The luminosity monitor of the G^0 experiment

Jianglai Liu, U. of Maryland, College Park

for the G^0 collaboration

G^0 experiment

E99-016, E01-115 and E01-116, Jefferson Lab

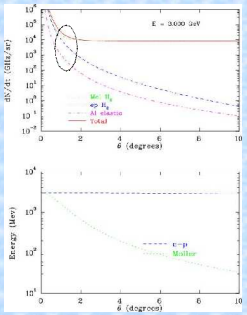
G^0 Collaboration :
Caltech, Carnegie-Mellon, William&Mary, Hampton, IPN-Orsay, LPSC-Grenoble, JLab, Kentucky, LaTech, NMSU, TRIUMF, U Con, UIUC, U Manitoba, U Maryland, U Mass, UNBC, VPI, Yerevan

As a rather new addition to the G^0 apparatus, what do lumis do?

- **Monitoring cryo target density reduction**
  - *Integrating electronics — deadtime free — so can dis-entangle target/deadtime effect*
- **Monitoring cryo target density fluctuation**
  - *High rate — sensitivity to noise due to the LH2 density fluctuation*
- **Checking the beam induced false asymmetry correction**
  - *Sensitive to the beam motion — good test of the correction procedure*
  - *A_{phys} ~ 0 — NULL asymmetry test*
- **Determining leakage current asymmetry**
  - *High rate, adjustable gain — sensitive to tiny leakage current (~50nA)*

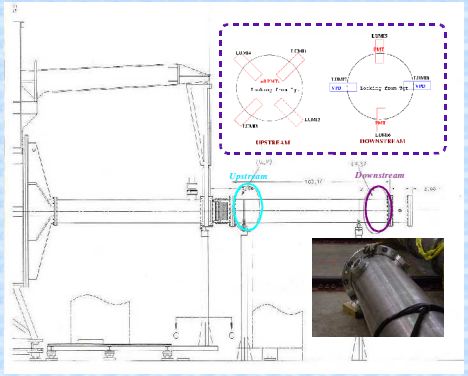
Scattering at small angle

- *High rates — high precision*
- *Rates dominated by Moller — $A_{pv}(Q^2\sim 0) \sim 0$ ppm*



Kinematics, geometry, etc

- Beam energy: 3.0 GeV
- Scattering angle: ~2.0 ° (US) and ~1.2 ° (DS)
- Solid angle: ~0.05 msr (US) and ~0.02 msr (DS)
- Moller rate: 0.5 GHz (DS) and 0.4 GHz (DS)
- Moller e- energy ~ 700 MeV and 1 GeV
- Expected asymmetry width from counting statistics ~ 130 ppm. Aimed for < 300 ppm width (full FPD statistics)

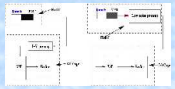


Detectors configuration

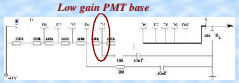
Radiators:
Quartz cubes (radiation hardness > 2 Grad) (**Spectrosil 2000**)
- 3.5x3.5x7.6 cm
- Light cone angle ~ 47.1°
- $\beta > \beta_{thresh} = 1/1.47$
- Critical angle ~ 42.9°
- ß > 0.93 trapped
- ~ 40 PEs/cm (27% QE, 70% light collection)

Phototubes:
- low gain (G=100-1000) 2-in PMTs with quartz window (**Hamamatsu R375**)
- 3-in VPD (**Hamamatsu**)

Preamplifiers:
- **Hamamatsu(C7319)** I-V (uA-V) for PMTs
- **TRIUMF** I-V (10nA-1.5V) for VPDs

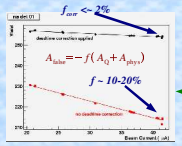


Low gain PMT base

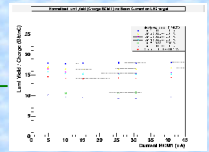


Lumi analysis task I: Deadtime or Target density REDUCTION

Q: *Raw FPD yield (normalized to beam current) drops with beam current. Deadtime? Target density reduction?*
Fortunately, lumis are deadtime free ...

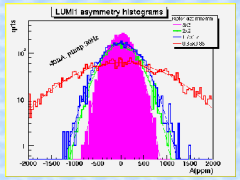


So this is due to deadtime!

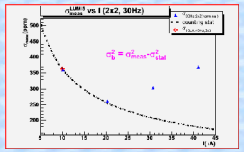


Lumi analysis task II: LH_2 Target boiling?

Boiling control Knobs:
beam current, raster size, pump speed



Q: What is the 30Hz density fluctuation at normal running condition (*2x2mm raster, 30Hz pump speed, 40 uA cw beam*)**?**
Is it negligible?



Detector	2x2 30Hz	2x2 40Hz	5x3 10Hz
LUMI1	268(5)	249(4)	172(4)
LUMI2	267(5)	250(4)	174(4)
LUMI3	269(5)	159(4)	158(4)
LUMI4	250(5)	161(4)	153(4)
SUM	265(5)	185(4)	152(4)

So under normal condition $\sigma_{boiling}$ ~ 260 ppm

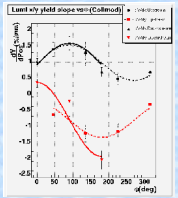
For FPDs,
$\sigma^2_{meas} = \sigma^2_{counting} + \sigma^2_{boiling}$
where $\sigma_{counting}$ ~1200 ppm per ring

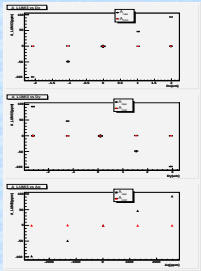
So the effect of the target boiling is completely negligible!

Lumi analysis task III: "Slopes" & false asymmetry due to the helicity correlated beam properties?

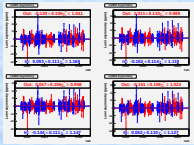
$$\Delta Y^{\pm} = \sum \frac{\partial Y}{\partial P_i} \Delta P_i^{\pm} \Rightarrow A_{false} = \sum \frac{1}{2Y} \frac{\partial Y}{\partial P_i} (P_i^+ - P_i^-)$$

$$P_i: \ (x, y, Q, \ldots)$$



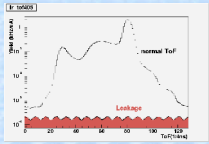


Lumi analysis task IV: Null false asymmetry test



Life is good so far, but ...

Lumi analysis task V: 499MHz leakage?

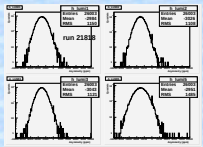


Note $\frac{R_C(\mathrm{ToF})}{R_L(\mathrm{ToF})} \neq \frac{I_C}{I_L}$!!!!

- *Leakage current ~ 50 nA. 2ns time structure. All 3 lasers!!*
- *The normal G0 ToF spectrum gets smear out over the 32 ns window*
- *Origin of the problem: different ToF structure of G0 and the leakage beams*

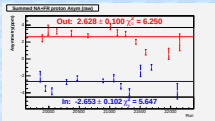
Discovery of significant leakage asymmetry

- *We thought leakage asymmetry should be small, since we feedback on Hall A charge asymmetry. But nobody knew the answer for sure ...*
- *Leakage current ~ 50 nA, too small for normal BCMs.*
- *Lumi PMT gains adjustable. Cranked the HV to get a x100 gain. Adjusted preamp to get another x10.*
- *With good precision, we measured significant leakage asymmetry coming from both Hall A and B.*



Leakage impact on the measured asymmetry

$$A_{meas} \approx A_{phys} - \frac{I_L}{I_{G0}}\left(1 - \frac{Y_L}{Y_{G0}}\right) A_L$$

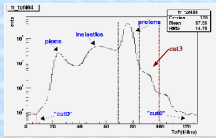


We needed a continuous leakage monitor in order to correct for the data taken so far.

"cut0" leakage monitor

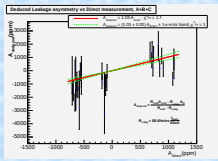
- **"Forbidden"** ToF region:
  ToF > ***slowest protons*** OR ToF < ***pions***
- ***Very sensitive to the leakage current***

$$A_{cut0} = A_{leak} \times r_{leak} \ \text{where} \ r_{leak} = \frac{R_{leak}}{R_{cut0}} \frac{1}{3}$$



Cut0 certification

Does the leakage asymmetry determined by cut0 agree with the direct measurement made by the lumi monitors?



A_L determined by cut0 agreed with direct measurements within 20%.

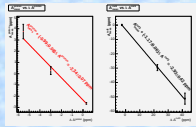
$$\delta \Delta A^{SYS}_{corr} / \Delta A_{corr} \sim 20\%$$

This eventually leads to a ~0.1ppm systematic uncertainty to the elastic proton asymmetry

Raw vs corrected FPD asymmetry

$$A_{phys} = A_{meas} + \Delta A_{corr}$$

So, A_{meas} vs ΔA_{corr} slope should be -1



Life is good again!

Conclusion:

G^0 Lumi monitors performance met (and superseded) design goals.
- No significant global target density reduction.
- Target boiling effect shown negligible.
- Linear regression technique is able to correct for the false asymmetry due to the helicity correlated beam properties
- Residual lumi asymmetry < 0.1 ppm (good null false asymmetry test)
- There has been significant leakage contamination throughout the run.
- We were able to certify the "cut0" technique, which could correct the leakage effect to ~0.1ppm precision.