eRD15
Compton electron detector R&D
Progress report & proposal

EIC R&D meeting

July 14th 2017

Alexandre Camsonne

eRD15 : Compton electron detector R&D

- Requirement
  - 1% or better electron polarization measurement (0.5 % for Parity program)
  - Best measurement Compton electron detector at SLD (~0.5%)
- Deliverables
  - Simulation to determine signal to background for JLEIC baseline Roman Pot and expected accuracy
  - Detector R&D for faster detector (signal at least shorter than 100 ns for eRHIC design, improves rate capability for JLEIC)
  - Test stand at JLab to measure precision polarization with the foreseen detector for EIC

Deliverable estimate for FY 2017

- Simulation
  - Implement beam pipe in magnet
  - More cross check with old simulation
  - Full simulation with Interaction Region and beam pipe
  - Run simulation large scale on batch farm will full setup
  - Halo modelling
  - Model beam laser interaction
  - Implement polarization extraction analysis
  - Study of systematics and optimization of the setup
  - Synchrotron radiation study, detector response to synchrotron photons
- Wakefield Higher Order Mode
  - Run first pass simulation and determine if Roman Pot is doable for Compton Electron detector
- Test stand
  - Procure Amplifier and SAMPIC and setup bench
  - Measure detector pulse width on the bench

Not funded

Deliverable estimate for FY 2017

- Simulation
  - Implement beam pipe in magnet ✓
  - More cross check with old simulation ✓
  - Full simulation with Interaction Region and beam pipe ✓
  - Run simulation large scale on batch farm will full setup ✓
  - Halo modelling ✓
  - Model beam laser interaction ✓
  - Implement polarization extraction analysis ✓
  - Study of systematics and optimization of the setup ✓ First iteration
  - Synchrotron radiation study, detector response to synchrotron photons ✓
- Wakefield Higher Order Mode
  - Run first pass simulation and determine if Roman Pot is doable for Compton Electron detector ✓
- Test stand
  - Procure Amplifier and SAMPIC and setup bench
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Not funded

Simulation work

Halo background study

Background from IP

Polarization extraction

Contribution from window

Beam halo

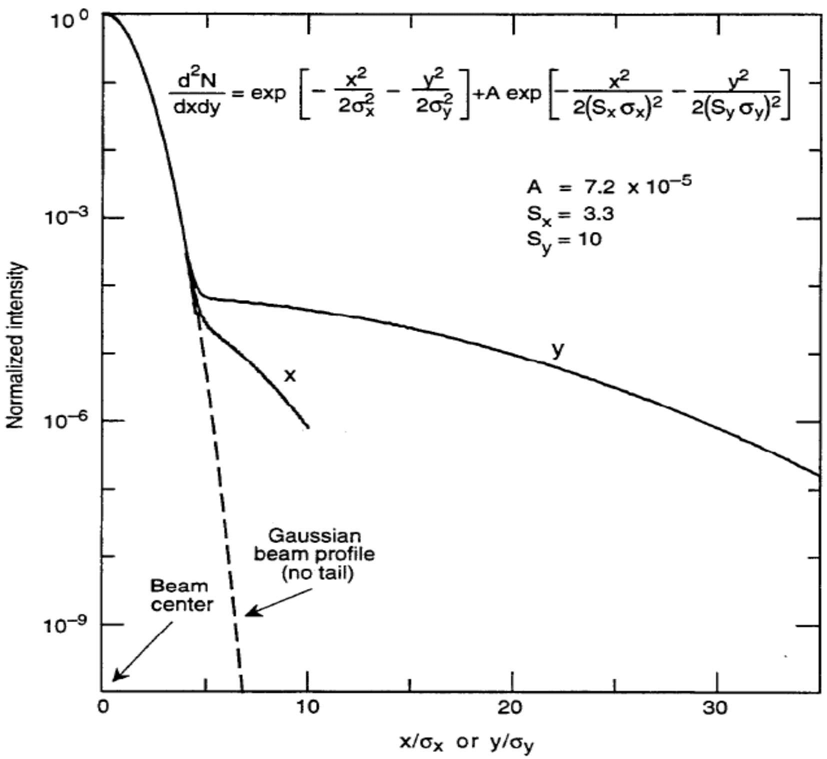
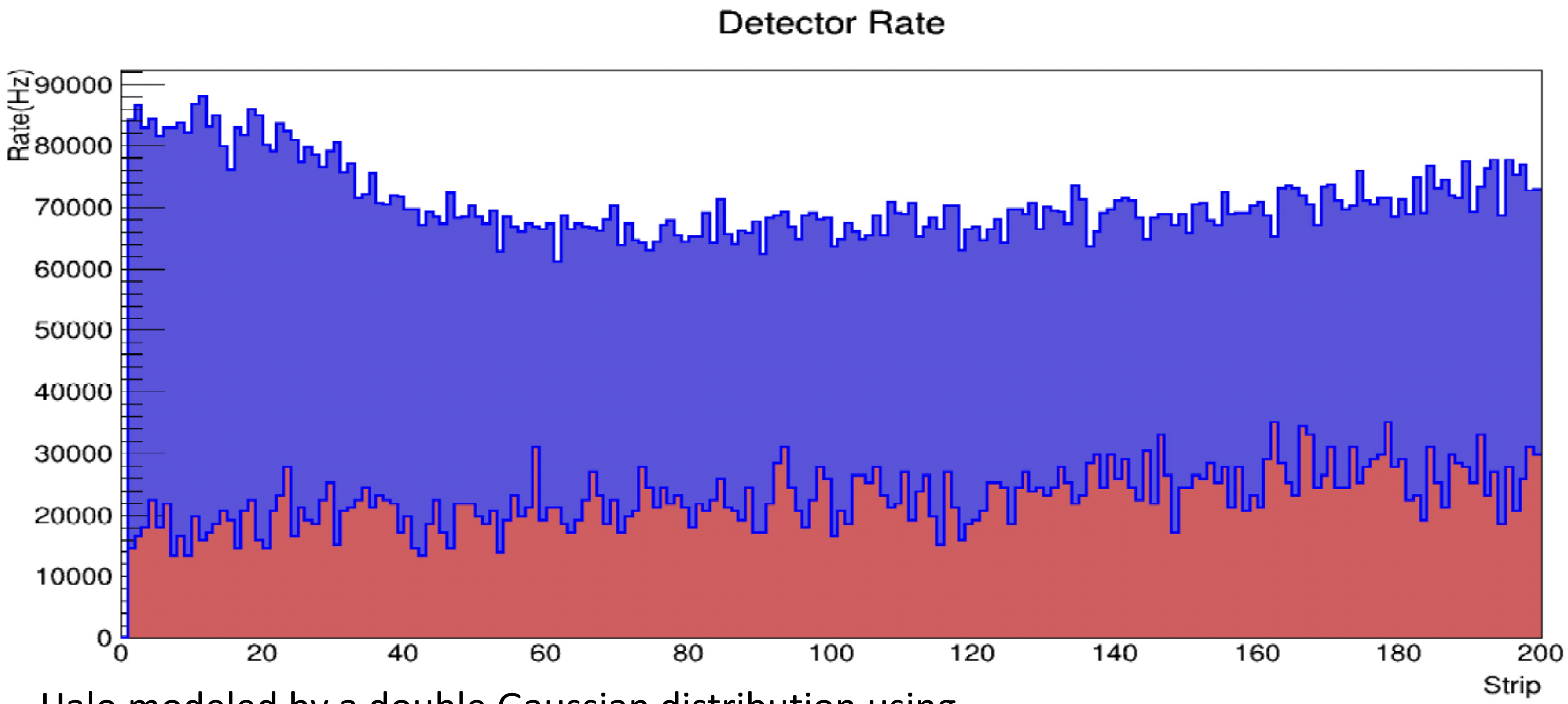


Fig. 4-51. Plot of the beam profiles assumed for the calculation of detector backgrounds due to synchrotron radiation. The integral of the background Gaussian is about 0.25% of the main beam Gaussian.

- Beam halo profile from PEP II design report
- Fraction of electrons around the main beam
- Will have to be evaluated for EIC

http://slac.stanford.edu/pubs/slacreports/reports07/slac-r-418a.pdf

Simulation background from halo

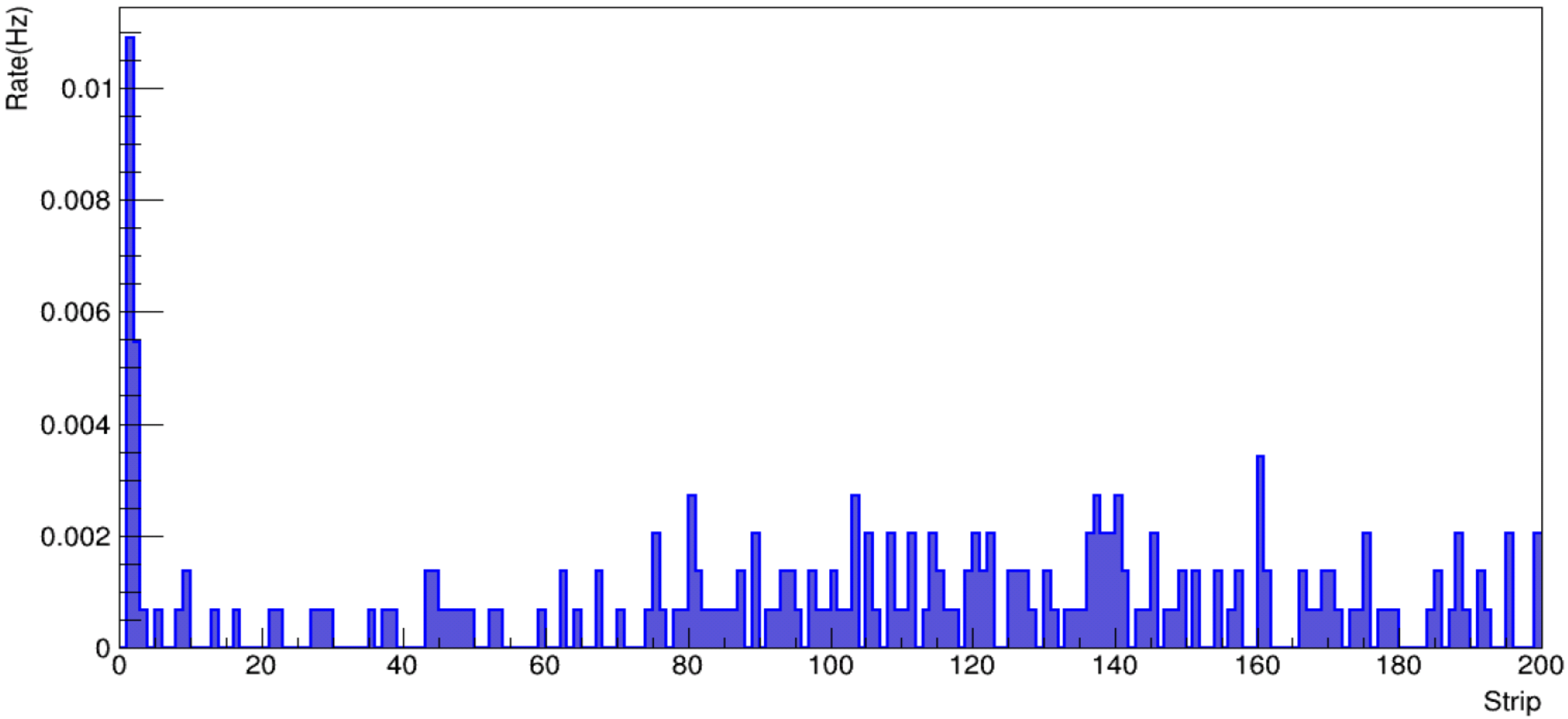


- Halo modeled by a double Gaussian distribution using beam size from PEPII
- Halo rates for 1 cm (blue) and 2 cm aperture (salmon)
- Can be used to reevaluate when more realistic halo available

$$\frac{dN}{dxdy} = e^{-\frac{x^2}{2\sigma_x^2}-\frac{y^2}{2\sigma_y^2}} + Ae^{-\frac{x^2}{2(S_x\sigma_x)^2}-\frac{y^2}{2(S_y\sigma_y)^2}}$$

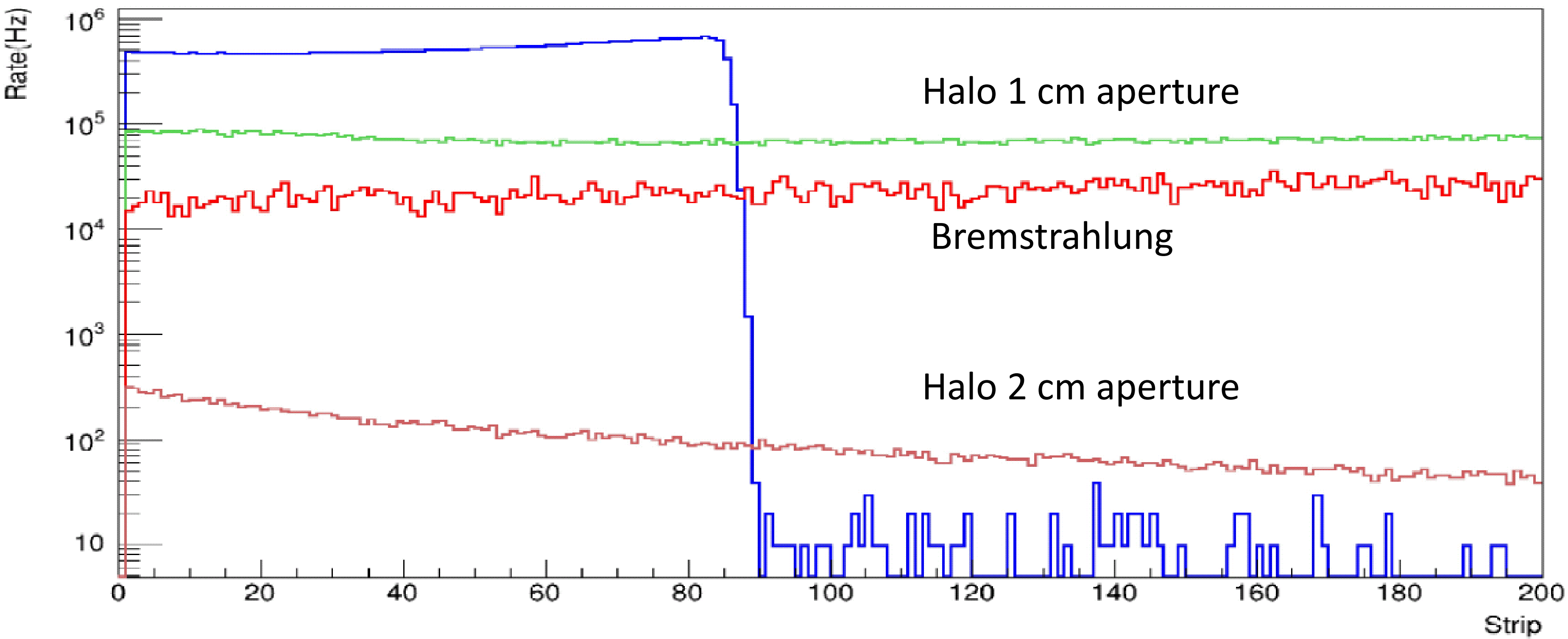
$$A = 7.2 * 10^{-5}$$

Simulation background from IP



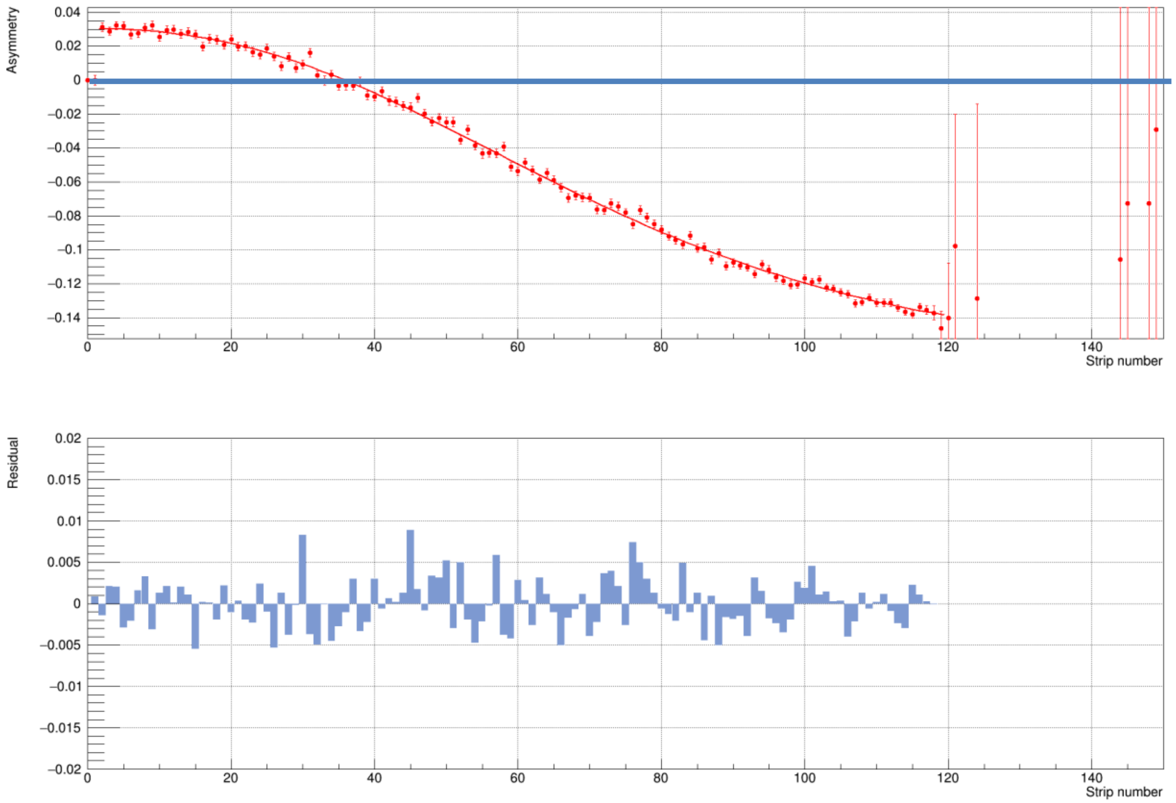
- Used Pythia event generator at IP
- Transport to Compton Detector
- Preliminary rate is negligible compared to other backgrounds

Compton Electron Det. Rates



- 10 W Green laser
- 1 A of beam
- Compton and Bremstrahlung assuming 10^{-9} Torr

Polarization fitting program



- EIC implementation of Hall C fitting program (see reference)
- Compton edge and asymmetry fit
- Will be useful to study systematics

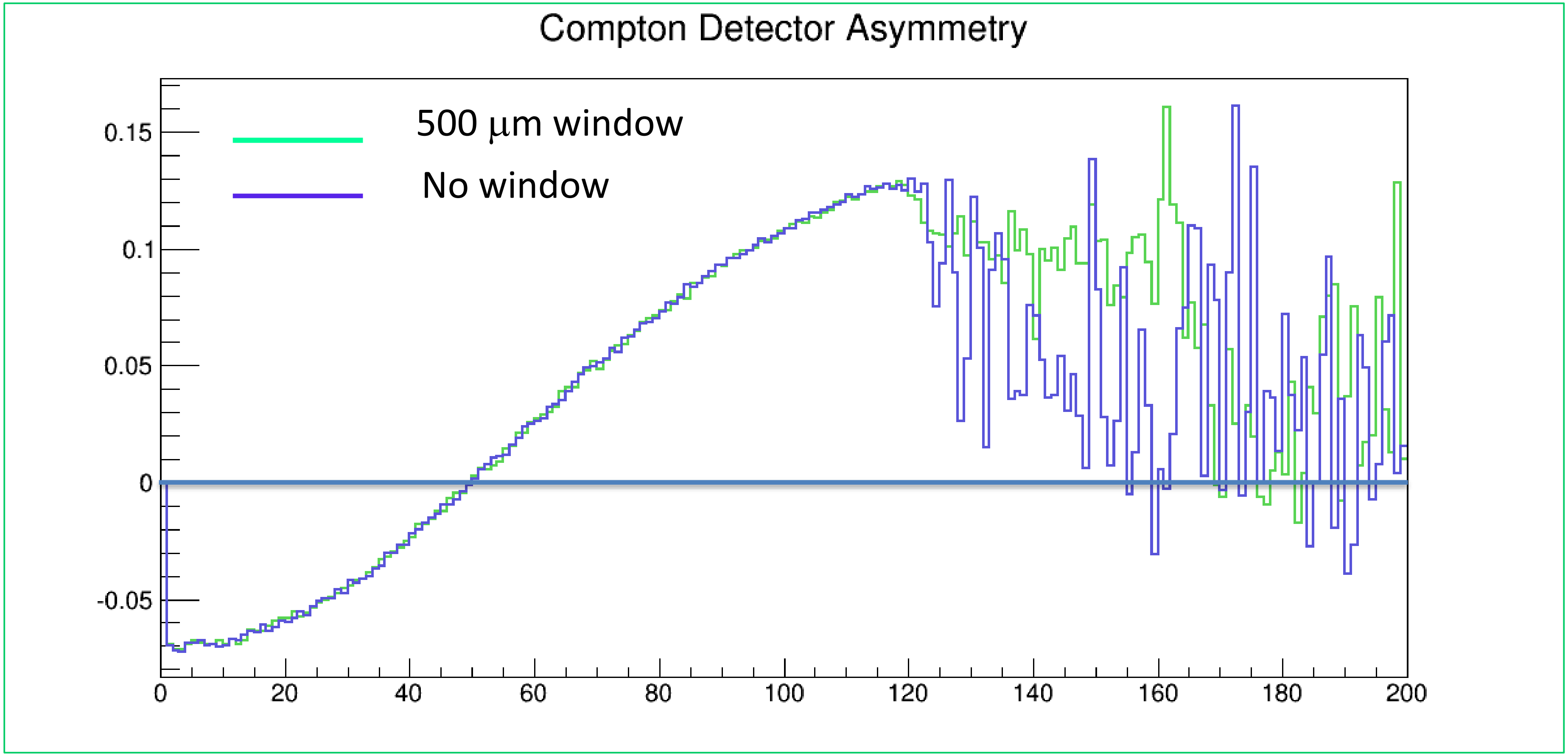
Precision Electron-Beam Polarimetry at 1 GeV Using Diamond Microstrip Detectors

A. Narayan et al.

Phys. Rev X6 (2016) no.1,011013

http://arxiv.org/abs/arXiv:1509.06642

Compton asymmetry with window



- Asymmetry with and without 500μm stainless steel window in front of detector

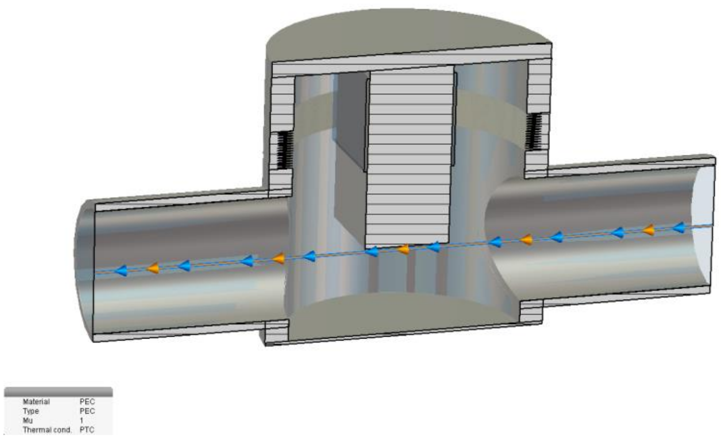
Compton asymmetry with window

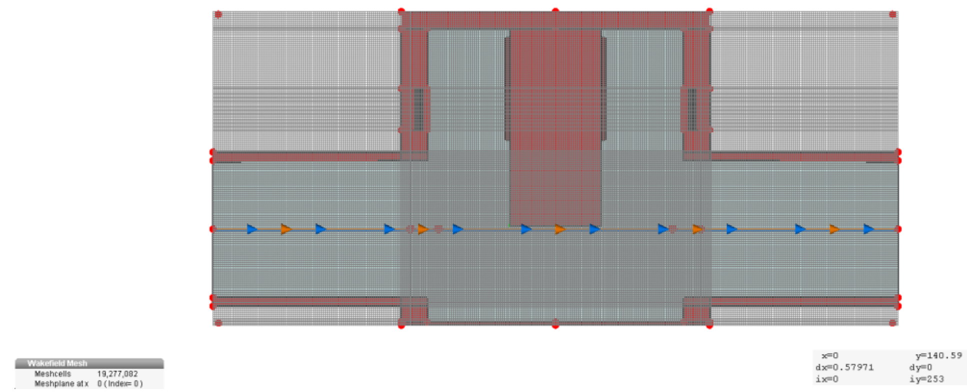
	Polarization	Compton Edge	χ^2/NDF
No Window	84.90 ± 0.39	118.24 ± 0.18	1.74
Window	84.40 ± 0.40	118.36 ± 0.28	2.48

- Extracted polarization with and without window
- Need to study systematics with high statistics to evaluate best accuracy possible
- more realistic geometry
- iterate with Wakefield studies
- Number consistent at 0.5 % level : Roman Pot option promising for polarimetry

Wakefield and impedance studies

CST Roman pot model by Nicola Minafra

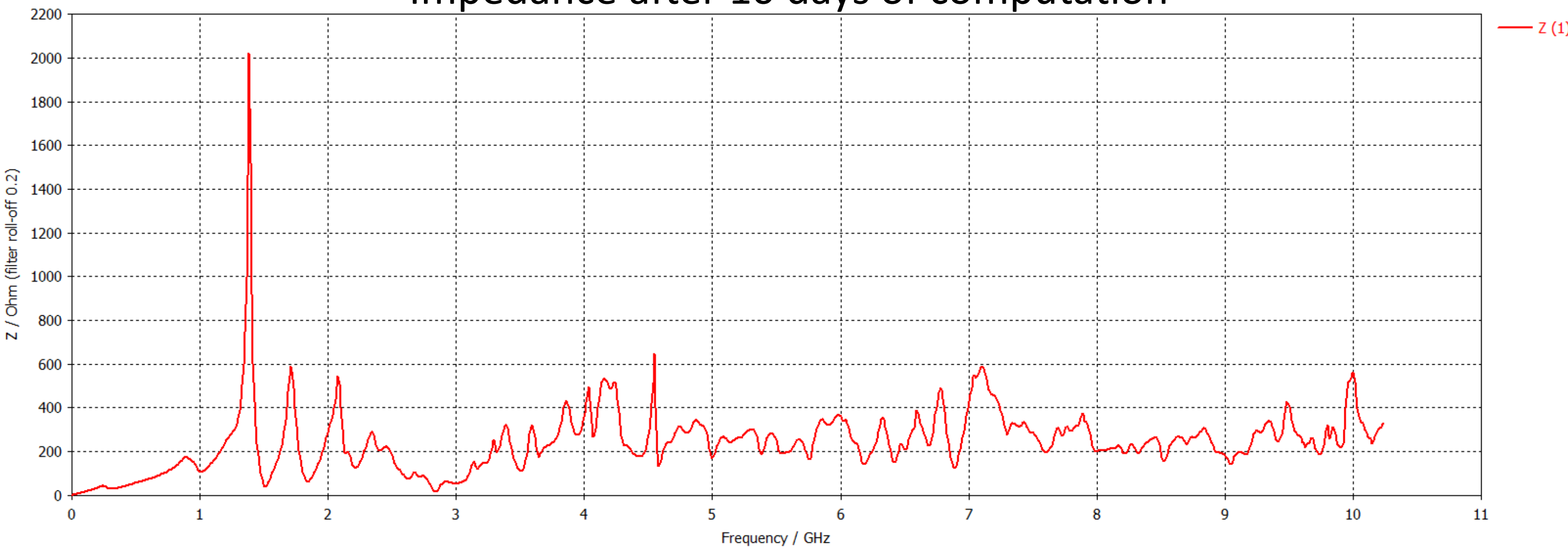




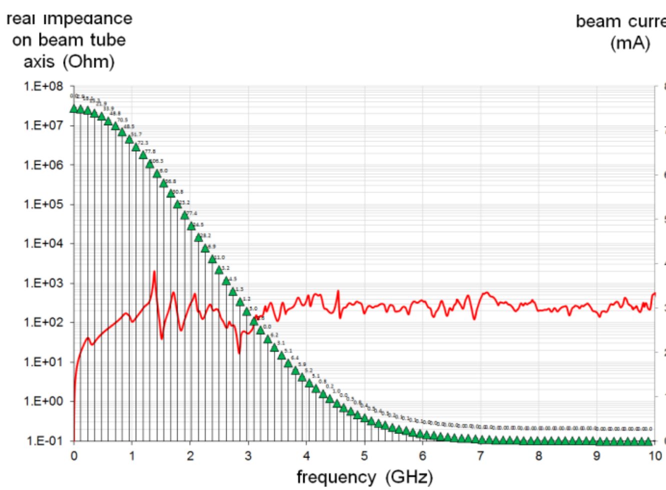
- beam couples to all elements from the beamline
- need to determine if each element disturbs the beam
- need to determine how much power is deposited by the beam in each elements (can be significant at high current)
- modelling of elements in CST particle studio

Wakefield progress

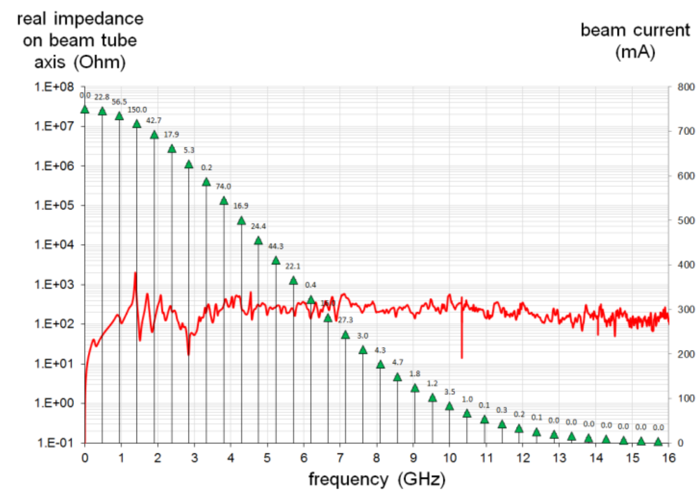
Impedance after 10 days of computation



Beam at 119 MHz High energy setting up to 0.75A

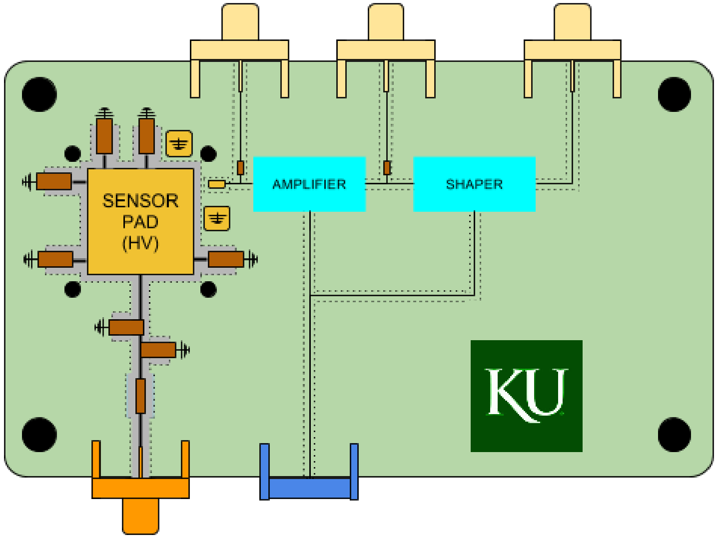


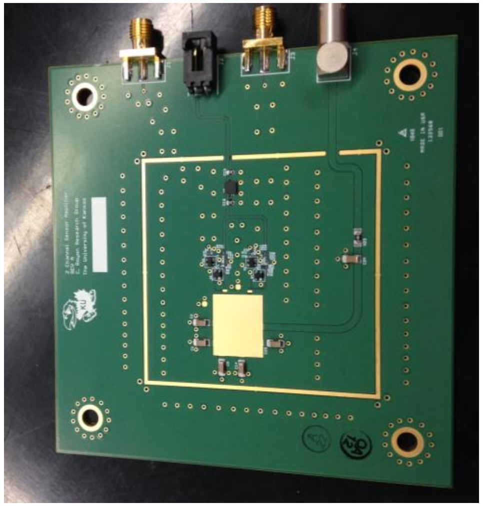
Beam at 476 MHz Low and medium energy setting up to 3 A

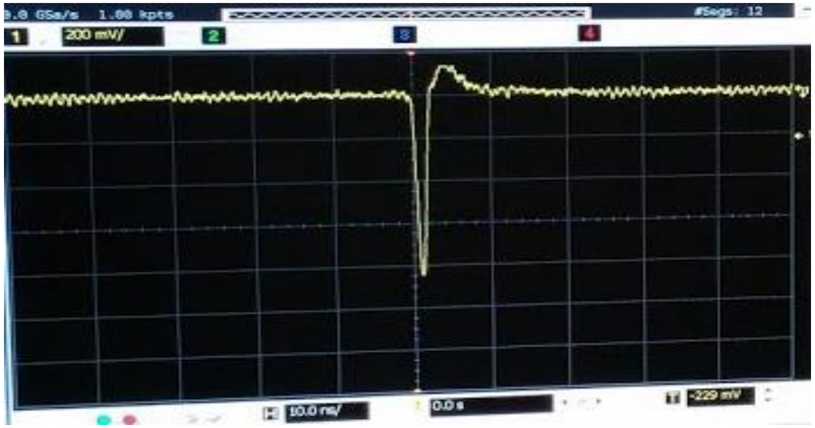


Around 2160 W at 3A at low and medium energy and 540 W at 0.75 A for high energy

Test during visit at KU



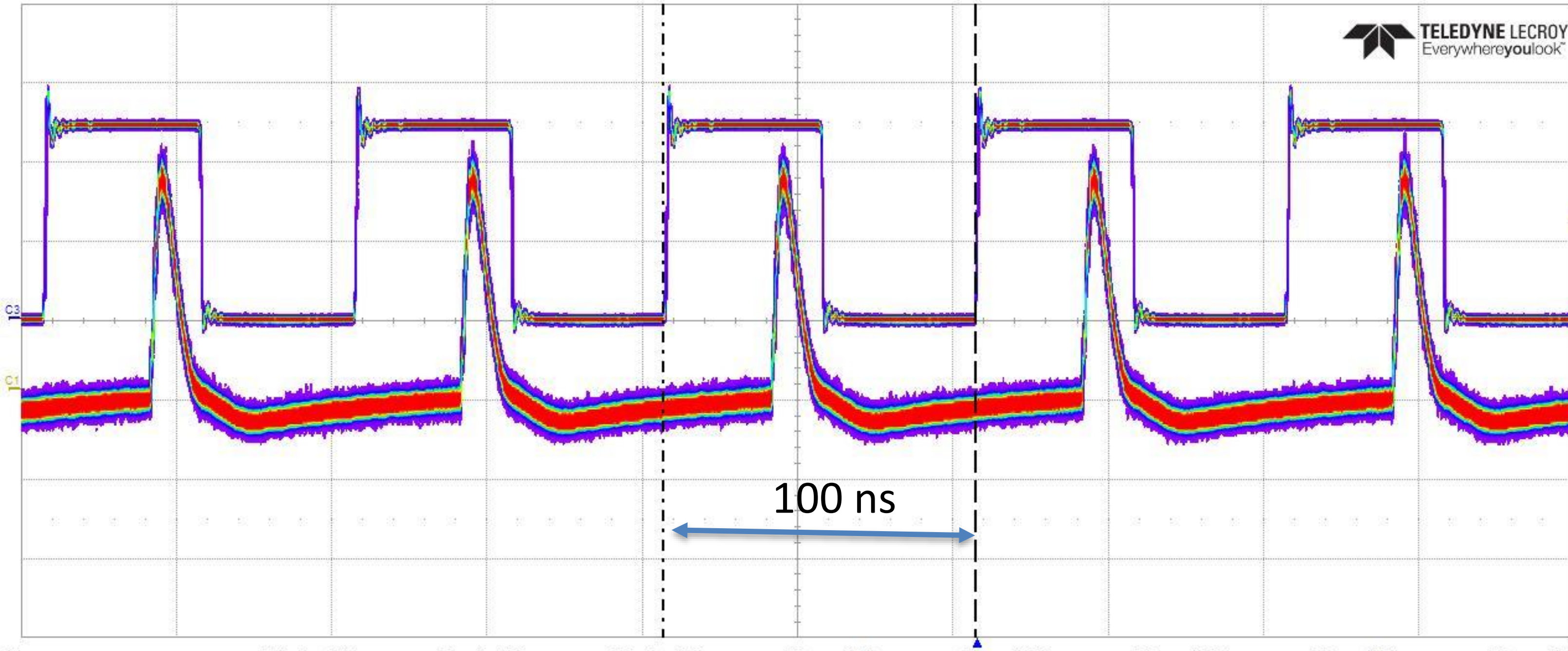


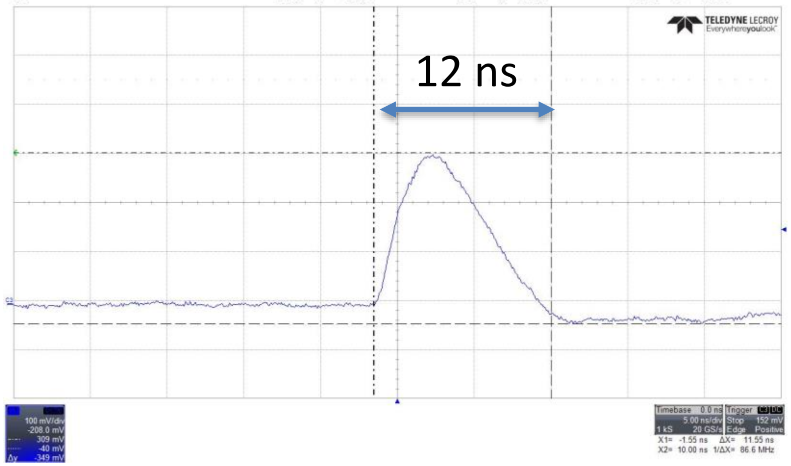


10 ns

- Kansas University single channel amplifier design
- Tested with MCP PMT
- Serve as base for multichannel amplifier

Silicon pulsed with laser at 10 MHz





Amplifier with silicon detector fast enough to separate successive sources for eRHIC Linac Ring at 10 MHz

(New proposal for up to 476 MHz)

Proposal for FY2018

Simulation: Study of systematics

- Simulation work by current postdoc Joshua Hoskins (University of Manitoba) at 50 %
- Take advantage of farm setup and fitting to start to study systematics
  - More realistic design for chamber (simple plate for now)
  - Systematic studies for different energies
  - Optimize granularity and channel count
  - Study of beam induced background
  - Radiation dose including beam induced background
  - Iteration with Wakefield optimization
- Final report, paper and documentation

Beam induced background

- Outgassing from beamline due to Wakefield and Synchrotron radiation

(evaluate outgassing and pumping)

- Possible neutron production from Synchrotron (add surrounding walls) that could add to detector and electronics dose

Main Parameters eRHIC ring-ring for Maximum Luminosity

		No Hadron Cooling		Strong Hadron Cooling	
Parameter	**Units**	**Protons**	**Electrons**	**Protons**	**Electrons**
Center of Mass Energy	GeV	100		100	
Beam Energy	GeV	275	10	275	10
Particles/bunch	10^{10}	11.6	31	5.6	15.1
Beam Current	mA	456	1253	920	2480
Number of Bunches		330		1320	
Hor. Emittance	nm	17.6	24.4	8.3	24.4
Vertical Emittance	nm	6.76	3.5	3.1	1.7
β_{x*}	cm	94	62	47	16
β_y^*	cm	4.2	7.3	2.1	3.7
$\sigma_x'^*$	mrad	0.137	0.2	0.13	0.39
$\sigma_y'^*$	mrad	0.401	0.22	0.38	0.21
Beam-Beam ξ_x		0.014	0.084	0.012	0.047
Beam-Beam ξ_y		0.0048	0.075	0.0043	0.084
τ_{IBS} long/hor	hours	10/8	-	4.4/2.0	-
Synchr. Rad Power	MW	-	6.5	-	10
Bunch Length	cm	7	0.3	3.5	0.3
Luminosity	$10^{34}cm^{-2}s^{-1}$	0.29		1.21	

E_p = 275 GeV

E_e= 10 GeV

New eRHIC ring ring design : beam interaction frequency going from initial RHIC 10 MHz to 30 MHz with 330 bunches and 100 MHz with 1320 bunches in a 3.8 km ring

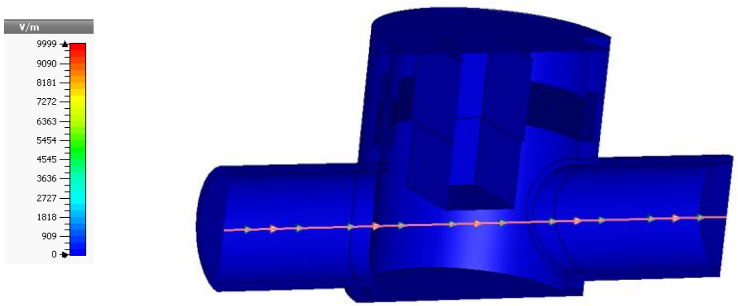
JLEIC Baseline New Parameters

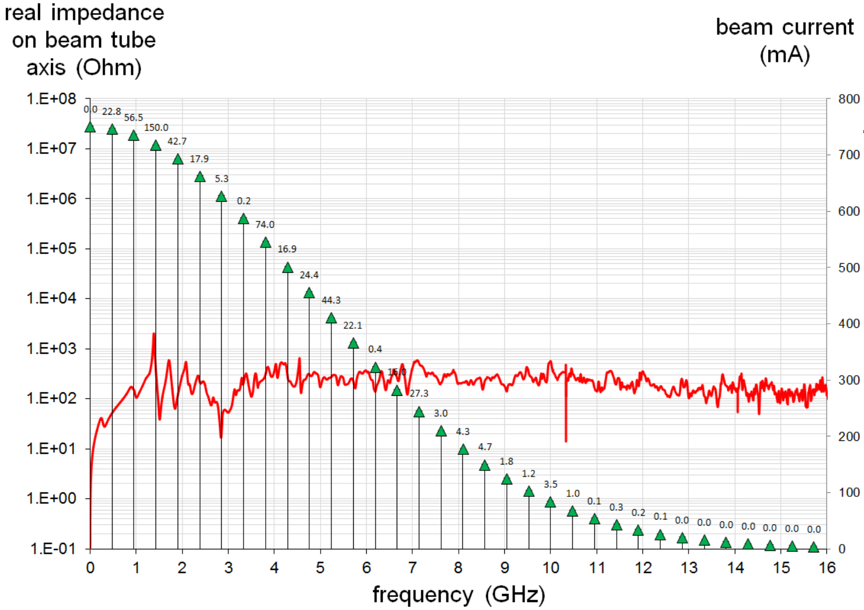
CM energy	GeV	21.9 (low)		44.7 (medium)		63.3 (high)	
		p	e	p	e	p	e
Beam energy	GeV	40	3	100	5	100	10
Collision frequency	MHz	476		476		476/4=119	
Particles per bunch	10^{10}	0.98	3.7	0.98	3.7	3.9	3.7
Beam current	A	0.75	2.8	0.75	2.8	0.75	0.71
Polarization	%	80	80	80	80	80	75
Bunch length, RMS	cm	3	1	1	1	2.2	1
Norm. emitt., hor./vert.	μm	0.3/0.3	24/24	0.5/0.1	54/10.8	0.9/0.18	432/86.4
Horizontal & vertical β*	cm	8/8	13.5/13.5	6/1.2	5.1/1	10.5/2.1	4/0.8
Vert. beam-beam param.		0.015	0.092	0.015	0.068	0.008	0.034
Laslett tune-shift		0.06	7×10^{-4}	0.055	6×10^{-4}	0.056	7×10^{-5}
Detector space, up/down	m	3.6/7	3.2/3	3.6/7	3.2/3	3.6/7	3.2/3
Hourglass(HG) reduction		1		0.87		0.75	
Luminosity/IP, w/HG, 10^{33}	$cm^{-2}s^{-1}$	2.5		21.4		5.9	

Ring circumference : 2.4 km

Max number of bunches :3416
Number of bunches : 1540 * 2 two macrobunches with 2.1 ns spacing between electron bunches

RP Impedance optimization





With a bunch length of ~100 ps, the power spectrum of the beam has a non negligible contribution up to ~ 10 GHz.

This means:

- Details as small as $\frac{c}{10\ \mathrm{GHz}} \sim 3\ \mathrm{cm}$ have to be considered:

  very fine mesh is required:

  lot of computing power required!

- cut-off frequency for a cilindrical pipe of diameter *8* cm

  $f_c \sim \frac{1.84\, c}{\pi\ 8\ \mathrm{cm}} \sim 2.2\ \mathrm{GHz} \ll 10\ \mathrm{GHz}$:

- different cavities are not decoupled by the beam pipe : interaction with other equipment has to be considered in simulations

  - check stability with mesh
  - geometry optimization
  - beam pipe optimization
  - study of crosstalk

Manpower 2018

Individual	Institution	Percentage in %	Task
Alexandre Camsonne	Jefferson Lab	20	Wakefield, general, postdoc supervision
David Gaskell	Jefferson Lab	5	Geant3, laser system, postdoc supervision
Joshua Hoskins	U. Manitoba	50	GEMC full simulation
Christophe Royon	Kansas U.	5	Detector, electronics, Wakefield
Nicola Minafra	Kansas U.	15	Wakefield
Michael Murray	Kansas U.	5	Detector, electronics, Wakefield

FY2018 Budget

	K$ direct	Total Cost With overhead K$	Cumulative	Task
Post doc	35	54.075	54.075	Simulation
Travel	15	23.175	77.25	
Minafra	12	18.54	95.79	Wakefield
CST license	7	10.815	106.605	Wakefield
Total	69	106.605		

Budget profiles

Budget	Amount	Deliverable
Full	106.605	Simulation , Wakefield
-20 %	85.284	Simulation, partial Wakefield
-40 %	63.963	Simulation only

	Simulation	Wakefield	Travel	Sum
University of Manitoba	54.075	0	0	54.075
Kansas University	0	18.54	0	18.54
Jefferson Laboratory	0	10.8	23.2	34
Sum	54.075	29.34	23.2	

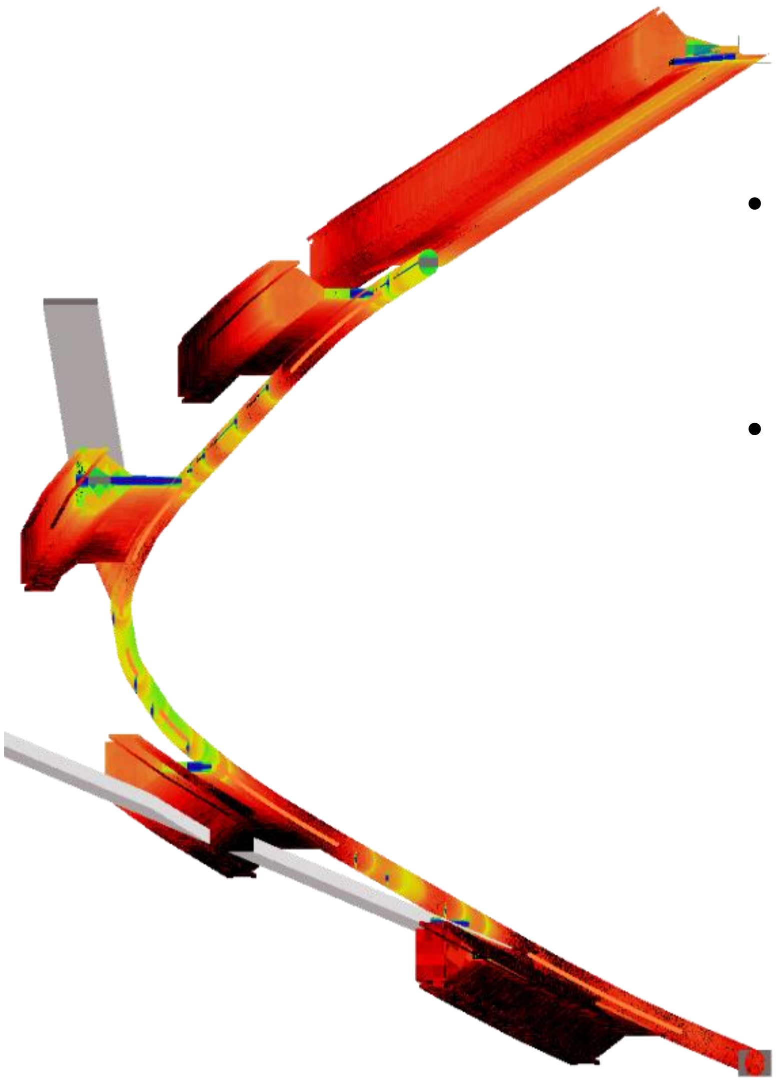
Conclusions

- Full simulation running on farm : high statistics with full setup available
- Realistic polarization extraction program complete
- Effect of thin window negligible at 1 % level
- More accurate Wakefield give 2.2 kW
- KU electronics can handle 10 MHz eRHIC beam structure

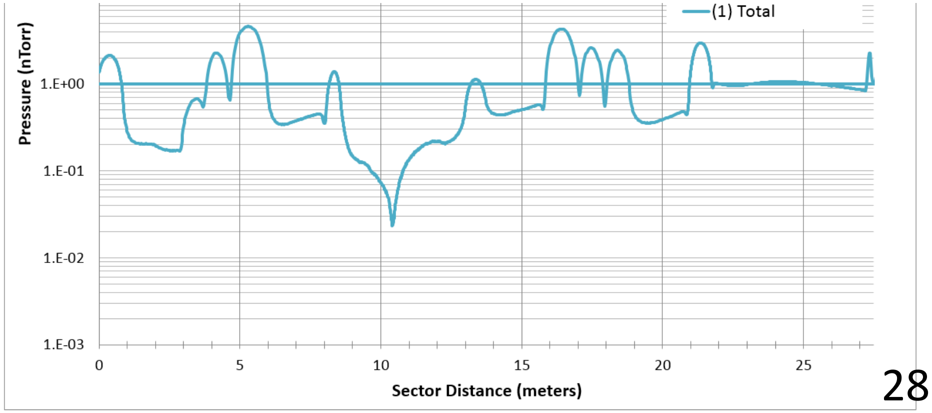
- Next proposal :
  - Complete simulation
    - More realistic geometry of Roman Pot
    - Polarization study with window thickness
    - Systematic study with strip size
    - Systematic study for different beam energies
    - Beam induced background
    - Dose from beam induced background
  - Wakefield
    - Optimization of geometry and more realistic model
    - Study stability of result with mesh size
    - Study of crosstalk with other beamline elements

Backup

Modeling available for both static vacuum and Photon Stimulated Desorption

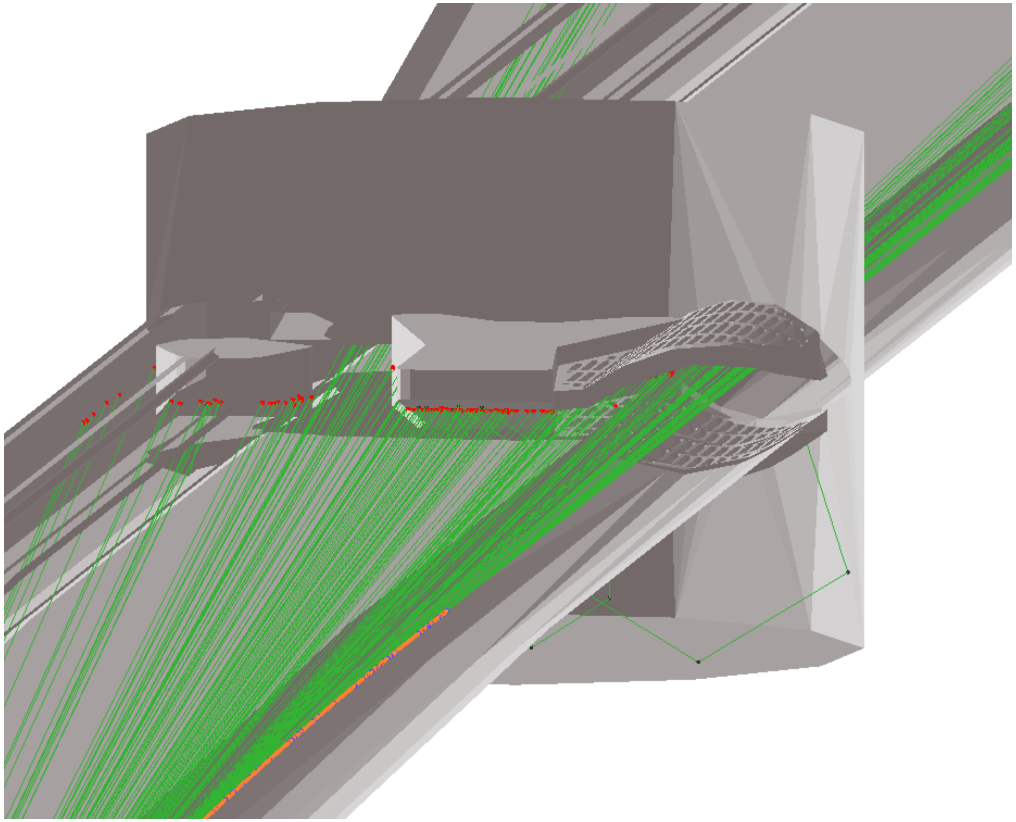


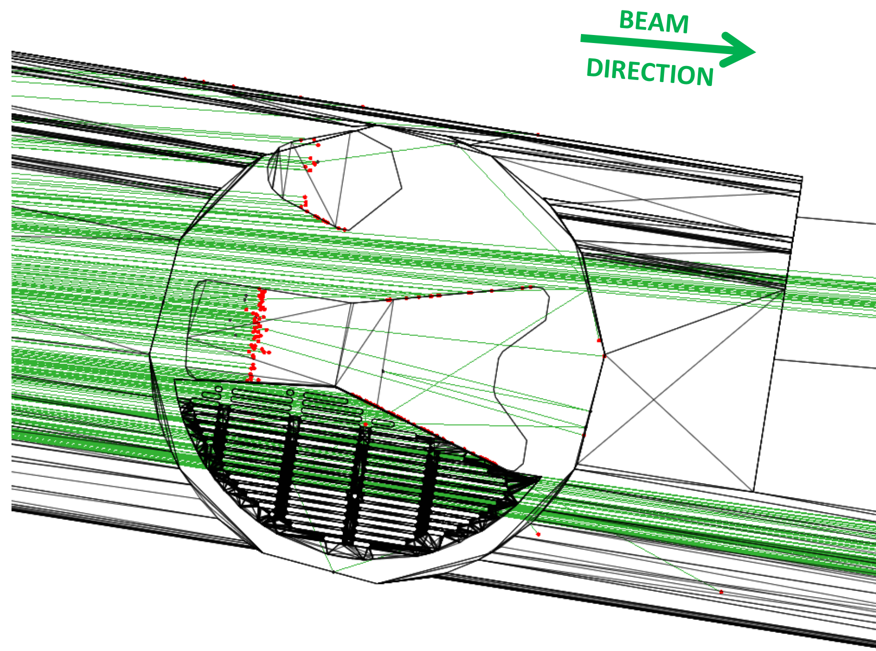
- Molflow+ and Synrad modeling software developed by Roberto Kersevan
- Jason Carter, ANL, used Molflow+/Synrad to model static and dynamic vacuum for APS upgrade
- CAD designs of beamline are combined with pumping speeds and outgassing rates of elements yield expected pressure



How SynRad works

- Magnetic elements generate synchrotron rays within 3D space





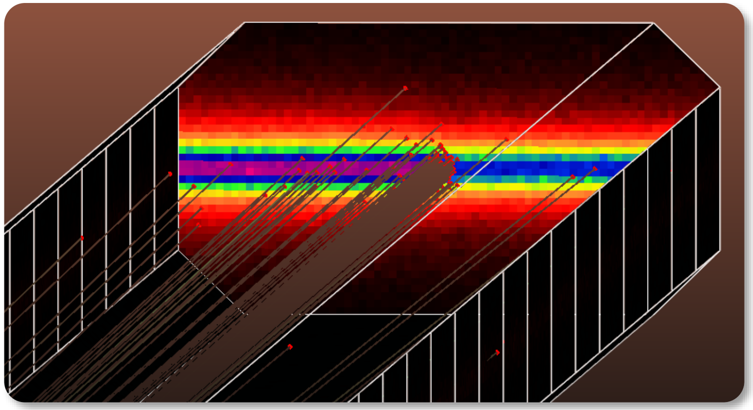
Magnetic elements in orange, program generated synchrotron fan in green, surface hit points in red

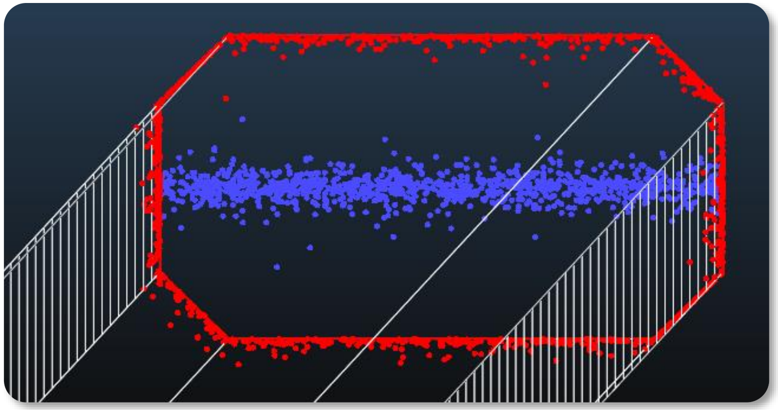
APS-U storage ring vacuum system design using SynRad/MolFlow+ with photon scattering

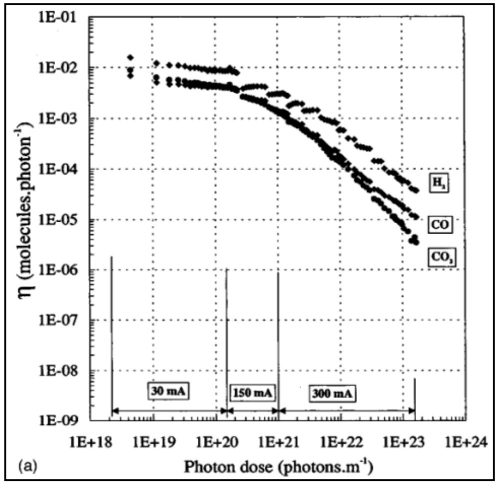
Jason Carter, AVS 2015 presentation

Coupled simulations

- Coupling feature translates SynRad flux density rates (photons/cm^2/s) to photon stimulated desorption, PSD, outgassing (mbar*L/cm^2/s)
- Translations based on conditioning time and PSD yield measurements for various vacuum materials



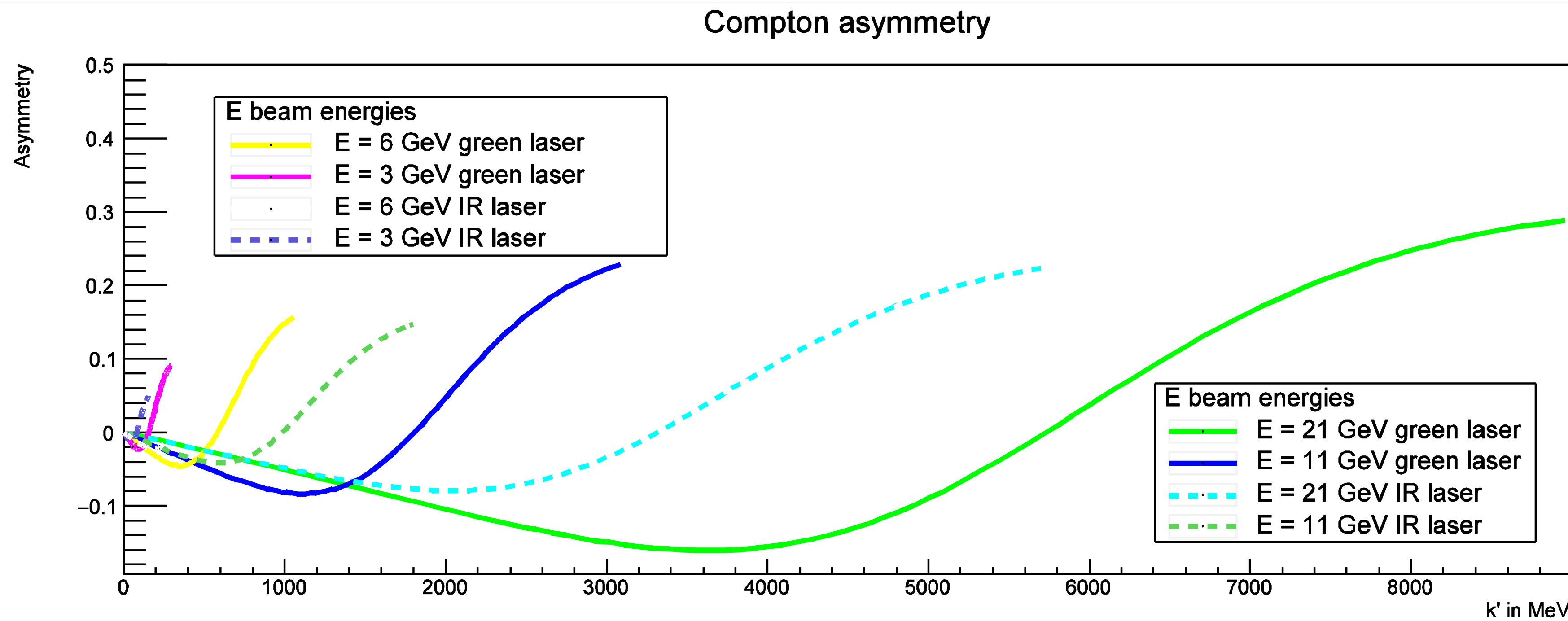




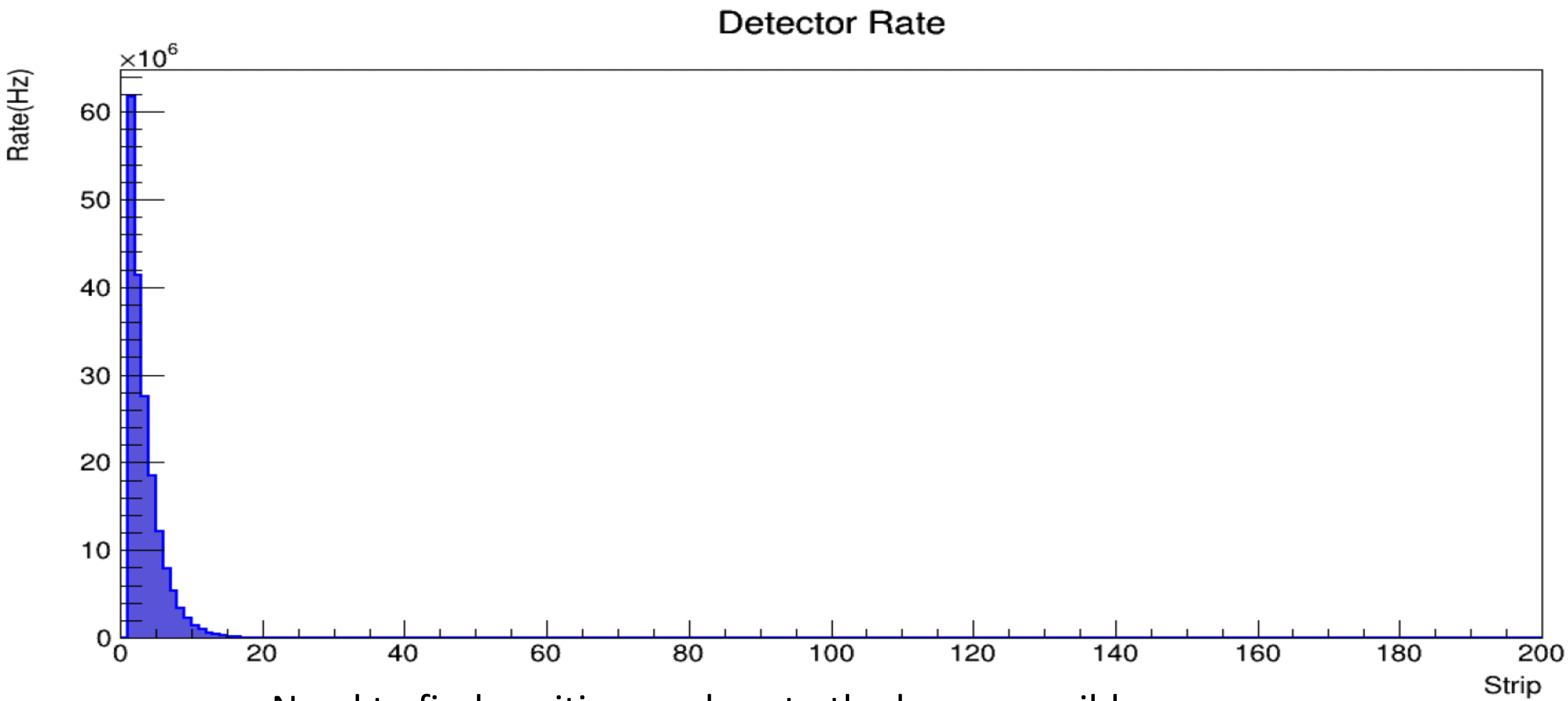
Compton asymmetry

σ(e + γ → e′ + γ′) ≠ σ(e + γ → e′ + γ′)

$$\frac{N^{+}-N^{-}}{N^{+}+N^{-}}\left(E_e, k_\gamma, k_{\gamma'}\right) = P_e * A(E_e, k_\gamma, k_{\gamma'})$$



Simulation halo direct hit in detector



- Need to find position as close to the beam possible
- Make sure zero crossing of the asymmetry is inside of the detector
- Position of the Compton edge and zero crossing highly dependent on beam energy
- Need to run for all different energies (only studied 5 GeV)