Parity Quality Beam (PQB) Working Group Report

OPS StayTreat

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Upcoming Parity Violation Experiments

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

- PREx-II is tentatively scheduled for Hall A in 2017
- C-REx is tentatively scheduled for Hall A in 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

   <u>What can we do to help?</u>

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 is a likely cause of 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)

To be ready for beam studies this Fall

- Beam modulation and accelerator Fast Feedback: Hall needs to pause FFB when modulation is ON – FFB does not 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

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

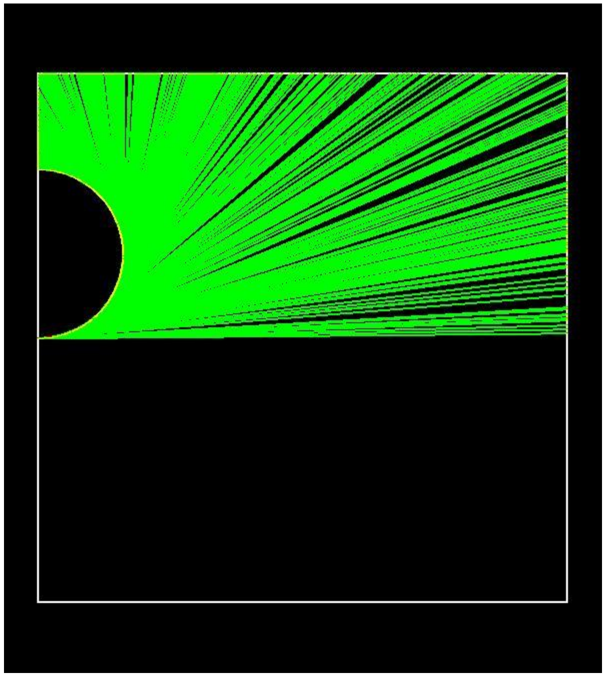
- Energy loss per electron per Arc:

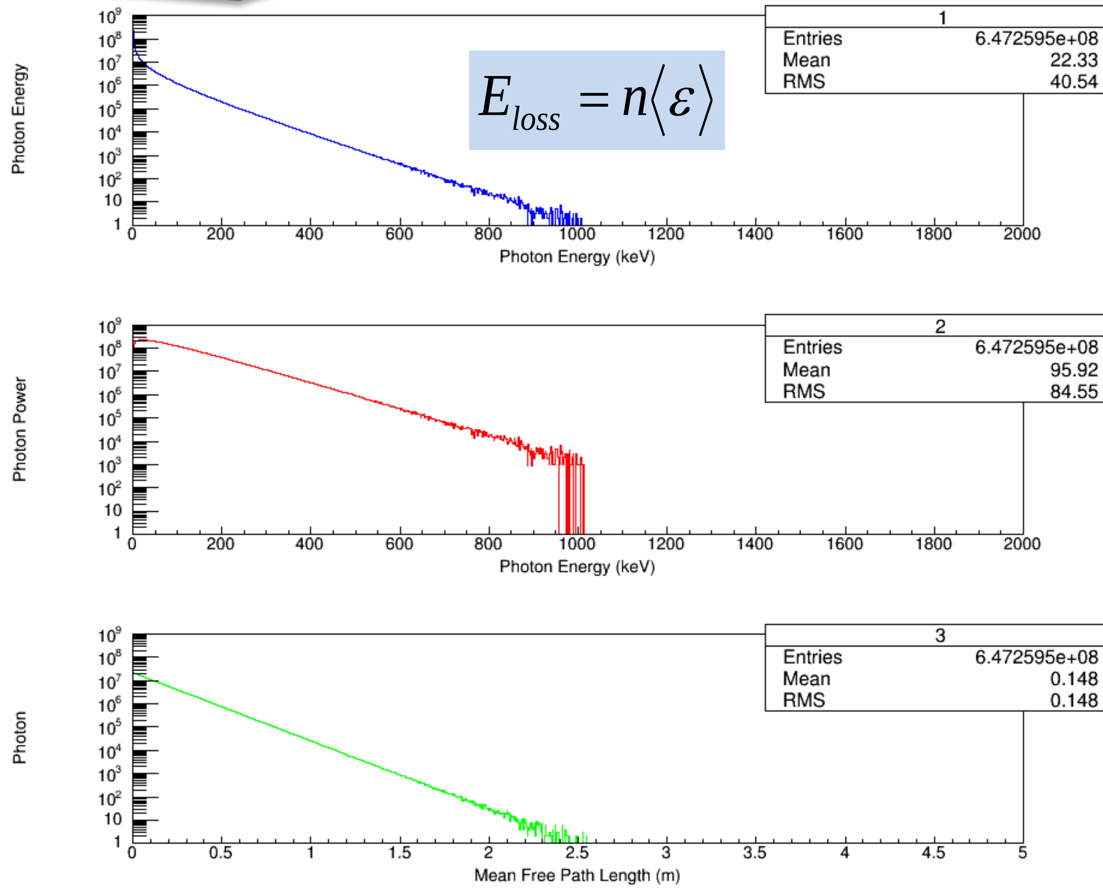
  E_{loss} [MeV] = 0.04423 E^4 [GeV] / ρ[m]

Area	ρ (m)	Energy Loss (MeV)
Arc 1	5.09	0.019
Arc 2	10.2	0.122
Arc 3	10.2	0.576
Arc 4	20.4	0.878
Arc 5	20.4	2.095
Arc 6	30.6	2.851
Arc 7	30.6	5.220
Arc 8	30.6	8.818
Arc 9	30.6	14.000
Hall A Arc	40.1	3.070
Total		38 MeV

Simple GEANT4 Model:

- 10^6 electrons at 10 GeV, Arc 9: ρ=30.6 m
- Average of n=647 photons per electron, each ⟨ε⟩=22.33 keV





$$E_{loss} = n\langle \varepsilon \rangle$$

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

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

Transverse Geometric Emittance and Energy Spread:

Provided by Yves

$$\varepsilon_n = \beta\gamma\varepsilon_g$$

Area	Δp/p (10^{-3})	$\varepsilon_{g,x}$ (nm)	$\varepsilon_{g,y}$ (nm)
Inj 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

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?

- Yves to implement an ELEGANT model to calculate spin precision with SR included – standard 6 GeV formula will not work
- Adiabatic Damping: amplitude of betatron oscillations (e.g., helicity-correlated position and angle differences etc.) is still damped by square root of ratio of momenta
- 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
2 kHz Helicity Reversal		MOLLER	Requires 10 μs settle time – No ringing (not required for PREX-II, 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 Pockels Cell uniformity, buy a properly engineered, one with the correct cell-diameter-to-laser-beam-diameter aspect ratio
Pockels Cell Stewart Platform		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
Study Depolarization at Higher Passes			
	Energy stability and precession to Hall		
Synchrotron Radiation		MOLLER	
	Spin precession		
	Adiabatic damping		
	Polarization dependence		
	Helicity-correlated emittance growth		
MOLLER (*g*-2) Spin Flip			Change beam energy by 100 MeV (few reversals)

Hall A Tasks

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