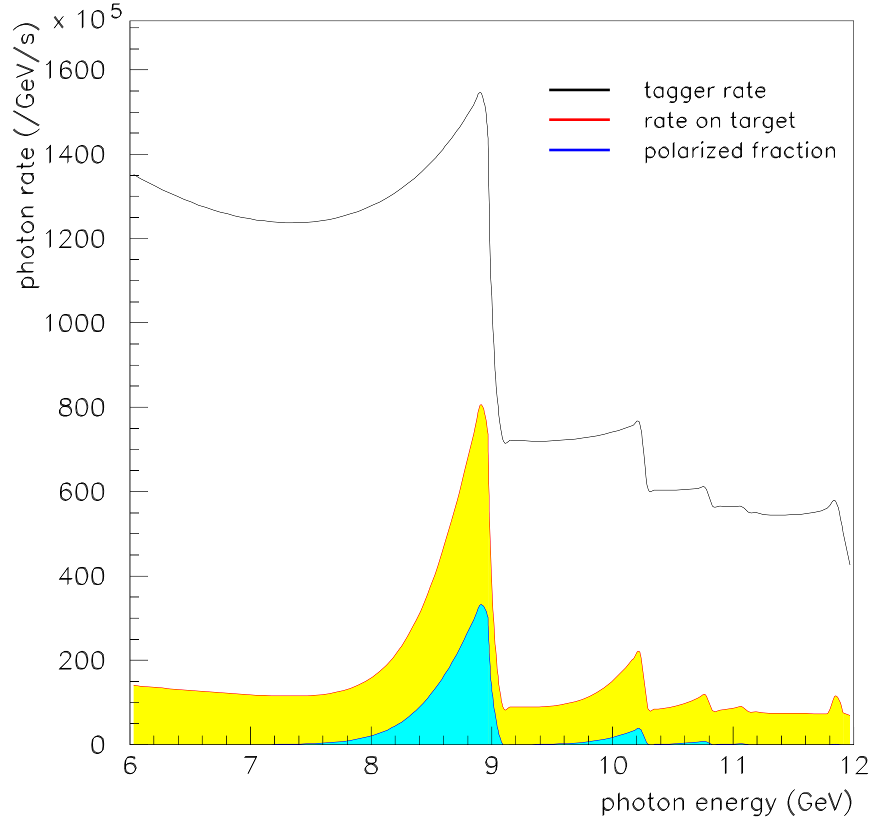
- Requirements
  - spectrum coverage

    25% -- 95% in 0.5% steps

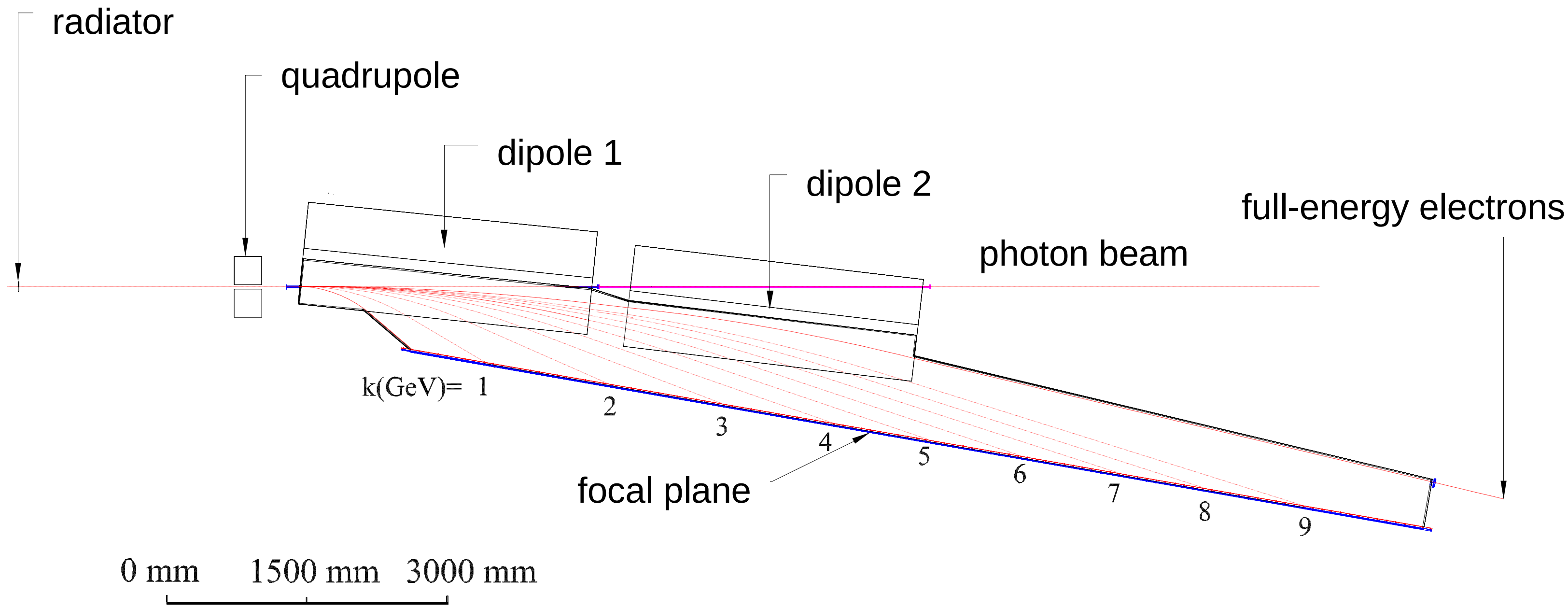
    70% -- 75% in 0.1% steps
  - energy resolution

    10 MeV r.m.s.
  - rate capability

    up to 400 MHz per GeV



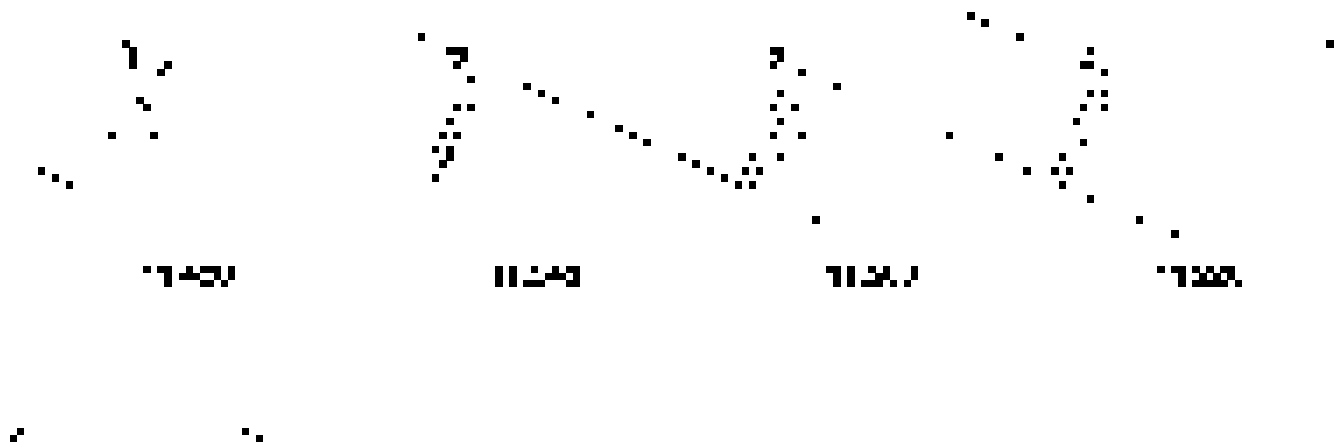
Tagging spectrometer: two dipole design



- final bend angle: 13.4°
- dipole magnetic field: 1.5 T
- focal plane length: 9.0 m
- energy resolution: < 10 MeV r.m.s.
- gap width: 3 cm
- pole length: 3.1 m
- dipole weight: 38 tons
- coil power: 30 kW

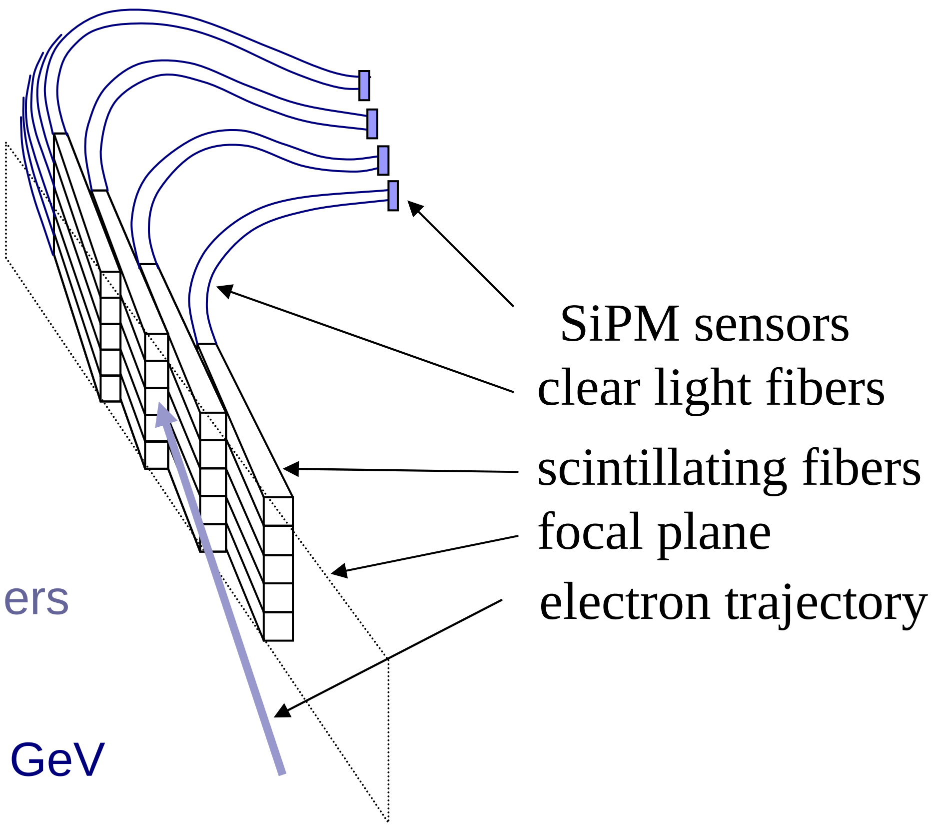
Tagger focal plane: fixed array

- 141 counters, each subtending 60 MeV (0.5% E_0)
- plastic scintillator paddles oriented perpendicular to rays
- designed for minimal overlap
- conventional phototube readout
- essential for diamond crystal alignment
- useful as a monitor of photon beam
- cannot run in counting mode at full source intensity



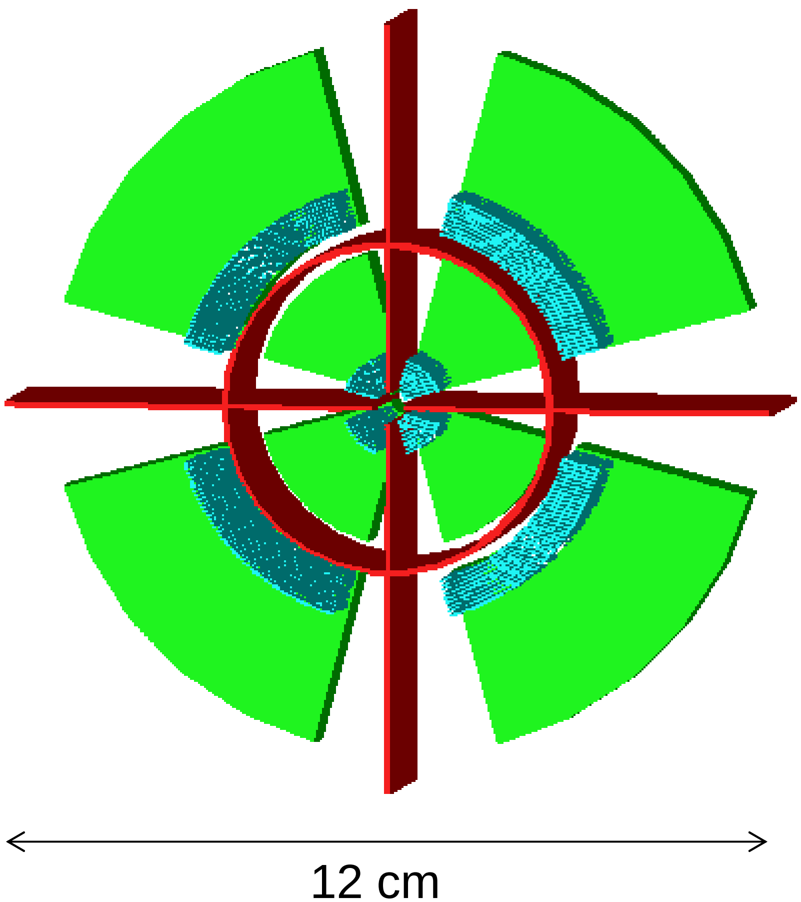
Tagger focal plane: microscope

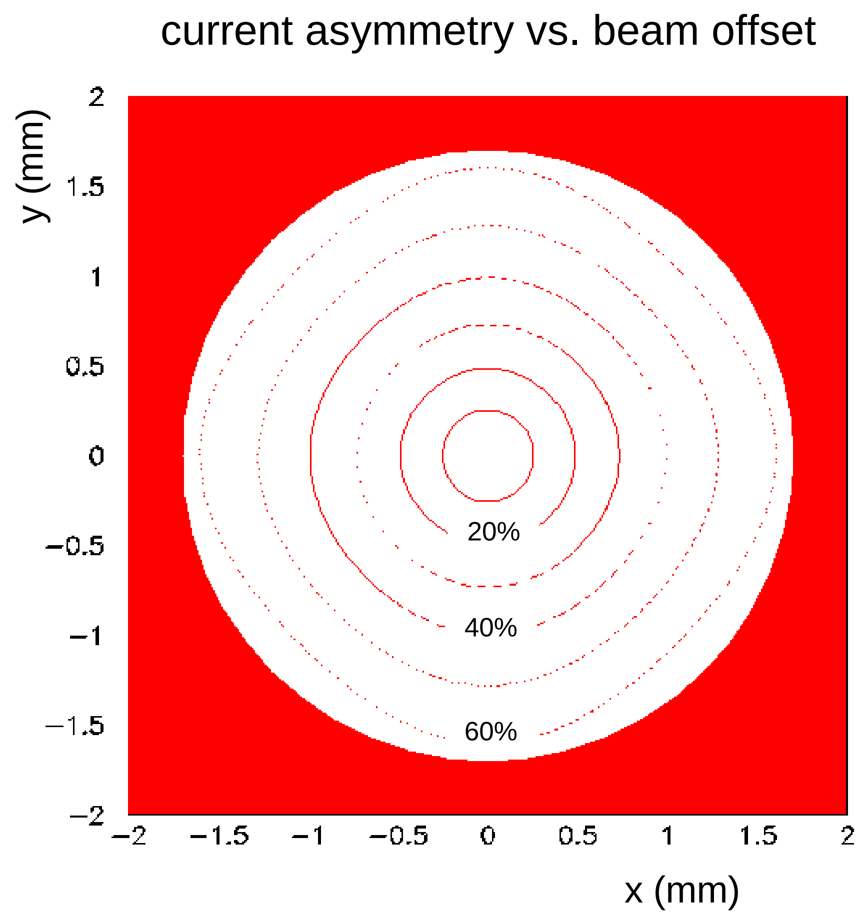
- Design parameters
  - square scintillating fibers
  - size 1 mm x 1 mm x 20 mm
  - clear light guide readout
  - aligned along electron direction
  - exploits the maximum energy resolution of the spectrometer
  - readout with silicon photomultipliers (SiPM devices)
  - dispersion is 1.4 mm / 0.1% at 9 GeV
  - 2D readout to improve tagging efficiency



Beam line: active collimator

- Monte Carlo simulation

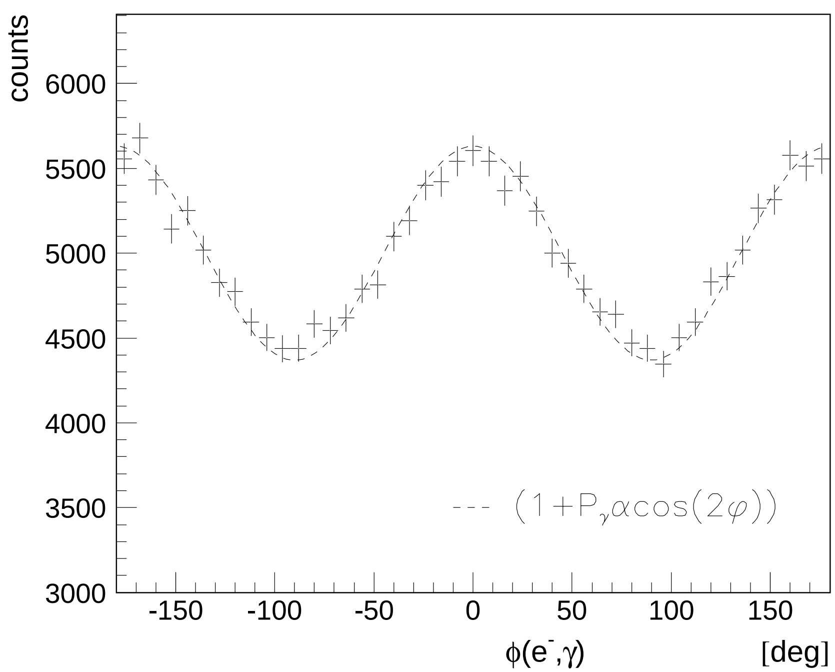




Beam line: polarimetry

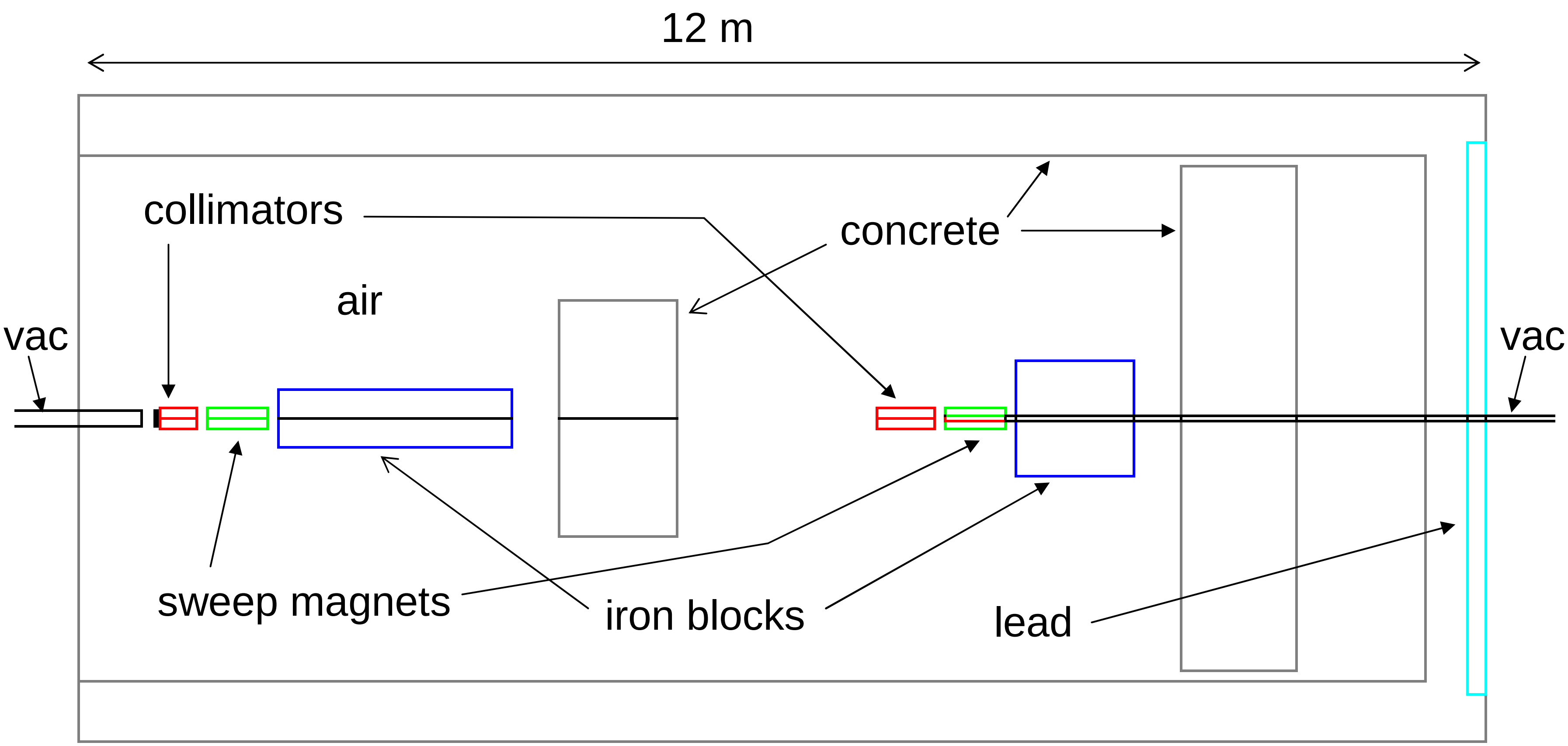
- Design parameters
  - measures azimuthal plane of e^+e^- pair production
  - pair spectrometer allows selection of symmetric pairs
  - typical opening angle of pairs is of order 100 μr
  - requires 1-2 *m* of flight path inside vacuum from target to microstrip tracker
  - pair spectrometer gap downstream of tracker planes
  - scintillators detect pairs from spectrometer, provide trigger

analysing power = 25 %



Beam line: shielding

overhead view of collimator cave cut through horizontal plane at beam height

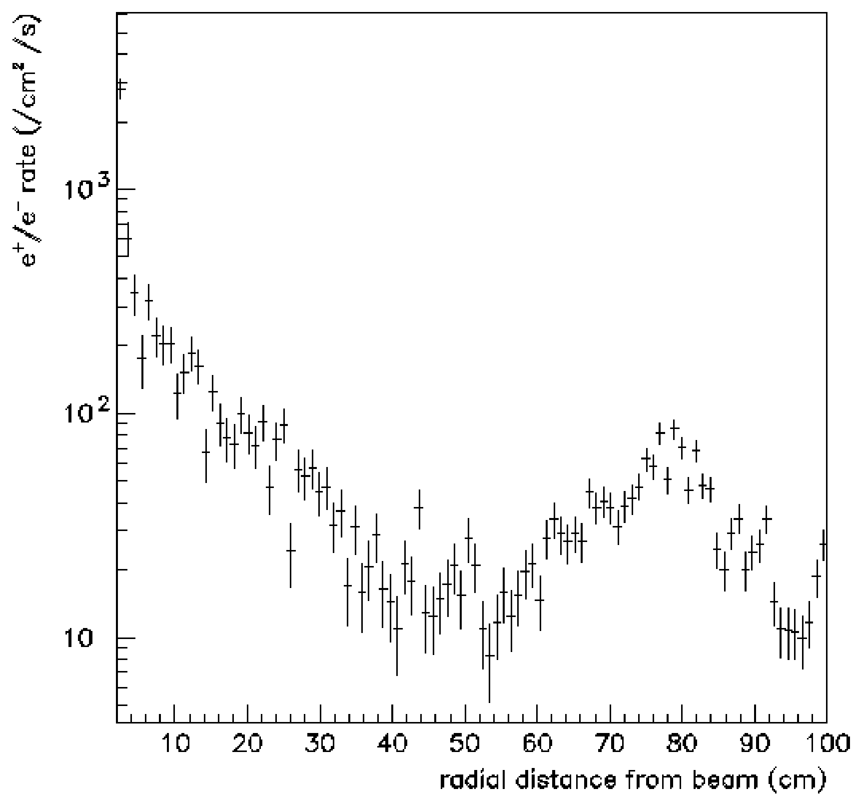


Beam line: physics simulation

- GEANT-based Monte Carlo
  - based on a coherent bremsstrahlung generator
  - good description of electromagnetic processes
  - extended to include hadronic photoproduction processes

    1. **γ,N scattering**
    2. **γ,A single nucleon knockout**
    3. **γ,π pion photoproduction**

  - complete description of beam line including collimator and shielding
  - integrated with detector sim.



Beam line: rates and background

1. Total hadronic rate is dominated by the resonance region
2. For a given electron beam and collimator, background is almost independent of coherent peak energy, *comes mostly from incoherent part.*

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)