G9A-FROST

Experiments

New generation of CLAS photoproduction experiments with FROzen Spin Polarized Target (FROST)

- E02-112: $\gamma p \rightarrow KY$ ($K^+\Lambda$, $K^+\Sigma^0$, $K^0\Sigma^+$)
- E03-105/E04-102: $\gamma p \rightarrow \pi^0 p$, $\pi^+ n$
- E05-012: $\gamma p \rightarrow \eta p$
- E06-013: $\gamma p \rightarrow \pi^+\pi^- p$

Goal: study of exited baryons.

Next step (after g1 and g8) towards “complete experiment”

Running configurations

Four possible combinations of beam-target polarization:

g9a this fall:

- circularly polarized beam, longitudinally polarized target
- linearly polarized beam, longitudinally polarized target

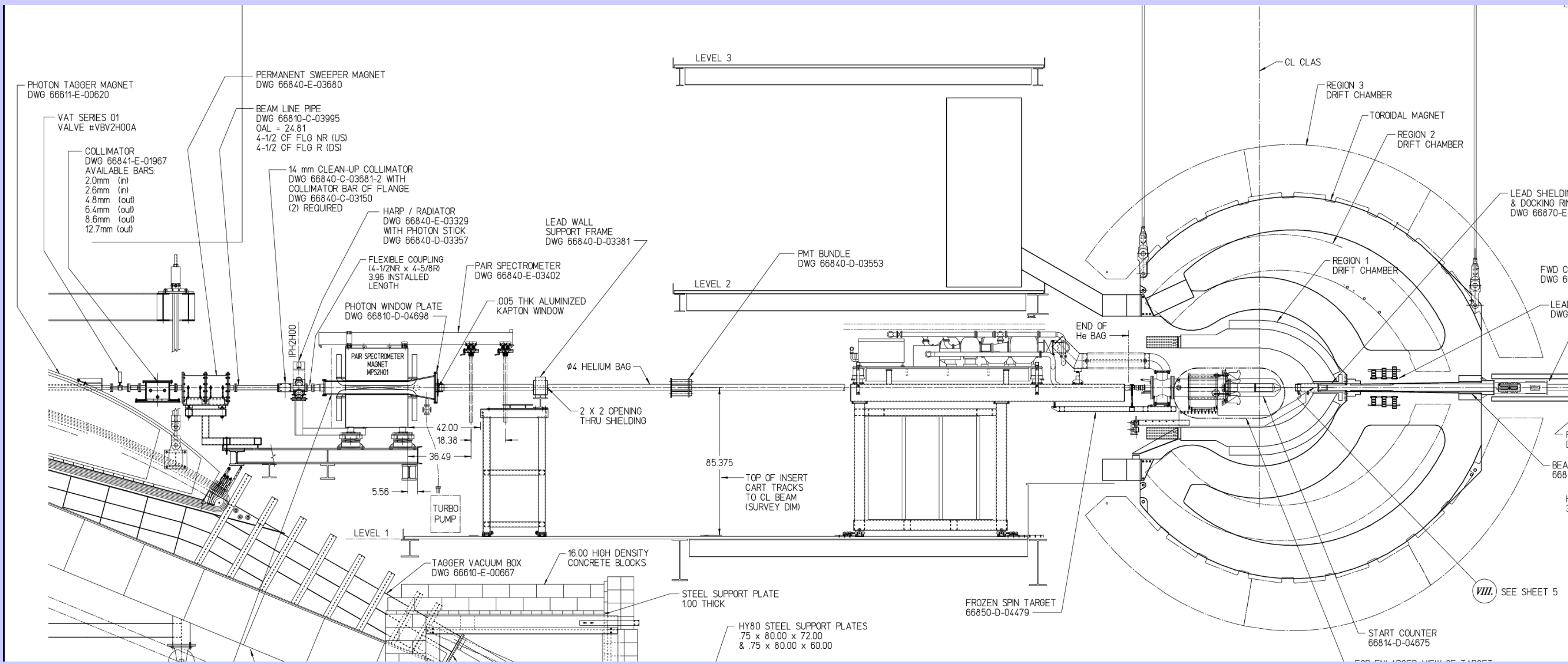
g9b in 2009:

- circularly polarized beam, transversely polarized target
- linearly polarized beam, transversely polarized target

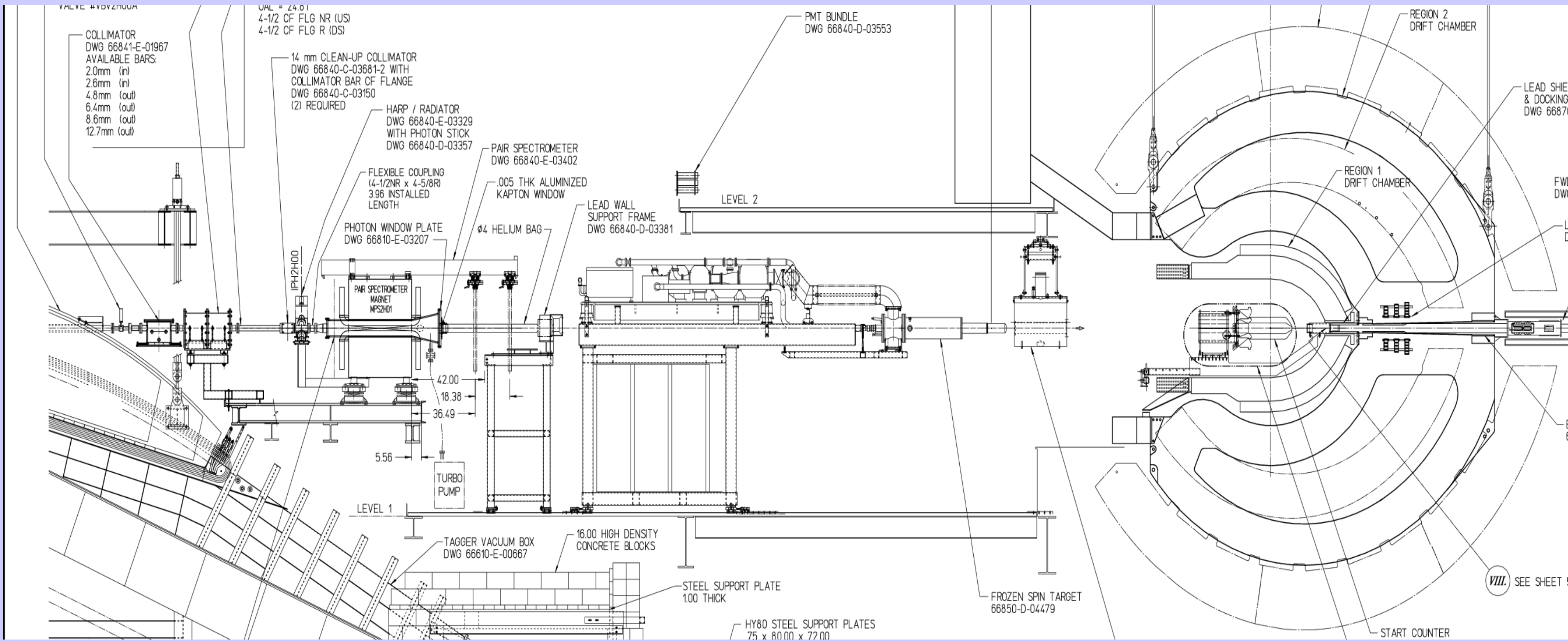
FROzen Spin Target

- Target material: butanol (C_4H_9OH) 50 mm long, 15 mm di-
ameter
- Dynamical polarization using microwaves outside of CLAS in high magnetic field (5T) at a temperature of about 1K.
- Switch to “Frozen” mode: temperature < 50 mK, holding magnetic field ~0.5T.
- Relaxation time of the order of a few hundreds hours.

FROST running configuration



FROST polarizing configuration



Polarized photon beam on polarized target

$$
\begin{aligned}
\frac{1}{\sigma_0}\cdot\frac{d\sigma}{d\Omega} = \; & 1 \\
& -P_{\odot}P_Z^{\mathrm{lab}}\cdot E \\
& +P_{XY}^{\mathrm{lab}}\cdot\sin(\beta-\phi)\cdot T \\
& +P_{\odot}P_{XY}^{\mathrm{lab}}\cdot\cos(\beta-\phi)\cdot F \\
& -P_T\cdot\cos 2(\alpha-\phi)\cdot\Sigma \\
& +P_TP_Z^{\mathrm{lab}}\cdot\sin 2(\alpha-\phi)\cdot G \\
& -P_TP_{XY}^{\mathrm{lab}}\cdot\cos(\beta-\phi)\sin 2(\alpha-\phi)\cdot H \\
& -P_TP_{XY}^{\mathrm{lab}}\cdot\sin(\beta-\phi)\cos 2(\alpha-\phi)\cdot P
\end{aligned}
$$

Photon		Target			Recoil			Target + Recoil			
	$-$	$-$	$-$	$-$	x'	y'	z'	x'	x'	z'	z'
	$-$	x	y	z	$-$	$-$	$-$	x	z	x	z
unpolarized	σ_0	0	T	0	0	P	0	$T_{x'}$	$-L_{x'}$	$T_{z'}$	$L_{z'}$
linear pol.	$-\Sigma$	H	(-P)	$-G$	$O_{x'}$	(-T)	$O_{z'}$	$(-L_{z'})$	$(T_{z'})$	$(-L_{x'})$	$(-T_{x'})$
circular pol.	0	F	0	$-E$	$-C_{x'}$	0	$-C_{z'}$	0	0	0	0

Circularly Polarized photon beam on longitudinally polarized target

$$
\begin{aligned}
\frac{1}{\sigma_0}\cdot\frac{d\sigma}{d\Omega} \quad = \quad & 1 \\
& -P_{\odot}P_Z^{\rm lab}\cdot E \\
& +P_{XY}^{\rm lab}\cdot\sin(\beta-\phi)\cdot T \\
& +P_{\odot}P_{XY}^{\rm lab}\cdot\cos(\beta-\phi)\cdot F \\
& -P_T\cdot\cos 2(\alpha-\phi)\cdot\Sigma \\
& +P_TP_Z^{\rm lab}\cdot\sin 2(\alpha-\phi)\cdot G \\
& -P_TP_{XY}^{\rm lab}\cdot\cos(\beta-\phi)\sin 2(\alpha-\phi)\cdot H \\
& -P_TP_{XY}^{\rm lab}\cdot\sin(\beta-\phi)\cos 2(\alpha-\phi)\cdot P
\end{aligned}
$$

Photon		Target			Recoil			Target + Recoil			
	–	–	–	–	x'	y'	z'	x'	x'	z'	z'
	–	x	y	z	–	–	–	x	z	x	z
unpolarized	σ_0	0	T	0	0	P	0	$T_{x'}$	$-L_{x'}$	$T_{z'}$	$L_{z'}$
linear pol.	$-\Sigma$	H	(-P)	$-G$	$O_{x'}$	(-T)	$O_{z'}$	$(-L_{z'})$	$(T_{z'})$	$(-L_{x'})$	$(-T_{x'})$
circular pol.	0	F	0	$-E$	$-C_{x'}$	0	$-C_{z'}$	0	0	0	0

Linearly Polarized photon beam on longitudinally polarized target

$$
\begin{aligned}
\frac{1}{\sigma_0} \cdot \frac{d\sigma}{d\Omega} = \; & 1 \\
& - P_\odot P_Z^{\mathrm{lab}} \cdot E \\
& + P_{XY}^{\mathrm{lab}} \cdot \sin(\beta - \phi) \cdot T \\
& + P_\odot P_{XY}^{\mathrm{lab}} \cdot \cos(\beta - \phi) \cdot F \\
& - P_T \cdot \cos 2(\alpha - \phi) \cdot \Sigma \\
& + P_T P_Z^{\mathrm{lab}} \cdot \sin 2(\alpha - \phi) \cdot G \\
& - P_T P_{XY}^{\mathrm{lab}} \cdot \cos(\beta - \phi) \sin 2(\alpha - \phi) \cdot H \\
& - P_T P_{XY}^{\mathrm{lab}} \cdot \sin(\beta - \phi) \cos 2(\alpha - \phi) \cdot P
\end{aligned}
$$

Photon		Target			Recoil			Target + Recoil			
	–	–	–	–	x'	y'	z'	x'	x'	z'	z'
	–	x	y	z	–	–	–	x	z	x	z
unpolarized	σ_0	0	T	0	0	P	0	$T_{x'}$	-$L_{x'}$	$T_{z'}$	$L_{z'}$
linear pol.	$-\Sigma$	H	(-P)	$-G$	$O_{x'}$	(-T)	$O_{z'}$	(-$L_{z'}$)	($T_{z'}$)	(-$L_{x'}$)	(-$T_{x'}$)
circular pol.	0	F	0	$-E$	$-C_{x'}$	0	$-C_{z'}$	0	0	0	0

$\pi^+\pi^-$

$$\frac{\mathrm{d}\,\sigma}{\mathrm{d}\,x_i} = \sigma_0 \{ (1 + \Lambda_z \cdot \mathbf{P_z}) + \delta_\odot (\mathbf{I}^\odot + \Lambda_z \cdot \mathbf{P_z^\odot})\}$$

$$(\rightarrow\Rightarrow - \leftarrow\Rightarrow) := \frac{\mathrm{d}\,\sigma(\rightarrow\Rightarrow)}{\mathrm{d}\,x_i} - \frac{\mathrm{d}\,\sigma(\leftarrow\Rightarrow)}{\mathrm{d}\,x_i} = 2 \cdot \sigma_0 \{\delta_\odot (\mathbf{I}^\odot + \Lambda_z \cdot \mathbf{P_z^\odot})\}$$

$$(\leftarrow\Leftarrow - \rightarrow\Leftarrow) := \frac{\mathrm{d}\,\sigma(\leftarrow\Leftarrow)}{\mathrm{d}\,x_i} - \frac{\mathrm{d}\,\sigma(\rightarrow\Leftarrow)}{\mathrm{d}\,x_i} = 2 \cdot \sigma_0 \{\delta_\odot (-\mathbf{I}^\odot + \Lambda_z \cdot \mathbf{P_z^\odot})\}$$

1) $(\rightarrow\Rightarrow - \leftarrow\Rightarrow) + (\leftarrow\Leftarrow - \rightarrow\Leftarrow) := \frac{\mathrm{d}\,\sigma_{3/2}}{\mathrm{d}\,x_i} - \frac{\mathrm{d}\,\sigma_{1/2}}{\mathrm{d}\,x_i} = 4 \cdot \sigma_0 \cdot \delta_\odot \cdot (\Lambda_z \cdot \mathbf{P_z^\odot})$

2) $(\leftarrow\Leftarrow - \leftarrow\Rightarrow) - (\rightarrow\Rightarrow - \rightarrow\Leftarrow) := -4 \cdot \sigma_0 \cdot (\Lambda_z \cdot \mathbf{P_z})$

Experiment configuration

- Torus current 1920 A. Out bending positive particles.
- Three targets:
  - 5 cm long polarized butanol at nominal CLAS center
  - 1.5 mm thick ^{12}C disk, 6 cm downstream of CLAS center
  - 3.5 mm thick CH2 disk, 16 cm downstream of CLAS center
- Trigger: at least one charged particle in CLAS
  - L1: ST.AND.TOF.AND.L2 sector based
- 2.6 mm collimator for circularly polarized beam
- 2 mm collimator for linearly polarized beam

Startup plan

- Take everything out of the beam line: radiator, collimator, converter, TAC, photon profiler.
- Verify with MCC that they have set up machine fast shutdown interlock from the tagger magnet.
- Let MCC establish beam in the Hall and tune it on the tagger dump.
- Ask MCC to set up digitizer on the tagger dump viewer to monitor electron beam position on the dump. Have strip-chart running for that.
- Set the beam current to 5 nA.
- Harp scans. Have width better than 150 μm and shoulder-to-peak ratio better than 10-4 on the tagger harp.
- Put the 10-4 r.l. radiator in.
- Ramp up pair spectrometer magnet and put converter in.
- Do photon harp scan with no collimation and 6.4 mm collimator.
- Center beam on the collimator using rates in the start counter and rates in the pair spectrometer with and without collimation. Use the larger collimator (6.4 mm) for alignment. Do a horizontal scan of the collimator position. After it is centered horizontally, do a vertical scan with MCC steering the beam vertically. If it turns out that when beam is centered on the collimator but off-center on the target, we would need to adjust the height of the collimator box using its supporting screws.
- Insert 2.6 mm collimator and recheck its alignment.
- Plateau tagger HV if necessary.
- Calibrate the SLM.
- Make sure MCC gives us control of the attenuator and adjust the beam charge asymmetry to 0.
- Perform a Moller run.

Startup plan

- Have all CLAS detectors ON and ready.
- Check that the L2 segment collectors are working.
- Start DAQ and make sure that we have data coming from all detectors.
- Check all on-line histograms. Pay special attention to the TOF decoupled paddles (at back angles). Establish a reference histogram set for monitoring.
- Check trigger rates.
- In fast reconstruction, check that we see three targets: the main one (5-cm long butanol) located at the nominal CLAS center, ^{12}C about 6 cm downstream of the CLAS center, and CH_2 about 16 cm downstream of the CLAS center.
- Choose beam intensity. Some factors to consider include:
  - Trigger rate. Live time >80%
  - Tagger rate. Singles rate of T-counters <4 MHz.
  - DC occupancy <2%.
- As soon as we have some data taken, cook the files and perform a TOF calibration to see if all software modifications work as expected

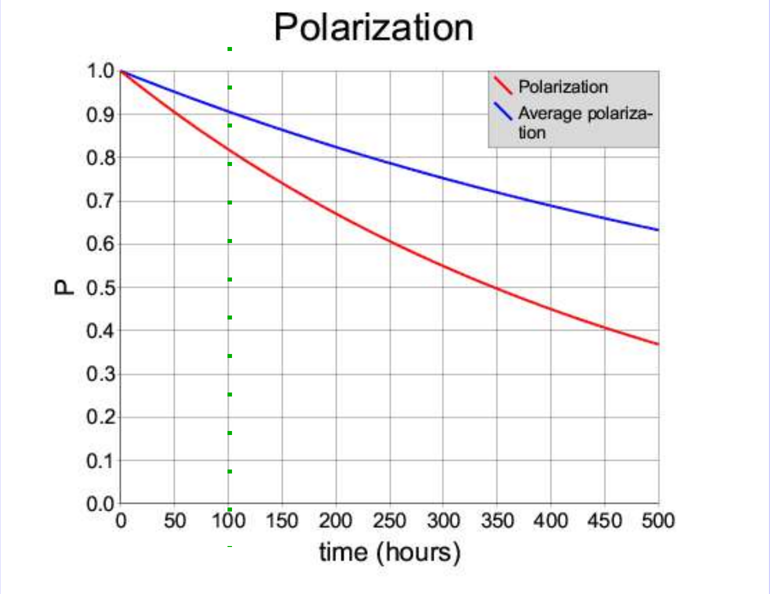
Schedule

Commissioning
October 23 - October 26 at 2.705 GeV/p 5 pass
October 27 Linac Energy change to 0.5 GeV
October 27- October 29 at 2.528 GeV/p 5 pass
Production
October 30 - November 5 at 2.528 GeV/p 5 pass
November 6 Linac Energy change to 0.8 GeV
November 6 at 2.445 GeV/p 3 pass
November 7 pass change to 2 pass
November 7 - November 19 at 1.645 GeV/p
November 20 - November 26 Holiday. Down.
November 27 Linac Energy change to 0.611 GeV
November 27 - December 6 at 2.478 GeV/p 4 pass
December 7 Linac Energy change to 0.7 GeV
December 7 - December 20 at 3.539 GeV 5 pass **linearly polarized beam**
December 21 - January 3 Holidays. Down.
January 4 Linac Energy change to 0.9 GeV
January 4 - January 10 at 1.851 GeV/p 2 pass
January 11 Linac Energy change to 0.379 GeV
January 11 - January 14 Down. Unusable beam.
January 15 Linac Energy change to 0.908 GeV
January 15 - January 30 at 4.591 GeV 5 pass **linearly polarized beam**
January 31 Shutdown

Running pattern

- Polarize target
- Do polarization measurement with NMR in high field
- Switch to frozen mode
- Take data for 4 days
- Monitor polarization with NMR in low field
- Do special runs (Moller, normalization)
- Measure residual polarization in high field
- Repolarize target, flip polarization (~ 1 shift)
- .....

Coordinate repolarization with energy changes and beam studies



General beam parameters

- Instability of the electron beam energy $<10^{-4}$
- Beam spot size at 2C21A and 2C24A
  $\sigma_x < 150\ \mu m$, $\sigma_y < 150\ \mu m$
- Beam position instabilities at 2C21A and 2C24A $<100\ \mu m$
- Beam halo at the tagger harp (shoulder/peak) $\sim 10^{-4}$
- Beam current ~20 nA
- Instability of beam current <5%
- In no circumstances beam spot position on the tagger dump should be adjusted by changing tagger magnet current!
- **Machine fast shutdown interlocked with the tagger magnet.**

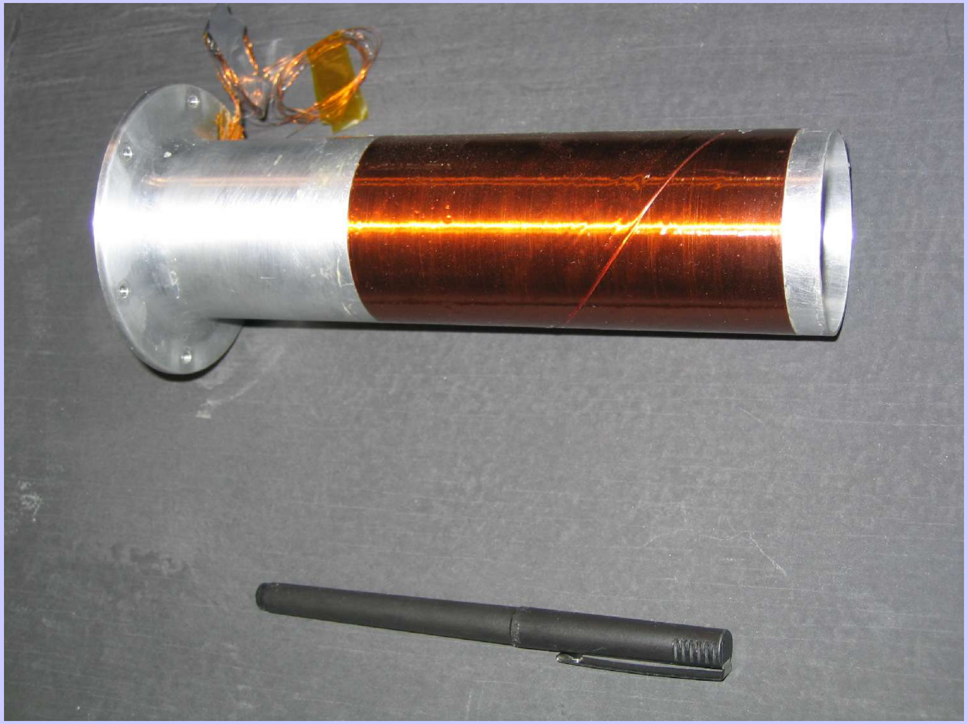
Circularly polarized beam

- 10^{-4} radiation length radiator at 2C24A
- 2.6 mm collimator.
- Maximum polarization of the electron beam.
- Beam charge asymmetry $<5\times10^{-4}$
- Bleedthrough from other halls $<10^{-3}$
- Beam halo at the tagger harp (shoulder/peak) $\sim10^{-4}$
- Half-wave plate IN-OUT periodically
- Møller runs every few days
- Normalization runs with Total Absorption Counter in the beam at very low intensity (<50 pA) every few days.

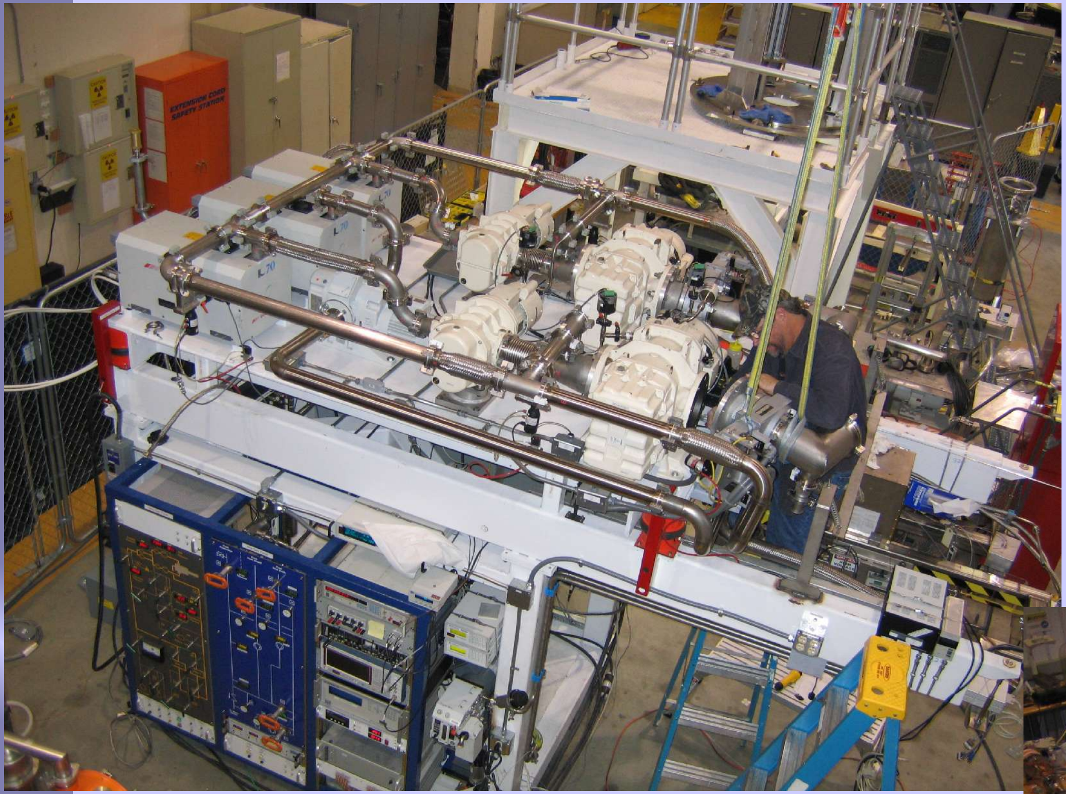
Linearly polarized beam

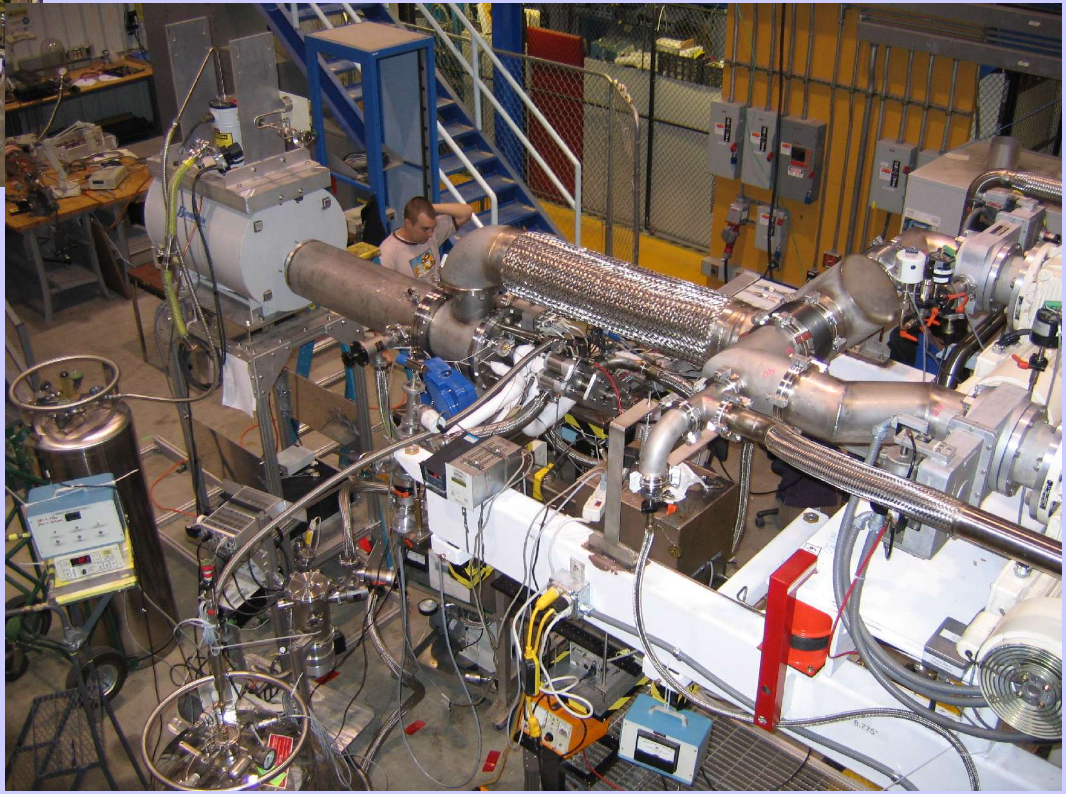
- 50 μm Diamond radiator on the goniometer at 2C21A
- 2 mm collimator
- All magnets between 2C21A and tagger degaussed and OFF!
- Equal spot size at 2C21A and 2C24A
- Position stability is very important.

Holding magnets



FROST in EEL





Installation in Hall B