Upgrade of Hall A Møller Polarimeter

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Møller Polarimeter in Hall A

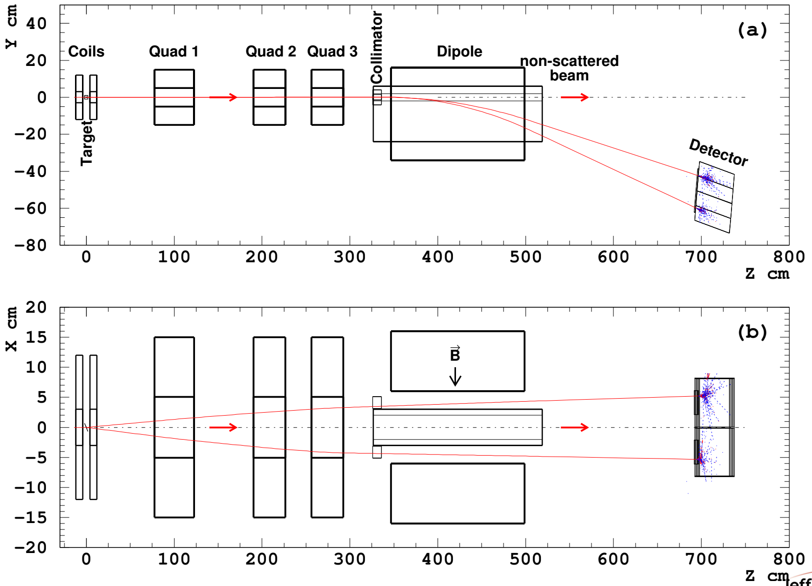
Traditional polarized electron target

- Longitudinally polarized ferromagnetic foils 7-30 μm thick
- Relatively low magnetic field $B \sim 250$ Gs
- Foils tilted at 20° to the beam

Spectrometer

- Quads and a dipole - minimization of $\theta - p$ correlation $\Rightarrow$ small Levchuk effect $< 1\%$
- Used at 0.6 - 6 GeV
- Acceptance $75^\circ < \theta_{CM} < 105^\circ$, $-10^\circ < \phi_{CM} < 10^\circ$
- Single arm rate at 0.5 μA $\sim$0.5 MHz

Møller Spectrometer



Systematic Errors

The goal for the systematic error

Variable	Error		
	OLD	Present	PREX goal
Target polarization	3.5%	2.0%	0.5%
Target angle	0.5%	0.5%	0.0%
Analyzing power	0.3%	0.3%	0.3%
Levchuk effect	0.2%	0.2%	0.2%
Dead time	0.3%	0.3%	0.3%
Others	-	-	0.3%
Total	3.6%	2.1%	$\sim$1.0%

Specs for the upgrade

Physics purpose, driven by PREX

- Improve the systematic error $\sim$3% $\Rightarrow$ $\sim$1%
- Measurements at high beam currents 0.5μA $\Rightarrow$ 50μA

General Approach

- Hall C target clone (the claim $\sigma\mathcal{P}_{beam} \sim 0.5\%$ @ $\sim 3\ \mu$A)
- Round target foil $\sim 1\ \mu$m thick $\Rightarrow$ rate factor $\sim$0.03
- Target heating $\Rightarrow$ $\langle\mathcal{I}_{beam}\rangle < 3\mu$A $\Rightarrow$ duty cycle $<$0.06
- Fast raster 0.7×0.7 mm^2
- Instantaneous rate $\times 2.5$ $\Rightarrow$ detector/electronics upgrade

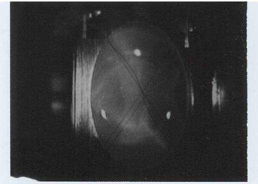
Ways to reduce the duty cycle

1. Hall C: fast motion of the beam on/off Moller foil with a kicker magnet
2. Change the micro-structure: similar to G0: use the "n"-th bunch only
3. Change macro-structure: similar to tune beam: 1 ms on / 30 ms off

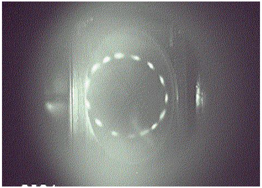
Bunch suppression

Options (from the draft of a paper by M.Poelker et al)

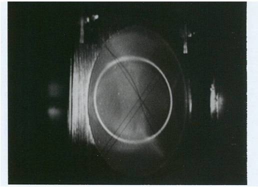
- G0: laser running at $499/16MHz$ - too long to install
- For regular bunch charges: laser at $\mathcal{F}_{laser} < \mathcal{F}_{RF}$ bunch suppresssion on the chopper.
  Beat frequency condition ($\mathcal{F}_{RF} = 499MHz$):
  $\mathcal{F}_{laser} \cdot (n+1) = \mathcal{F}_{RF} \cdot n$,
  $n = 3, 4, 7, 15, 31, ...$ - "magic" numbers



regular $\mathcal{F}_{laser} = \mathcal{F}_{RF}$



$n = 15$

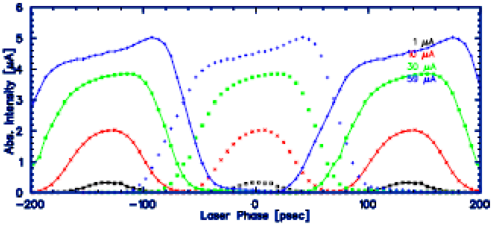


continuous

Beat frequency mode - leak through

Pulses overlap

- τ_{pulse} ~200 ps @50 μA
- τ_{pulse} grows with $\mathcal{I}_{beam}$ (electro-repulsion)
- Fully open slit 110 ps
- No leak: $\Delta\tau > 160$ ps



Optimization

- n=15 same slit $\Delta\tau = 133$ ps, contamination $\sim$ 5% - bad
- n=7 same slit $\Delta\tau = 285$ ps, no contamination; other slit $\Delta\tau = 95$ ps leak $\sim$ 30% - invasive for other halls
- n=4 other slit $\Delta\tau = 166$ ps non-invasive?

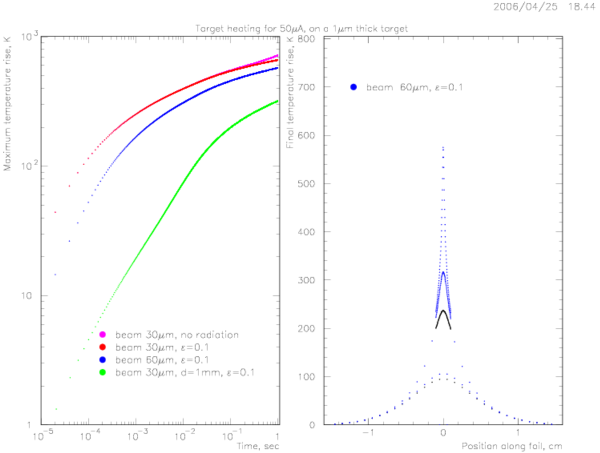
Macro-pulsing - tune beam

- Pulses $\Delta t > 4\ \mu$s at repetition rate $k \times 30$ Hz
- Limitation: at $\mathcal{I}_{inst} = 50\ \mu$A accelerator stabilization time $\sim 100\ \mu$s
- No micro-suppresssion: $\Delta t = 1$ ms at $k \times 30$ Hz
- Micro-suppresssion n=4: $\Delta t = 1$ ms at $k \times 120$ Hz

Target heating

Numerical solution

- Beam
- Conductivity
- Radiation



Target heating with the real raster

Average heating by 1.5 μA

- $\Delta T_{max} \sim$ 22 K no raster
- $\Delta T_{max} \sim$ 12 K raster 1 $\times$ 1 mm^2

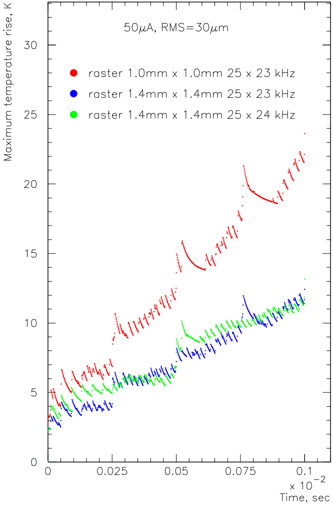
50 μA, $\sigma_X \sim$ 30 μm, $\Delta t = 1$ ms
Raster $\sim$ 1.4 $\times$ 1.4 mm^2, 25$\times$24 kHz

Results

- In pulse $\Delta T_{max} \sim$ 12 K
- Total $\Delta T_{max} \sim$ 24 K - acceptable!

Issues

- Beam optics for this raster



Counting rates

Instantaneous rates with bunch suppression

	OLD	NEW
Beam current	0.3 μA	50 μA
Target thickness	12 μm/sin 20°	1 μm
Ap.counter's rate	2 MHz	($\times$1.2)$\sim$ 2.4 MHz

Modifications needed

- 8 ns between bunches
- Electronics upgrade: pulses 12 ns $\Rightarrow$ 7.0 ns

Statistical accuracy

Duty cycle 3% $\Rightarrow$ 1% in $\sim$ 20 min

Regime

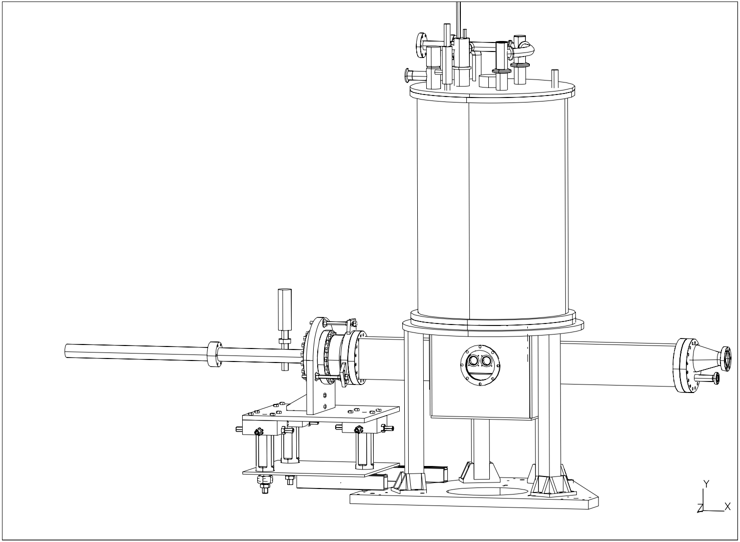
Non-invasive, small raster

- Bunch suppression n=4 - non-invasive
- Tune beam $\Delta t = 1$ ms at 120 Hz
- Small raster of 0.7×0.7 mm^2

Design and Construction

- New taget holder: design nearly finished
  - Design - end of December
  - Manufacturing - end of January, 2009
- Cryo-supply: general concept only
  - Design - end of March
  - Manufacturing - end of May, 2009
  - Temporary - run from a dewar
- Magnet mounting
  - Alignment - not easy! Our beam tune is often far from the center.
  - Design of alignment tools
  - Main focus at the moment
- Power supplies and instrumentation: ordered
- Installation June-July 2009

Target area



Target holder