Beam Induced Detector Background

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Sources of Detector Backgrounds

1) Beam particles-residual gas interaction
   a) Coulomb scattering
   b) Bermsstrahlung
2) Synchrotron radiation
   a) direct radiation generated in upstream magnets
   b) backward scattering from down stream components
   c) forward from mask tip and upstream vacuum chamber
3) Touschek Scattering
   only important for low energy colliders
4) Thermal Photon Compton Scattering
   only important for very high energy colliders
5) Beam-beam interaction
   (Yue Hao's simulation)
6) Operational particle losses
   (Injection, machine tuning, beamloss, etc.)

What Vacuum Can We Expect?

(Input from vacuum expert Dick Hseuh, BNL)

1) Pressure=1×10^{-9} mbar (electron lifetime > 30 hours)

(with special effort, it may reach 1×10^{-10} mbar, but one can't count on it.)

2) Inside of the detector 50% H_2 , 50% CO (including H_2O etc.)

(Could reach 80% H_2, 20% CO in the vacuum chamber away from detector. But it is hard to reduce CO in detector due to particle hitting the surface)

3) Photon desorption rate (C+O=CO per photon hit):
10^{-3} to 10^{-2} for a virgin material, surface dominated
10^{-5} after surface becomes clean, reaches equilibrium

4) The pumping speed of the lumped pumps (>>10^2 L/s) are much larger than the conductance (~ 10^1 L/s), so the pressure is decided by conductance solely.

Pipe Length vs. Radius

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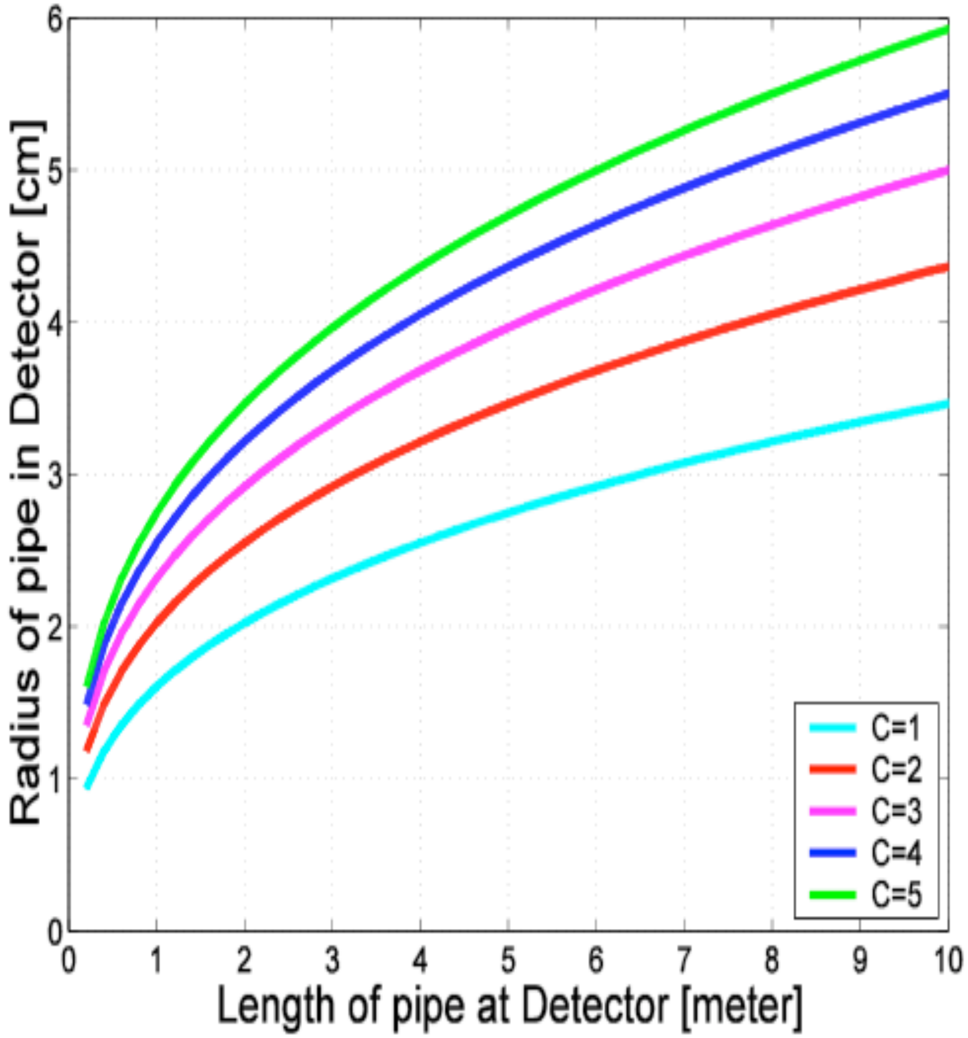


Conductance of pipe for CO:

$C=12r^3/L$ [Litters/sec]

STAR:

L=4m, r=3.5cm

C=1.3 [Litters/sec]

PHENIX:
L=3m, r=3.5cm
C=1.7 [Litters/sec]

Synchrotron Radiation into eRHIC IR

Two directions of synchrotron radiation in the eRHIC IR:

Forward (direction of the electrons) generated by 10GeV electrons bent through a 0.2 Tesla detector integrated dipole magnet located 1m (from the magnet center to IP) upstream.

backward (opposite direction of the electrons) caused by the secondary radiation of the absorber located 7.2m downstream, (proportional to the primary radiation on the absorber.)

In the current design, the fraction of the forward radiation fan hitting the absorber is 20% and 27%, generated in the magnets located 1m (from the magnet center to IP) upstream and downstream of the detector, respectively.

Number of Dipole Magnets at IP	**2**
Magnetic Field	**0.2 Tesla**
Magnet Effective Length L	**1.0 m**
Electron Beam Current	**0.5 A**
Electron Relativistic Factor γ	**1.96E+04**
Synchrotron Radiation Power P_0	**5.08 kW**
Critical Photon Energy E_0	**13.3 keV**

Spectrum of Synchrotron Radiation from the Magnets Upstream of the Detector

The photon spectrum of forward synchrotron radiation:

$$\frac{d^2n}{dtdE} = \frac{P_0\gamma}{E_c^{\,2}}\frac{S(\omega/\omega_c)}{(\omega/\omega_c)}$$

P_0 = synchrotron radiation power

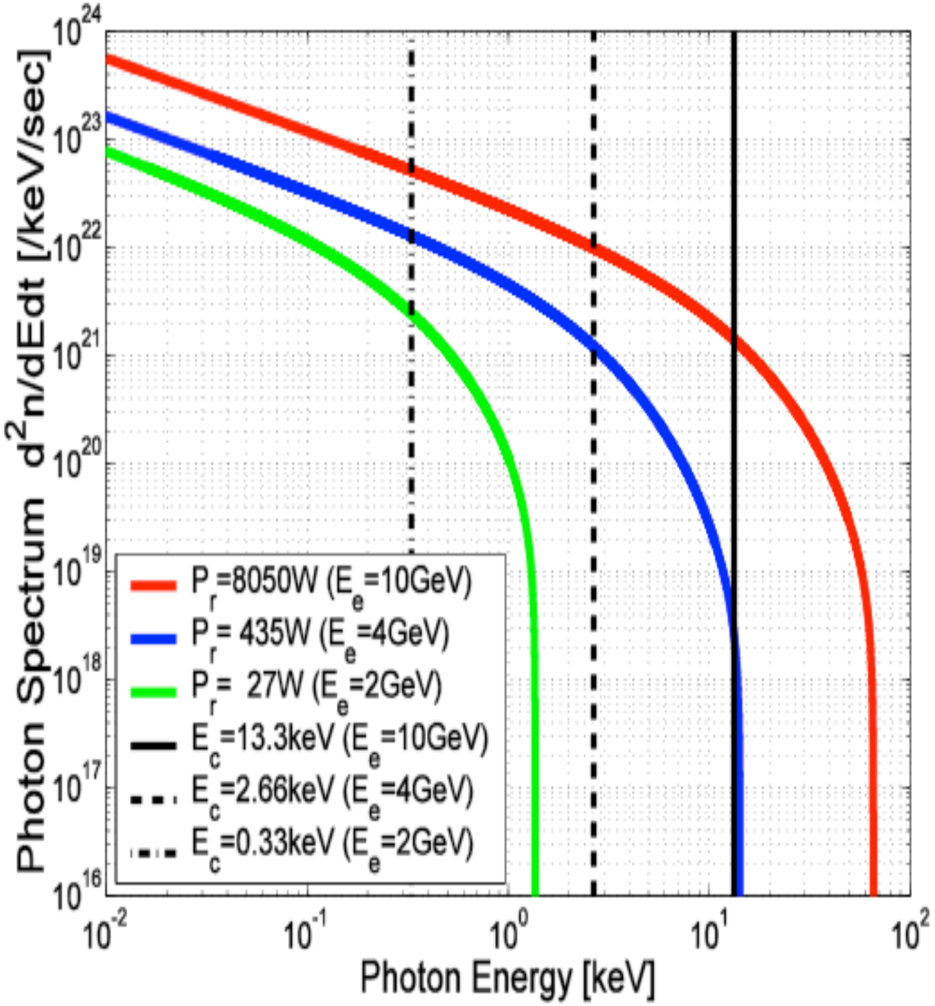
γ = electron relativistic factor (E^e_{total}/E^e_{rest})

E_c = the critical photon energy

S-function defined as:

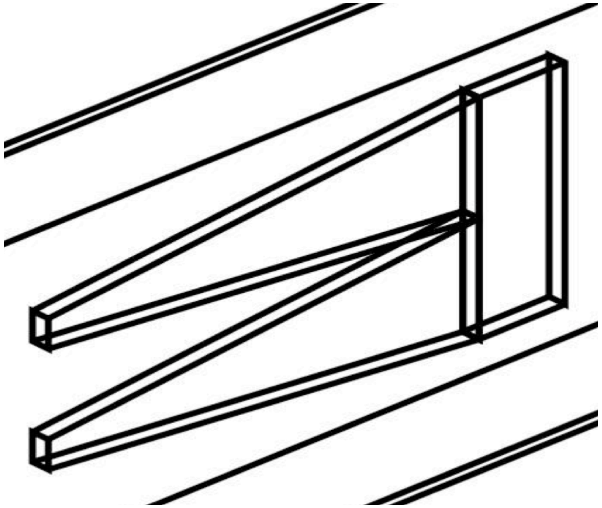
$$S\left(\frac{\omega}{\omega_C}\right) = \frac{9\sqrt{3}\,\omega}{8\pi\,\omega_C}\int_{\omega/\omega_C}^{\infty} K_{5/3}(z)\,dz$$

$K_{5/3}(z)$ = the modified Bessel function of the second kind.



Backward Radiation Into IR

The Absorber design is based on the high power synchrotron radiation absorber of HERA.



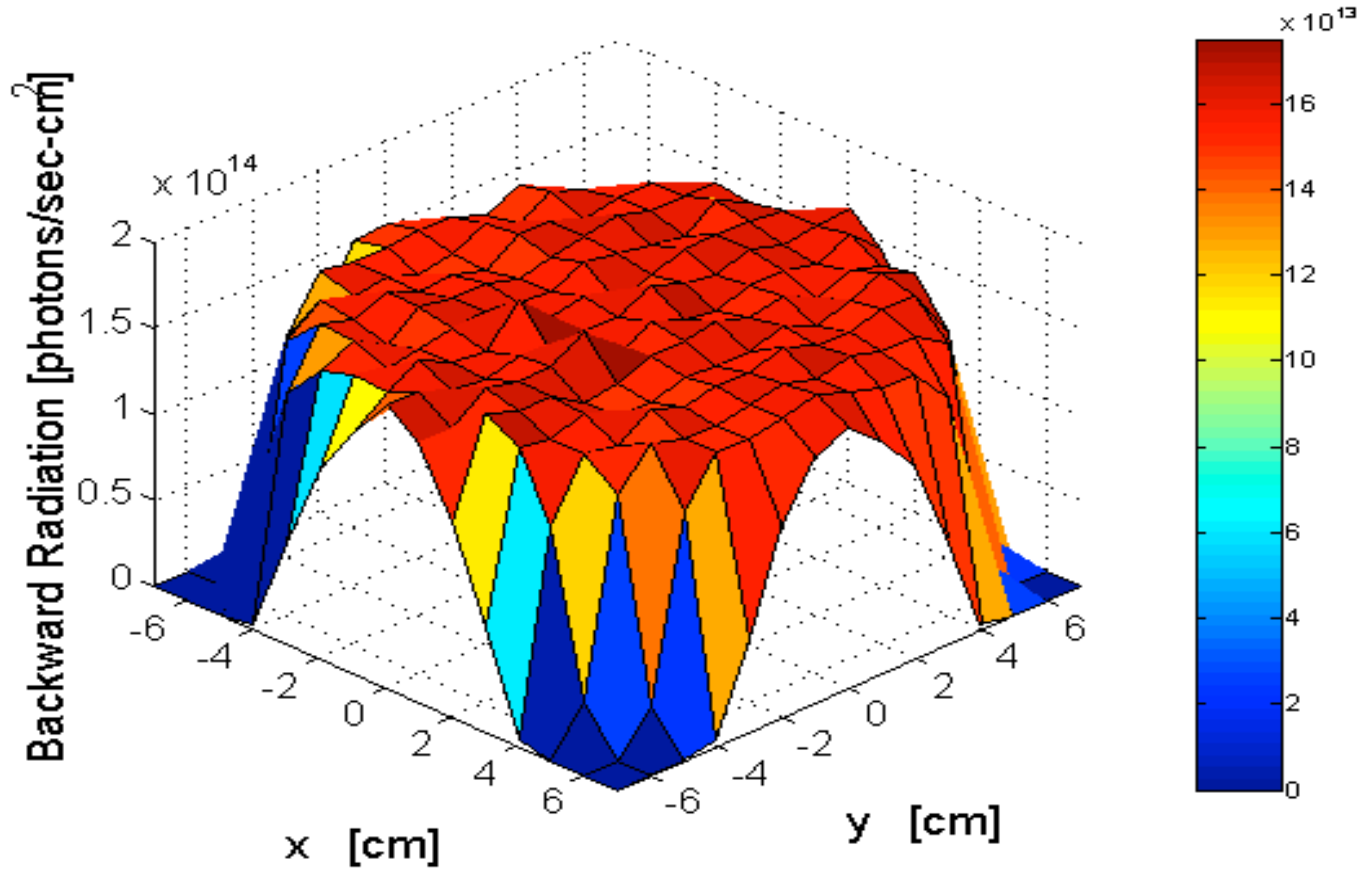
Material of V-shaped Absorber	Copper
Absorber V-opening Width	1 cm
Absorber V-opening Height	3 cm
Absorber V-opening Depth	25 cm
Surface tilt angle of the V-opening	60 mrad
Interaction Point from Absorber	7.2 m
Upstream Magnet from Absorber	8.2 m
Downstream Magnet from Absorber	6.2 m
Material of Vacuum Chamber	Stainless Steel
Diameter of Vacuum Chamber	15 cm
Material of the Detector Surface	???
Diameter of Detector Opening	15 cm

Physics Processes

Involving Photon-Material Interactions

Physics Process	Energy Range (keV)	Interaction Coefficents	Included in
	keV	cm^2/g	Simulation
Photoelectric Effect	1e-1 to 1e3	1e-3 to 1e5	Yes
Rayleigh (Coherent) Scattering	1e-1 to 1e4	1e-4 to 1e1	Yes
Compton (Incoherent) Scattering	1e-1 to 1e5	1e-4 to 1e0	Yes
Continuous Energy Loss			Yes
(e+, e-) Pair Production	>1e3	<1e-1	Yes
Positron Annihilation			Yes
Hadronic Interaction			Yes
Bremsstrahlung			Yes
Ionisation and d-ray Production			Yes
Photo-induced fission	only Z>90		No

Backward Radiation Into IR



Backward Radiation into IR

vs. the Length of Absorber

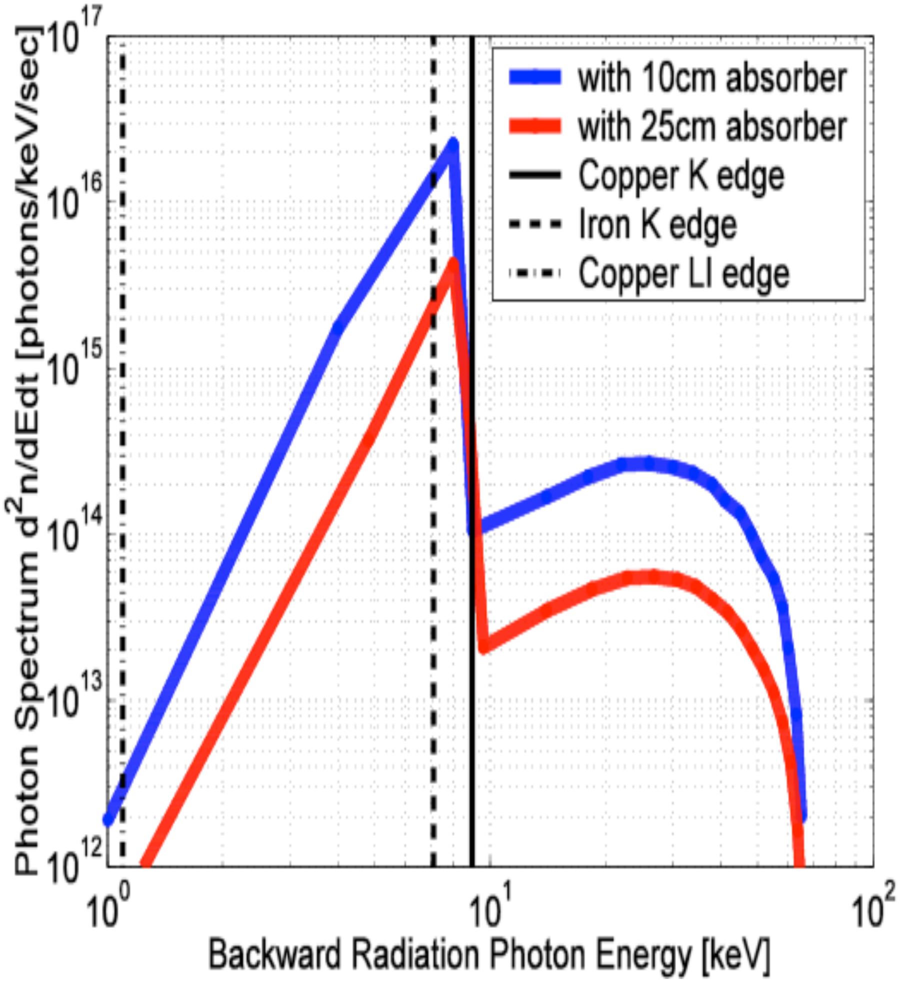
Total Backward Radiation Level:

[photons/sec]

P_{25cm} = 1.2e16

P_{10cm} = 7.0e16

P_{10cm} / P_{25cm} = 6



What have we learnt from simulation

1. The integrated forward SR onto absorber: 4.8×10^{22} p/s.
   The integrated backward Radiation into IR: 1.2x1016 p/s.
   Backward scattering rate: 2.5×10^{-7} for a copper absorber.

2. At the back entrance of IR the radiation is cylindrically symmetric with a very uniform spatial distribution and very small angles . So, most of photons go though the front entrance without hitting the detector wall.

6. The integrated backward radiation levels into the detector are 7.0x1016p/s and 1.2x1016p/s for the absorber depth of 10cm and 25cm, respectively.

7. Most backward photons into the detector have very low energy (<10keV).

What Simulation Results Can We Use for MEeIC from the Previous Study of eRHIC?

1. The simulation of backward radiation of higher energy photons in MEeIC is similar to that of eRHIC.
2. Due to the large density differences (10^{17}–10^{22} photons /keV/Sec) cross the photon spectrum. The GEANT simulation for eRHIC was decomposed into smaller energy ranges, then reconstructed back based on the forward distribution of photons. So, it is possible to use these GEANT results to reconstruct it into MEeIC.
3. The official low energy cutoff in GEANT is 10keV. Based on CERN experiences, GEANT can correctly treat photons with energy>=1keV. So, the cutoff was 1keV in the eRHIC simulations.
4. Estimate the secondary radiation using diffuse scattering theory for lower energy photons (<10^0 KeV)

Diffuse Scattering Rate from MEeIC Vacuum Chamber

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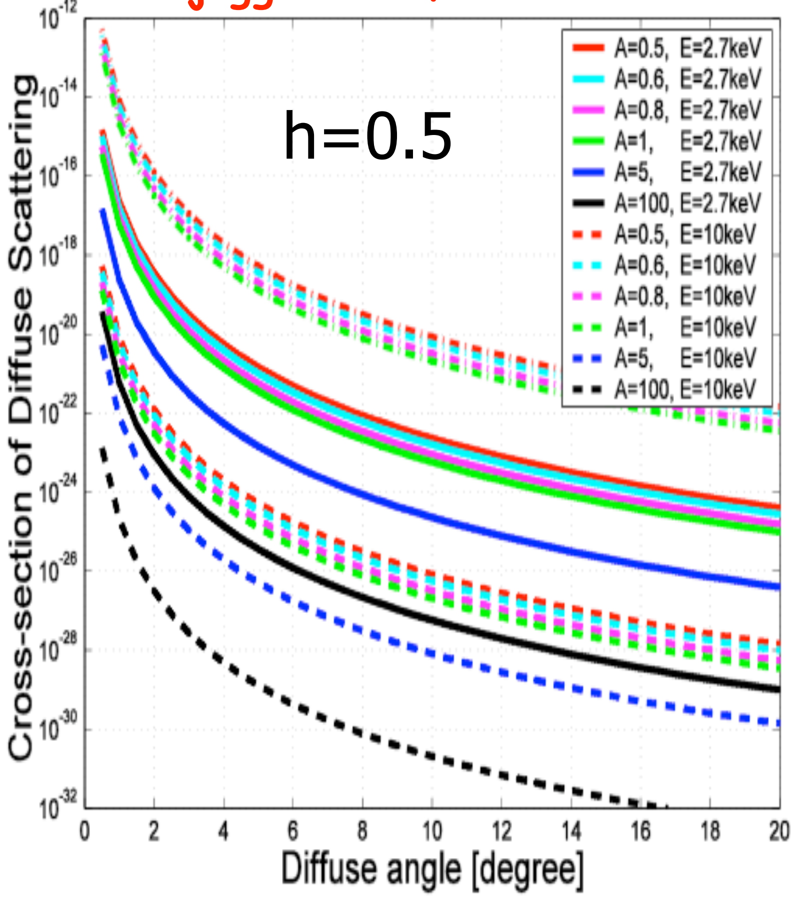
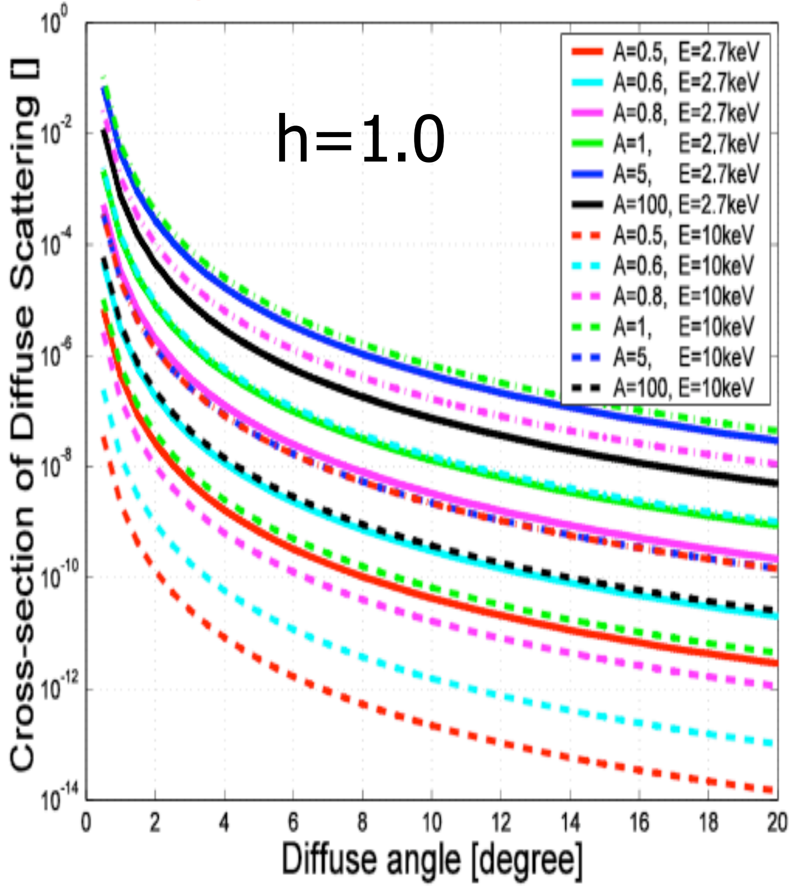
stainless steel chamber with some what "jagged" surface structure



stainless steel chamber with extremely "regular" surface structure



Estimate Detector Backgrounds

In general the estimate depend on:

beam current, vacuum pressure, molecular composition, surface property of the vacuum chamber, mask, absorber, etc
(AP group)

and material, geometry and surface property inside detector
(Length, radius, Al, SS, NEG coating, etc)
(Phys. Group)