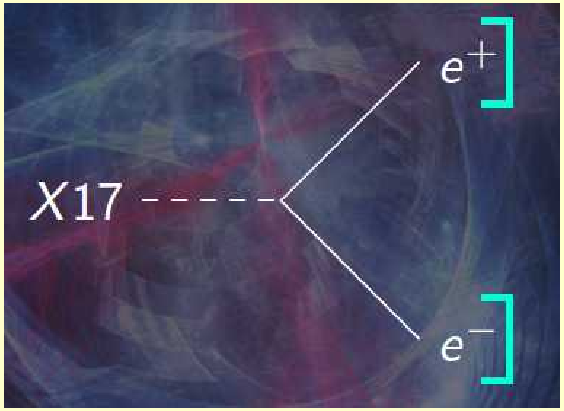
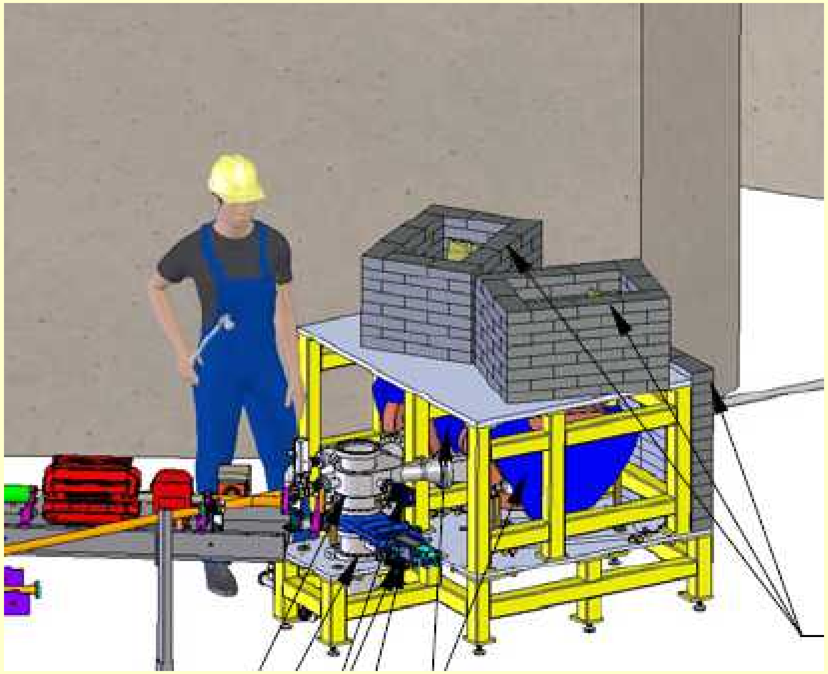
Magnetic field monitoring for DARKLIGHT

Stan Yen
12 August 2021

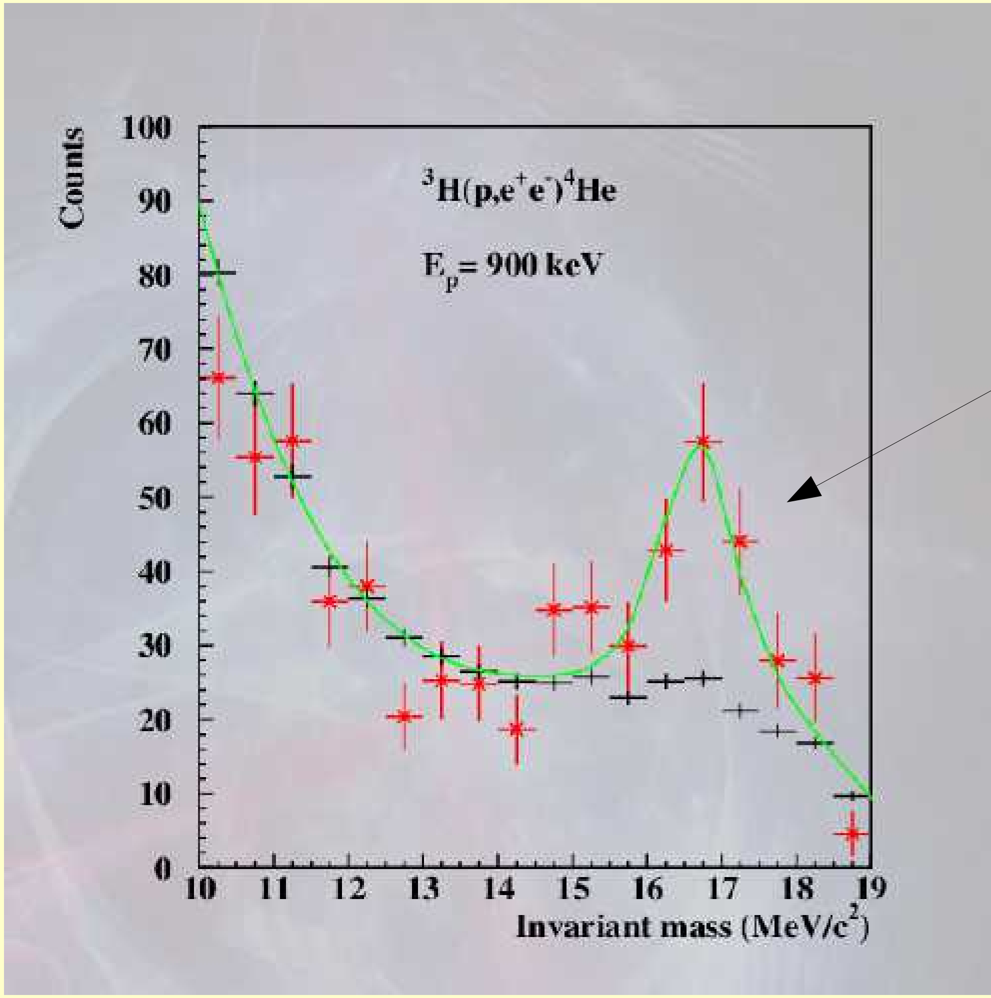
How accurately do we need to measure and stabilize the magnetic fields in the two spectrometers?





The energy resolution of the two spectrometers contributes to the invariant mass resolution of the $e^+ e^-$ pair. For each of the two arms, and assuming the electron (positron) are highly relativistic

E(energy) ~ p(momentum) ~ B(magnetic field strength)

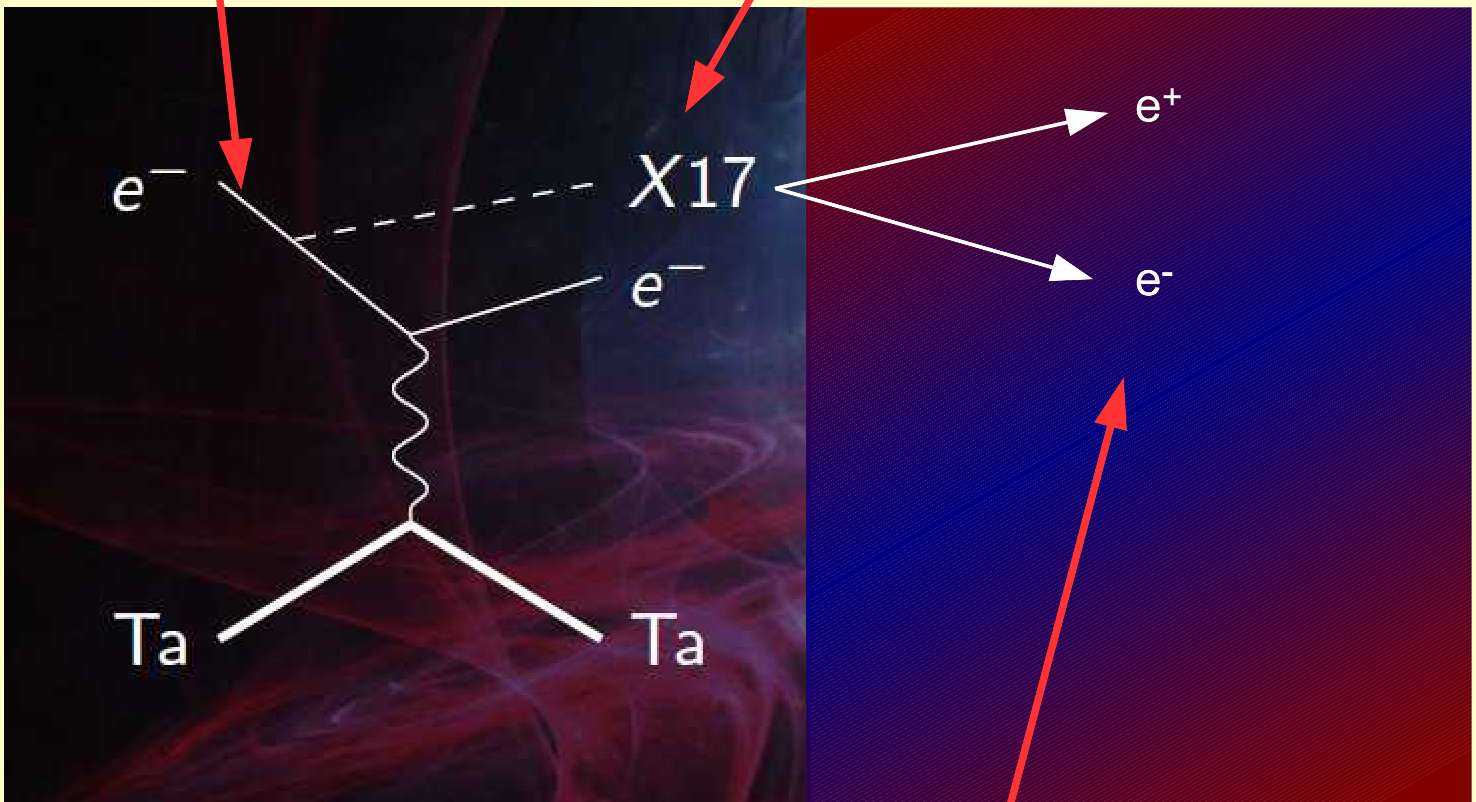


bump seen by Atomki is about
1 MeV wide.

Let's say we want the magnetic
field irreproducibility of the two
spectrometers together
to contribute no more than
100 keV to the mass uncertainty,
and assuming a symmetric
situation, this means 50 keV
energy resolution for each spectrometer.

Assume incident electron is 50 MeV

Maximum phase space when X17 takes away almost all of the available 50 MeV



Assuming symmetry of the e^+ and e^- energies, each of them has energy ~ 25 MeV, On slide 3 we said each spectrometer could contribute at most 50 keV energy uncertainty, so for each one,

$$\frac{\Delta p}{p} = \frac{\Delta E}{E} = \frac{50\,keV}{25\,MeV} = 2\text{x}10^{-3}$$

and since p ~ B, the magnetic field must be kept steady to precision 0.2% or better.

- At present time, no plans to monitor B-field continuously
- current through coils can be used as a proxy for the B-field, and this can be read via

1) voltage drop across shunt resistor in the power supply

2) current transformer

GMW associates claims < 1 ppm drift per year for their devices

However, current is only a proxy for the B-field, not a measurement of the B-field itself ... due to hysteresis, B vs I is not linear and depends on past history. although this should be small at the 0.32 T field the dipoles are designed for. How small? Small at the 0.2% level?

B vs I relationship can also fail if there is any physical deterioration of the shunt resistor or of the electrical continuity of the coils during the course of the experiment.
I have experienced the latter during my time at TRIUMF.

e.g. bending magnet 2 in M11 meson channel had several pancake coils wired together; one pancake burned out and drastically altered the B vs I relationship

If DARKLIGHT claims discovery of a new particle, will we be able to convince people that any bump we see above a smooth background is not an artifact due to a changed B-field partway through the data taking?
How can we do this if we never directly measure the B-field, at least periodically?

Hall probes are only accurate to ~ 1%
NMR is accurate to parts per million, but not cheap – see next slide.

GMW

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1	2026 NMR Teslameter, Frequency Range to 1GHz.	1	25490.00	0.00	25,490.00
2	3026-10m 10m cable for PT 2026 to 6026 Multiplexer, or as extension cable for probe	1	610.00	0.00	610.00
3	MUX6026-4 4-port Multiplexer for PT 2026	1	7160.00	0.00	7,160.00
4	1326-0.13-0.48 Amplified NMR Probe 0.13T to 0.48T, Proton, 10m cable.	1	4770.00	0.00	4,770.00
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If you have any questions regarding this quotation, please contact me personally, Brian Richter at (650) 200-4734, or at brian@gmw.com.

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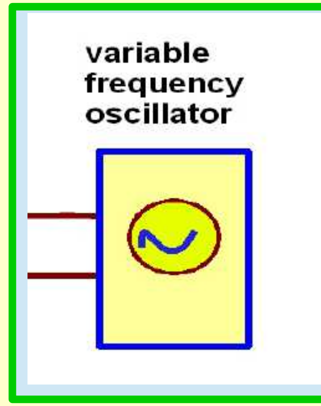
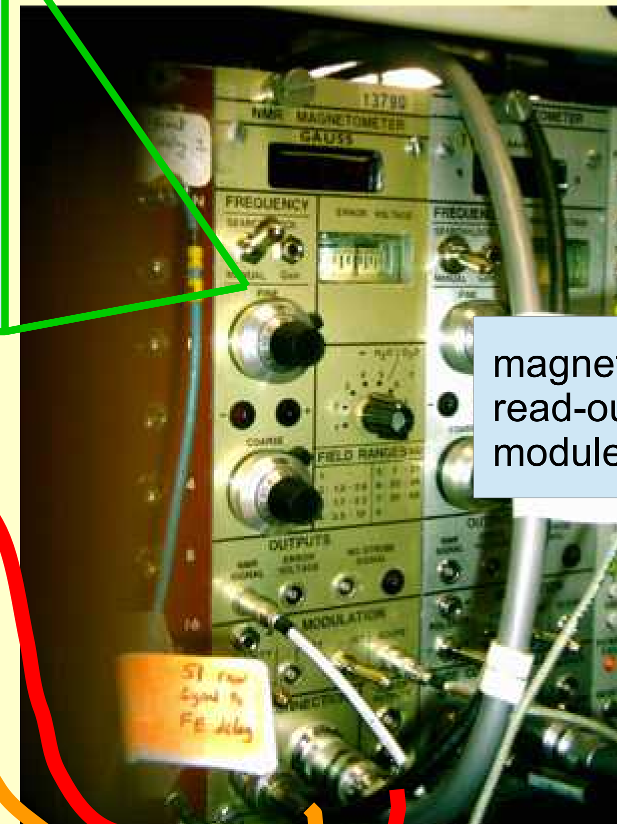
$42,800 USD !!

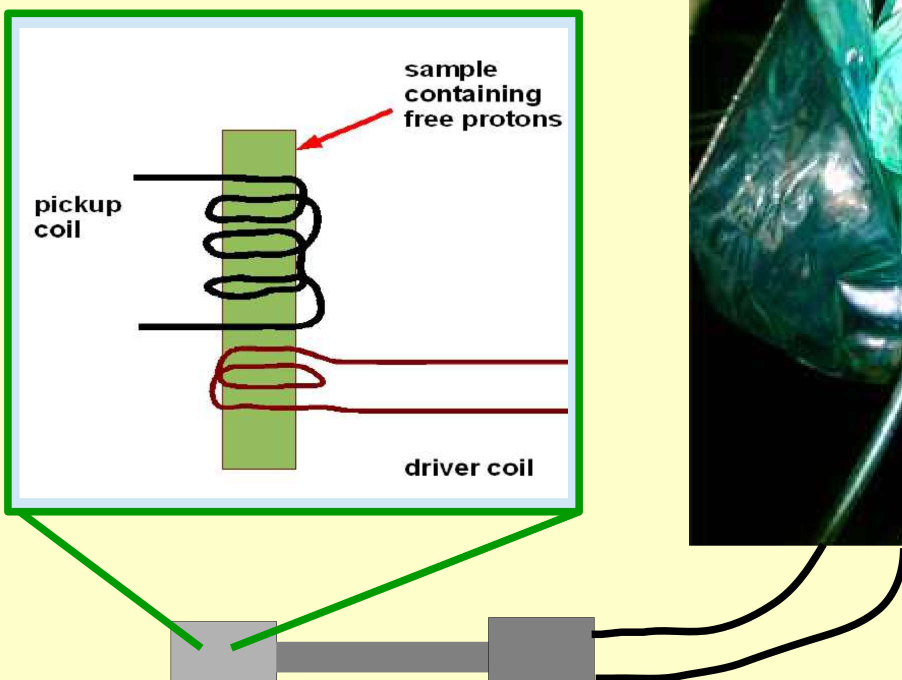
For the past 40 years, TRIUMF has used the CERN NMR design, and in the past, provided this to users.



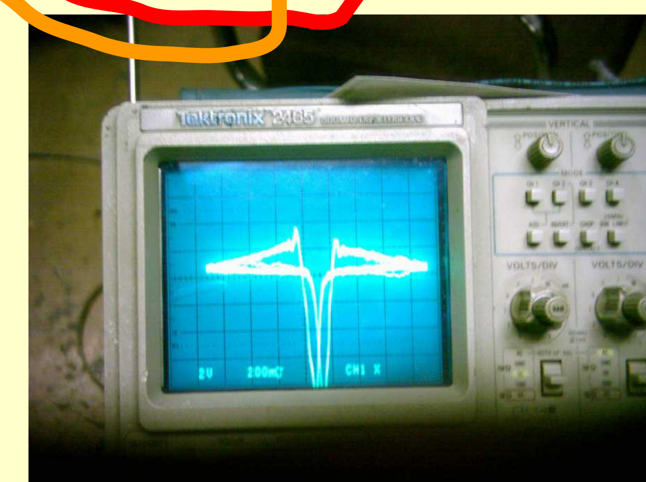


magnetometer read-out module

pre-amp



probe



resonance signal displayed on oscilloscope

On Aug 11, 2020, Mike Hasinoff and I met with Alex Sorokin, the TRIUMF tech who is responsible for magnetic probes.

Situation: TRIUMF still has a lot of these CERN NMR probes and magnetometers around, but pre-amps are in short supply and needed for use in the cyclotron as first priority. Everything is 40 years old and getting increasingly hard to maintain. If we choose to use this legacy system, and our pre-amp fails, it may not be repaired in a timely fashion. There is only one technician doing it and he is being discouraged by his supervisors to maintain the NMR systems – that is a TRIUMF management decision, just like TRIUMF management decided not to maintain a pool of electronics modules any more.

- TRIUMF is now searching for a new lab standard for magnetic field measurements, but will not provide systems for users any more; we will have to buy our own

- discussion document with options will be ready in about 1 week, initial discussions with all stakeholders in 1 month

- probably no decision on a lab standard for another year

- new graphene Hall probes are as precise as NMR, cost ₤2500 per probe, ₤12,500 for electronics, performance specs not yet firmly established

- can our US collaborators provide magnetic field monitoring?

- idea: U of Winnipeg MRS person could design new rad-hard pre-amp to replace the old CERN design?

- vacuum vessel for dipole needs to provide location for insertion of a magnetic probe