

# Parity Quality Beam (PQB) Working Group Report

OPS StayTreat

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# Upcoming Parity Violation Experiments

Experiment	Energy (GeV)	Pol (%)	I ( $\mu\text{A}$ )	Target	$A_{\text{pv}}$ (ppb)	Maximum Charge Asym (ppb)	Maximum Position Diff (nm)	Maximum Angle Diff (nrad)	Maximum Size Diff ( $\delta\sigma/\sigma$ )
<b>QWeak (Achieved)</b>	1.155	89.0	180	$^1\text{H}$ (35 cm)	$281\pm 46$	$8\pm 15$	$5\pm 1$	$0.1\pm 0.02$	$10^{-4}$
<b>PREx-II</b>	1.0	90	70	$^{208}\text{Pb}$ (0.5mm)	$500\pm 15$	$100\pm 10$	$1\pm 1$	$0.3\pm 0.1$	$10^{-4}$
<b>C-REx</b>	2.2	90	150	$^{48}\text{Ca}$ (5mm)	$2000\pm 42$	$100\pm 10$	$1\pm 1$	$0.3\pm 0.1$	$10^{-4}$
<b>MOLLER</b>	11.0	90	60	$^1\text{H}$ (150 cm)	$35.6\pm 0.74$	$10\pm 10$	$0.5\pm 0.5$	$0.05\pm 0.05$	$10^{-4}$

- PREx-II is tentatively scheduled for Hall A in Fall 2016
- C-REx is tentatively scheduled for Hall A in Spring 2017
- MOLLER is planned for Hall A in 2022

# Issues from QWeak

1. Beam Halo: there was beam halo that could develop a large helicity-correlated charge asymmetry

Beam halo charge asymmetry was found to depend on:

- Beam loss at Injector Apertures
- Laser phase
- Machine tuning

What can we do to help?

2. BCM Resolution is not suitable for MOLLER:
  - QWeak achieved 65 ppm but MOLLER requires 10 ppm
  - BCM digital receiver bench studies found that local oscillator phase and amplitude noise being responsible for 65 ppm noise floor
  - Try new digital receivers
  - Improve phase/amplitude noise of local oscillator

# Hall A 2015/2016 Beamline Plan for PQB

1. Install QWeak halo monitor in Hall A beamline
2. Equip two BCMs with new-style digital receivers
3. Install QQQ cavity triplet in Hall A beamline
4. Reinstate Hall A beam modulation system (air-core coils and associated control/drive electronics)
  - Beam modulation and accelerator Fast Feedback: is there a need to pause FFB when modulation is ON? does FFB implement a digital notch filter to attenuate modulation frequency (QWeak: 125 Hz for 20 s every 320 s) while passing all other frequencies?
  - Need software support

To be ready for  
beam studies  
this Fall

# Synchrotron Radiation @ 11 GeV

- Total synchrotron radiation (SR) power (integrated over solid angle) :

$$P = \frac{2}{3} \frac{e^2 \gamma^4 c}{\rho^2} + P_{pol}$$

Energy gain per  
Linac is 1090 MeV

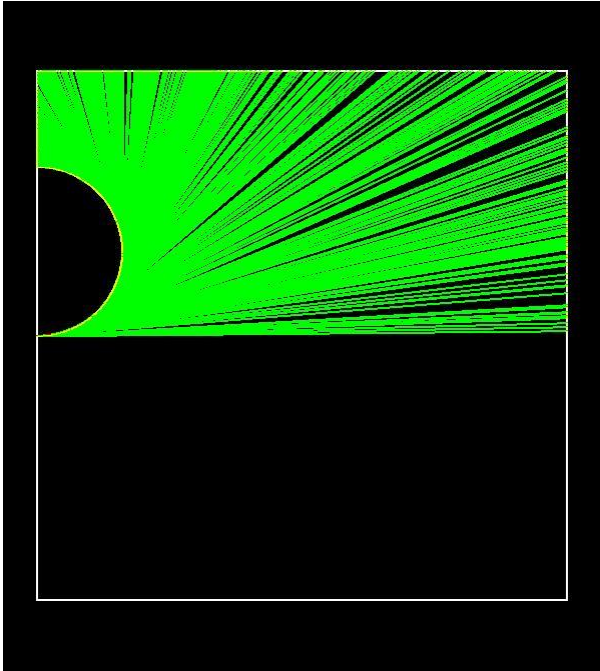
Area	Energy Loss (MeV)
Arc 1	0.019
Arc 2	0.122
Arc 3	0.576
Arc 4	0.878
Arc 5	2.095
Arc 6	2.851
Arc 7	5.220
Arc 8	8.818
Arc 9	14.000
Hall A Arc	3.070

- Energy loss per electron per Arc :

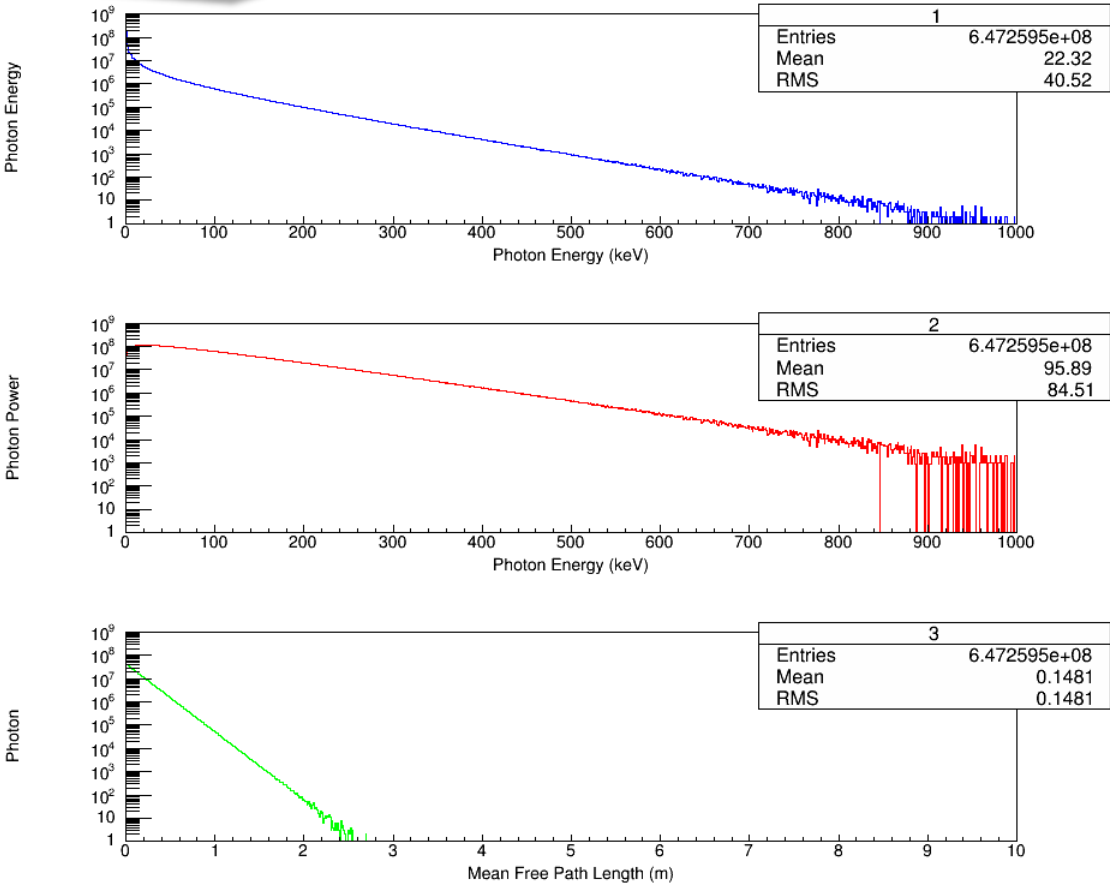
$$\delta E [\text{MeV}] = 0.04423 E^4 [\text{GeV}] / \rho [\text{m}]$$

# Simple GEANT4 Model:

- $10^6$  electrons at 10 GeV, Arc 9:  $\rho=30.6$  m
- Average of  $n=647$  photons per electron, each  $\langle \epsilon \rangle = 22.32$  keV



$$\frac{\Delta E}{E} = \frac{\sqrt{n} \langle \epsilon \rangle}{E} = 5.7 \times 10^{-5}$$



- Energy spread due to SR in Arc 9
- No tails since number of photons per electron per Arc is large ( $n \sim 65 E$  [GeV])

# Transverse Geometric Emittance and Energy Spread:

Area	$\delta p/p$ ( $10^{-3}$ )	$\epsilon_x$ (nm)	$\epsilon_y$ (nm)
Chicane	0.5	4.00	4.00
Arc 1	0.05	0.41	0.41
Arc 2	0.03	0.26	0.23
Arc 3	0.035	0.22	0.21
Arc 4	0.044	0.21	0.24
Arc 5	0.060	0.33	0.25
Arc 6	0.090	0.58	0.31
Arc 7	0.104	0.79	0.44
Arc 8	0.133	1.21	0.57
Arc 9	0.167	2.09	0.64
Arc 10	0.194	2.97	0.95
Hall D	0.18	2.70	1.03

$$\epsilon_n = \beta\gamma\epsilon_g$$



Damping



Synchrotron Radiation

Energy spread in Hall A is  $\sim 2 \times 10^{-4}$

Values are calculated at start of each Arc

# What are the issues? Any polarization dependencies?

- Yes to implement an ELEGANT model to calculate spin precision with SR included – standard 6 GeV formula will not work
- Adiabatic Damping: orbit divergence still gets damped by square root of ratio of energies
- Polarization Dependencies:
  - I. Total SR power depends on transverse polarization,  $P_{pol}/P_{unpol} \sim 10^{-4}$
  - II. Spin-flip SR (Sokolov–Ternov self-polarization effect) of about

$$\delta_{pol} = \frac{\tau_{JLab}}{\tau_{ST}} = \frac{20\mu s}{113s} \sim 10^{-7}$$

Both cancel with helicity reversal

- III. Total SR power for longitudinal polarized electrons is spin independent but power radiated into space above and below orbital plane is different and thus spin dependent ( $A \sim 10^{-5}$ ) – principle of Spin-Light Polarimeter

➤ Helicity-correlated SR → Helicity-correlated emittance growth



# Beam Studies:

- Measure helicity-correlated beam properties in Hall A:
  - Energy difference at 1C12 in middle of Hall A Arc
  - Position and angle differences
  - Charge asymmetry
- Measure beam halo
  - Measure at 1 GeV and confirm QWeak results
  - Measure at 11 GeV to study SR effects

# **TASKS SUMMARY**

# Laser Table Tasks

Task	Sub Tasks	Date	Description
<b>2 kHz Helicity Reversal</b>		MOLLER	Requires 10 $\mu$ s settle time – No ringing (not required for PREX, but hoped to test at this time). No Kerr Cell.
	RTP Pockels Cell		Buy test crystals to characterize, design RTP quarter-wave system.
	KD*P re-design		Model E-field to maximize PC uniformity, buy a properly engineered, one with the correct cell-diameter-to-laser-beam-diameter aspect ratio
<b>Pockels Cell Stewart Platform</b>		2016	For remote optimization using e-beam. Assemble, build control software, qualify

# Injector Tasks

Task	Sub Tasks	Date	Description
Reinstate Injector Parity DAQ			
Improve 2-Wien Flip Optics		PREx-II	
Injector Matching		PREx-II	Maximize damping
Helicity-correlated Beam Size Monitor		PREx-II	Looking for ideas!
Upgrade Helicity Magnet controls		PREx-II	
Locate Helicity Magnets to span $(x,x')$ and $(y,y')$ to minimize both position and angle		Fall 2015	
Augment helicity steering dipoles with helicity size quads		PREx-II	
Share Injector apertures' current read-back with parity DAQ		Fall 2015	
MOLLER Feedback to minimize transverse polarization			Once a shift, adjust Wien angle

# Accelerator Tasks

Task	Sub Tasks	Date	Description
<b>Study Depolarization at Higher Passes</b>			
	Energy stability and precession to Hall		
<b>Synchrotron Radiation</b>		MOLLER	
	Spin precession		
	Adiabatic damping		
	Polarization dependence		
	Helicity-correlated emittance growth		
<b>MOLLER (<math>g-2</math>) Spin Flip</b>			Change beam energy by 100 MeV (few reversals)

# Hall A Tasks

Task	Sub Tasks	Date	Description
<b>Reinstate Hall A Parity DAQ</b>			
<b>Beam Halo</b>			
	Install QWeak halo monitors in Hall A	Fall 2015	
<b>BCM Resolution</b>			
	New cavities and receivers	Fall 2015	
	BCM receiver bench studies and beam studies	Fall 2015	
<b>Beam Modulation</b>		Fall 2015	
<b>Beam Polarimetry</b>			
<b>Spin Dance</b>			
<b>Beam Matching and Optics</b>			
<b>Phase Trombone</b>			