Performance test of ACEM-detector (Aluminum Cathode Electron Multiplier)

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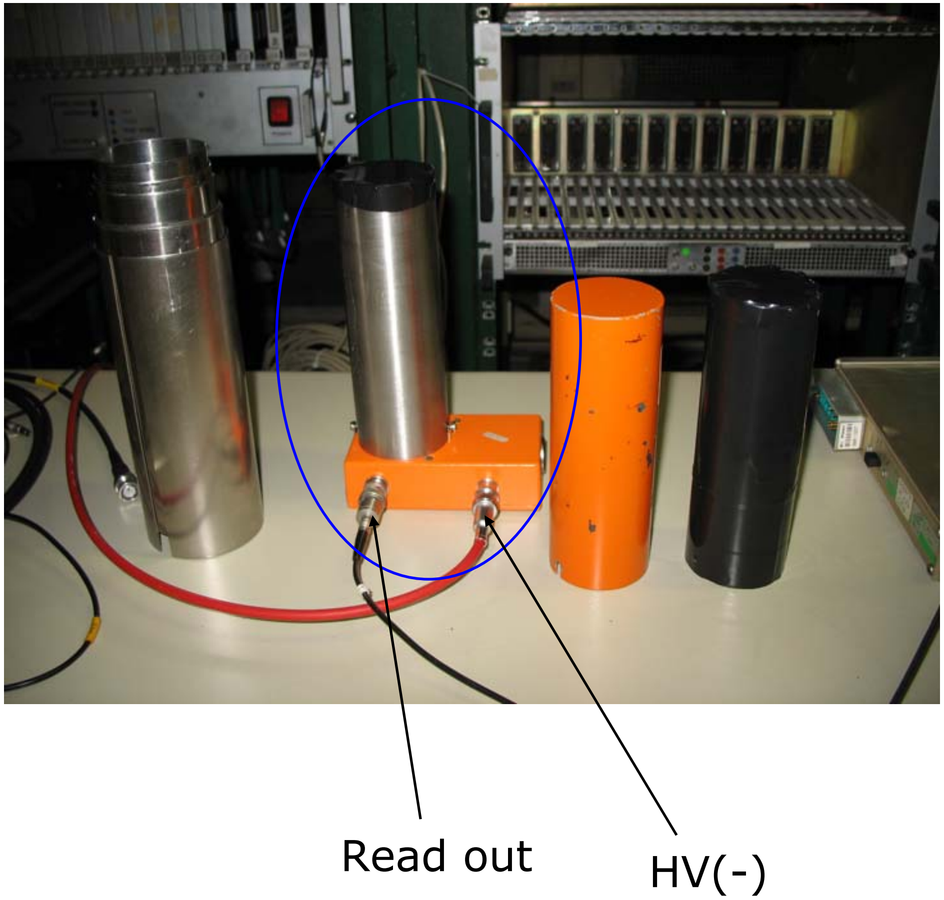
ACEM Specifications

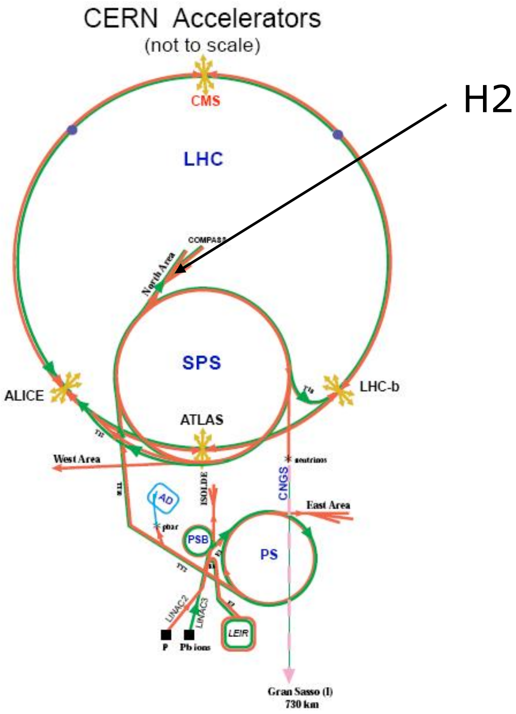
- Basically a regular photomultiplier, but with an aluminum foil as cathode (works as a secondary electron emitter when irradiated).
  - 10 dynodes
  - High voltage: 0.5-1.5 kV
  - Max. current: 20 mA for short pulses
  - Electron transit time: 40 ns
  - Cathode surface area: 7 cm^2
- Positive aspects
  - Simple operation
  - Works with high rate if gain is low
  - Easy to purchase
- Negative aspects
  - Sensitive to magnetic field

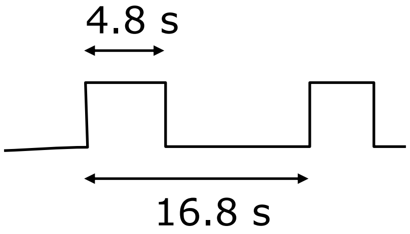


Test conditions

- Test in particle beam
    - Tested in North Area, H2 – secondary particle beam from SPS.
    - Proton beam:
        - Intensity: ~10^8 particles per spill (4.8 s)
        - Energy: 80 GeV
    - Hadron intensity very low compared to MERIT (1:10^9)
- Test in magnetic field
    - Detector placed inside dipole magnets; 0-450 Gauss.
    - β-source (^{90}Sr)

- Plan for MERIT: Use very low gain with minimal HV.

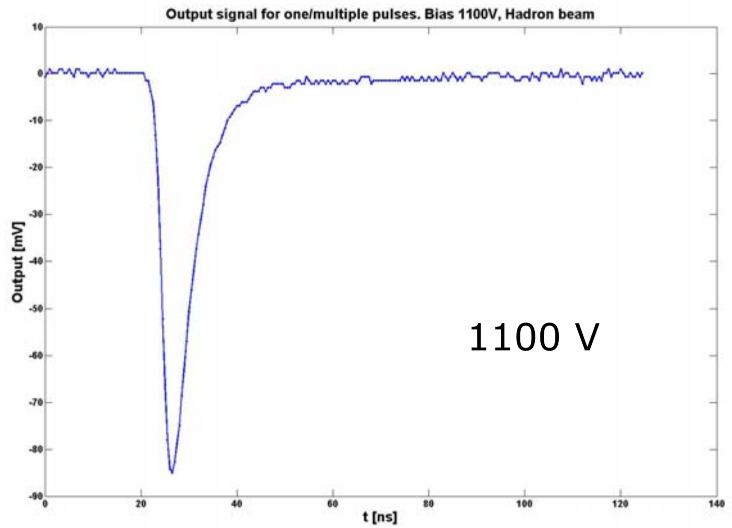




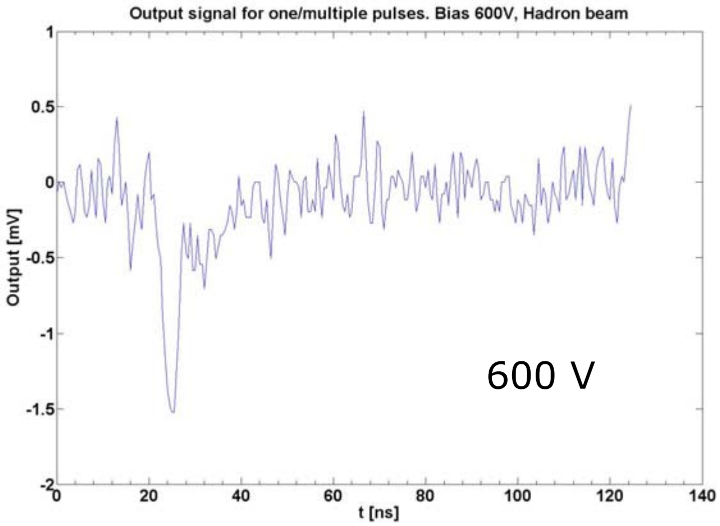
In-beam test

- Oscilloscope: TDS 744A, Tektronix
  - Input resistance: 50 Ohm
  - Sample speed: 2 GHz
  - 8 bits resolution
- 600 V minimum HV for detectable signal

Single pulse response:



1100 V



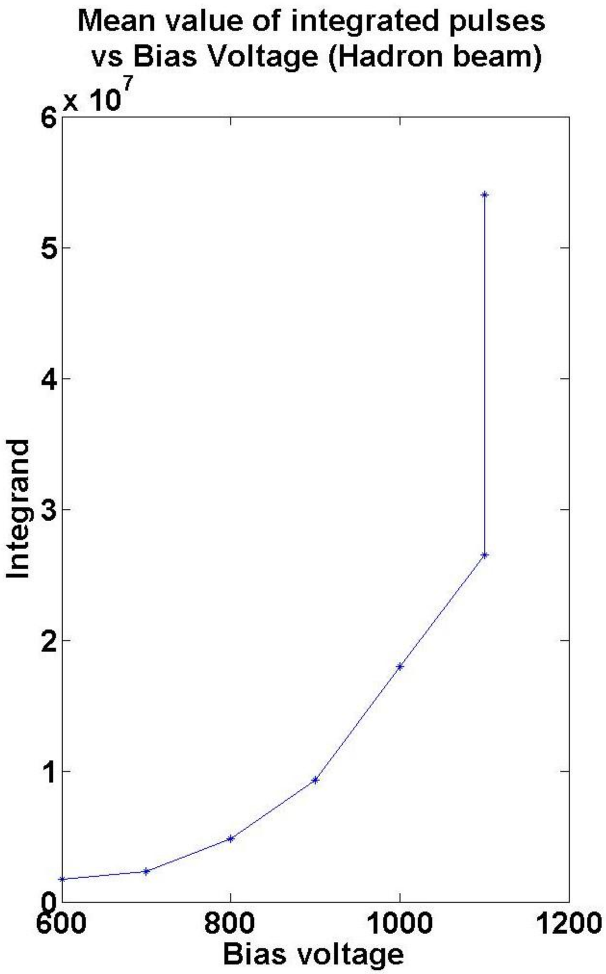
600 V

Single pulses

- Results
  - Rise times (20-90%): ~2.5 ns
  - Fall times (90-20%): ~7 ns
  - FWHM: ~5 ns
  - Times independent of HV
  - Pulse height: ~60 mV at 1100 V to ~1.5 mV at 600 V
- The mean value of the integrated pulses are to be taken with caution, since trigger level varies with HV (As seen in figure: two different trigger levels at 1100 V).
  - To be repeated using a tuned source.

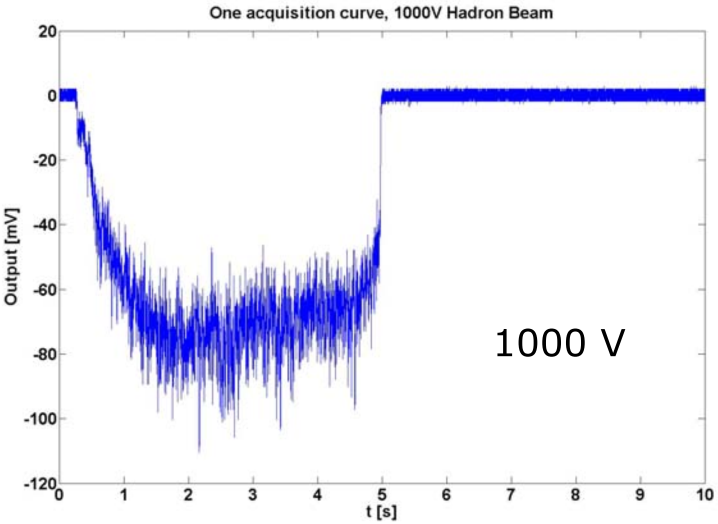
$$I = \frac{1}{q_e}\int_0^T \frac{u_{osc}(t)}{R}dt$$

50 Ω

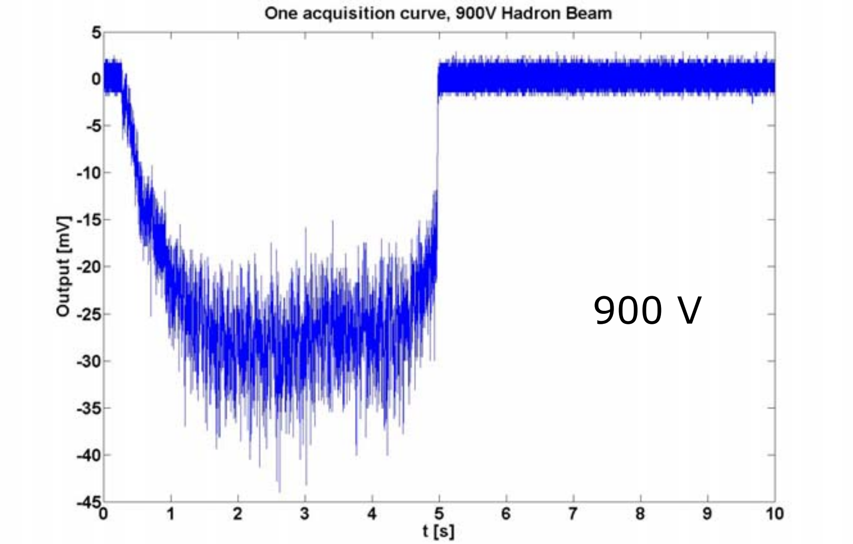


Test with Hadron Beam

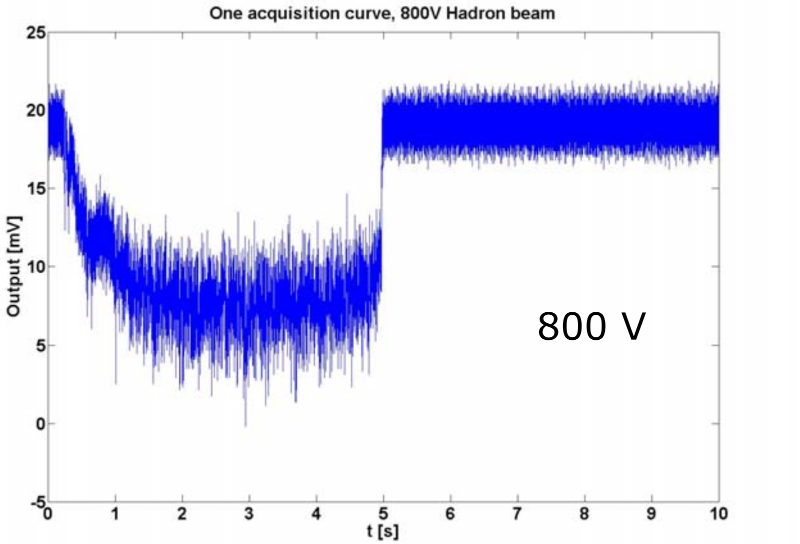
- Sample curves for one spill acquisition
  - Sample speed: 5 kHz
  - Memory: 50.000 samples
  - Input resistance: 1 MΩ (slow integration)


One acquisition curve, 1000V Hadron Beam

1000 V


One acquisition curve, 900V Hadron Beam

900 V

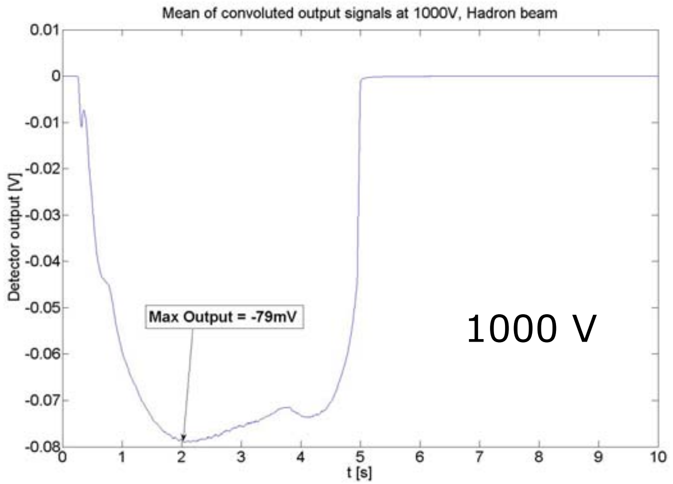

One acquisition curve, 800V Hadron beam

800 V

Test with Hadron Beam

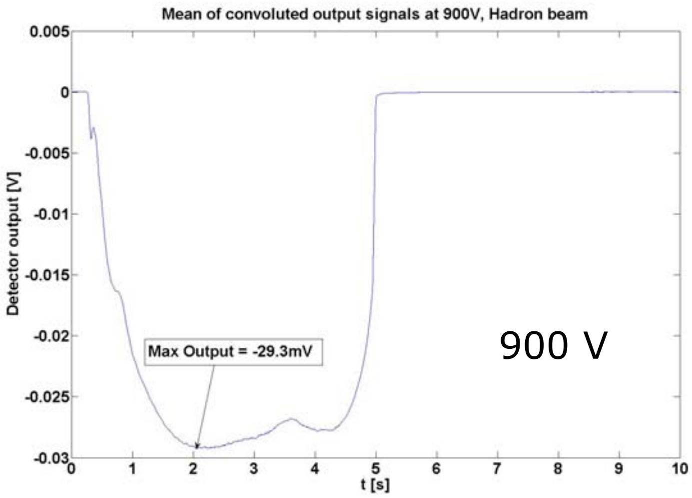
- Average signal
  - N signals convoluted with unit step of t_0=50 ms, to smooth out noise, then summed together

$$S(t)=\frac{1}{N}\sum_{i=1}^{N}\left\{s_i(t)*\frac{1}{t_0}\left[H(t)-H(t-t_0)\right]\right\}$$


Mean of convoluted output signals at 1000V, Hadron beam

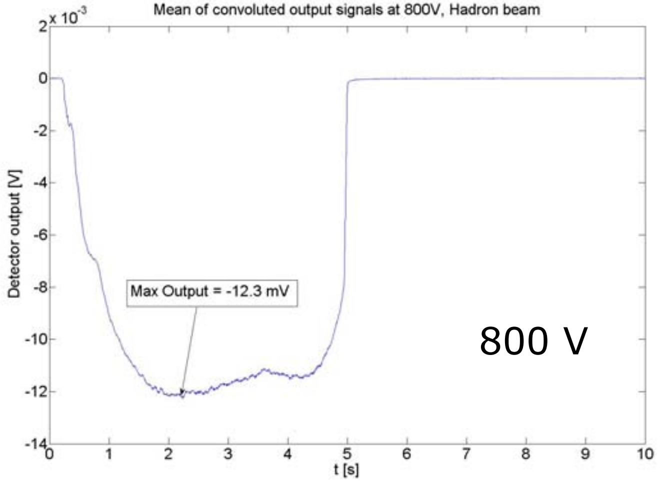
Max Output = -79mV

1000 V


Mean of convoluted output signals at 900V, Hadron beam

Max Output = -29.3mV

900 V


Mean of convoluted output signals at 800V, Hadron beam

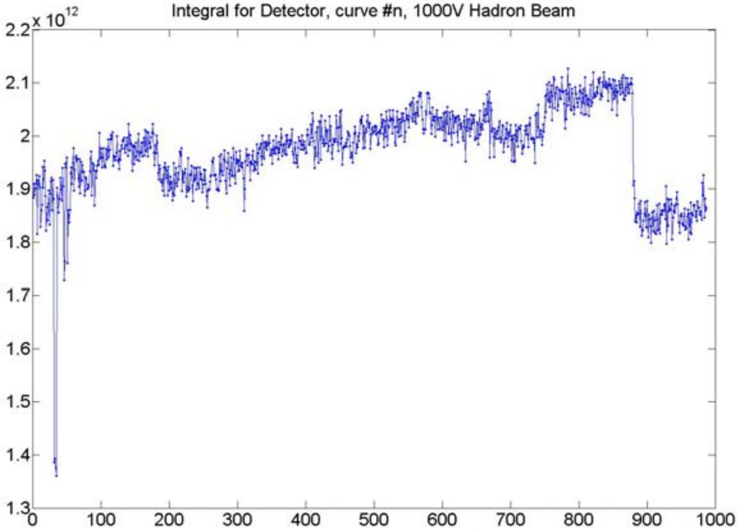
Max Output = -12.3 mV

800 V

Test with Hadron Beam

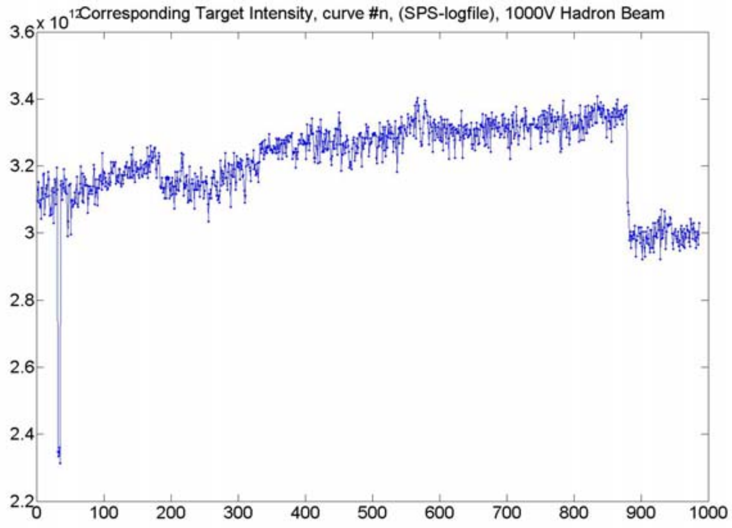
- Statistics: Reliability
  - Integrate signal for each curve *i*. Gives a number which (ideally) is equal to some number of electrons.
  - Quotient between the integral and target intensity should be as constant as possible.

$\int \text{Signal}$

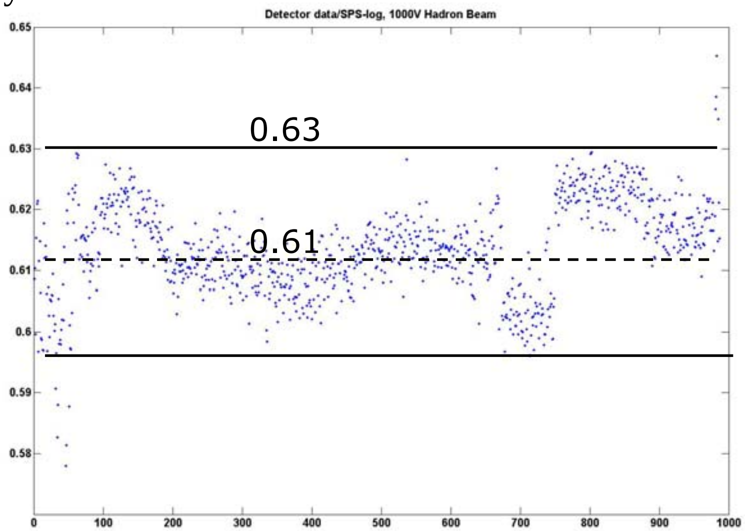


Spill number ⟶

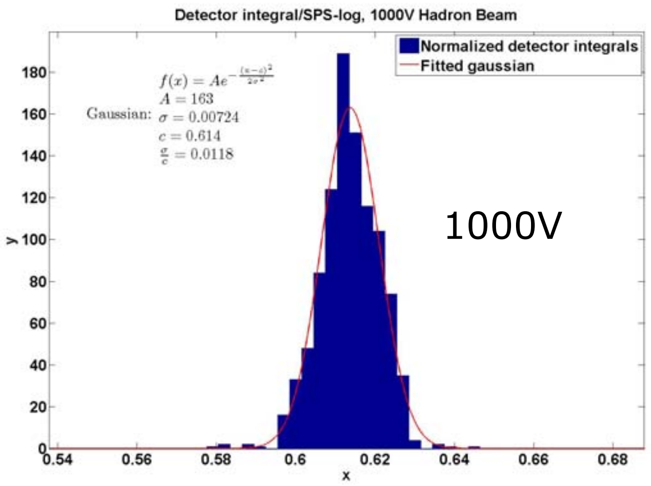
Target intensity

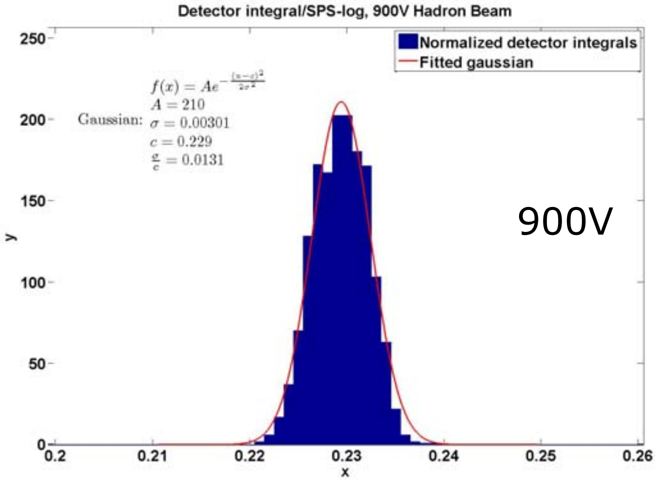


$$\frac{\int \text{Signal}}{\text{Target intensity}}$$

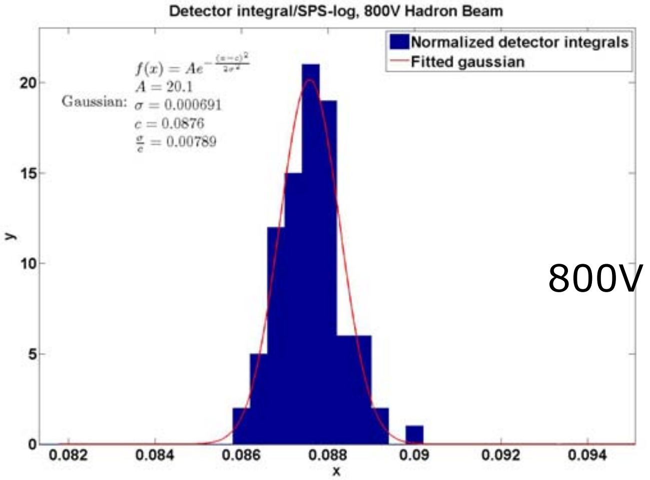


Test with Hadron Beam



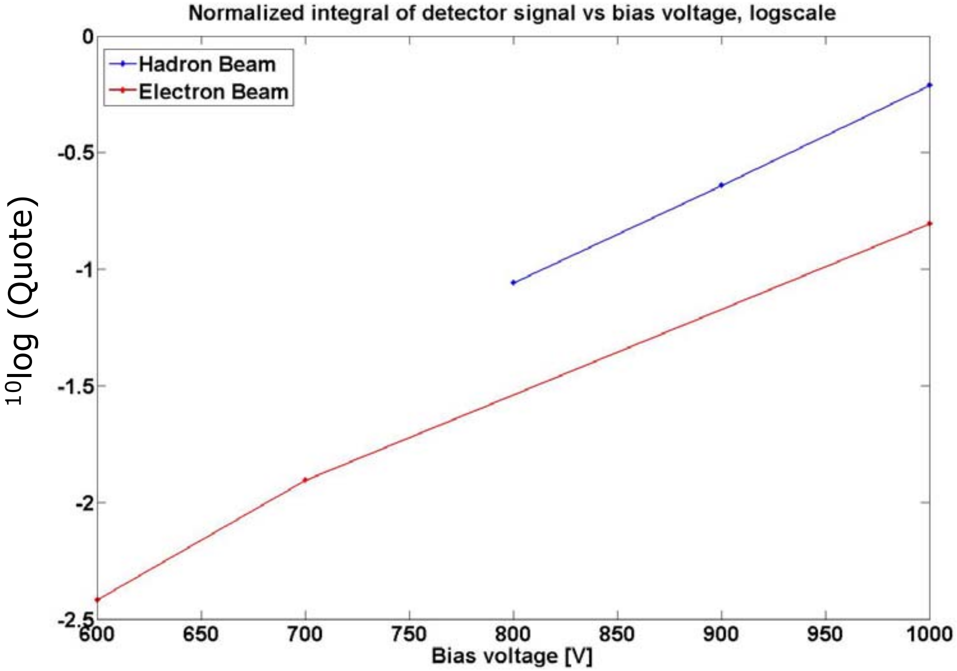


- Stability:
  - Histograms over the quotes fitted with Gaussians shows ~1% variation (σ/<x>).



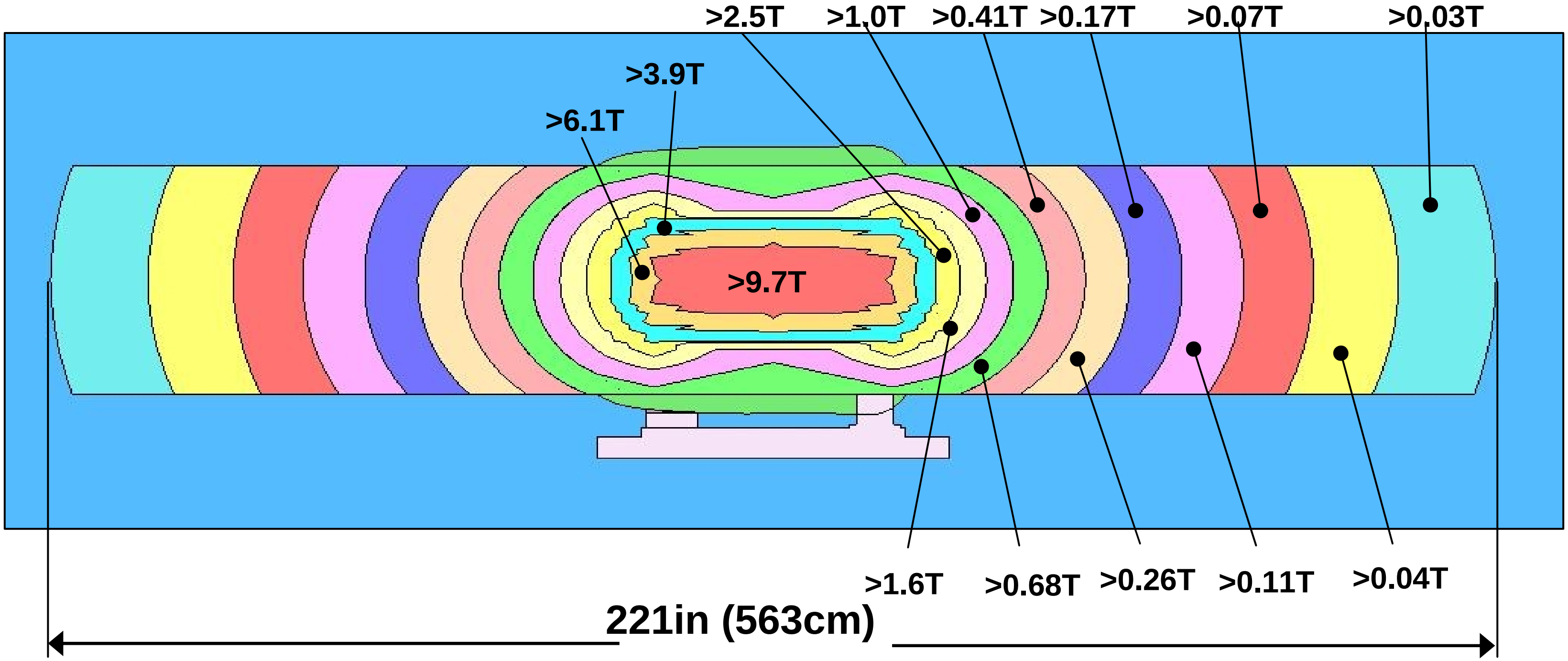
Test with Hadron Beam

- Gain vs. HV
  - The integrated signal decreases by a factor of ~40 when the HV is lowered from 1000 V to 600 V (red curve)



Performance in magnetic field

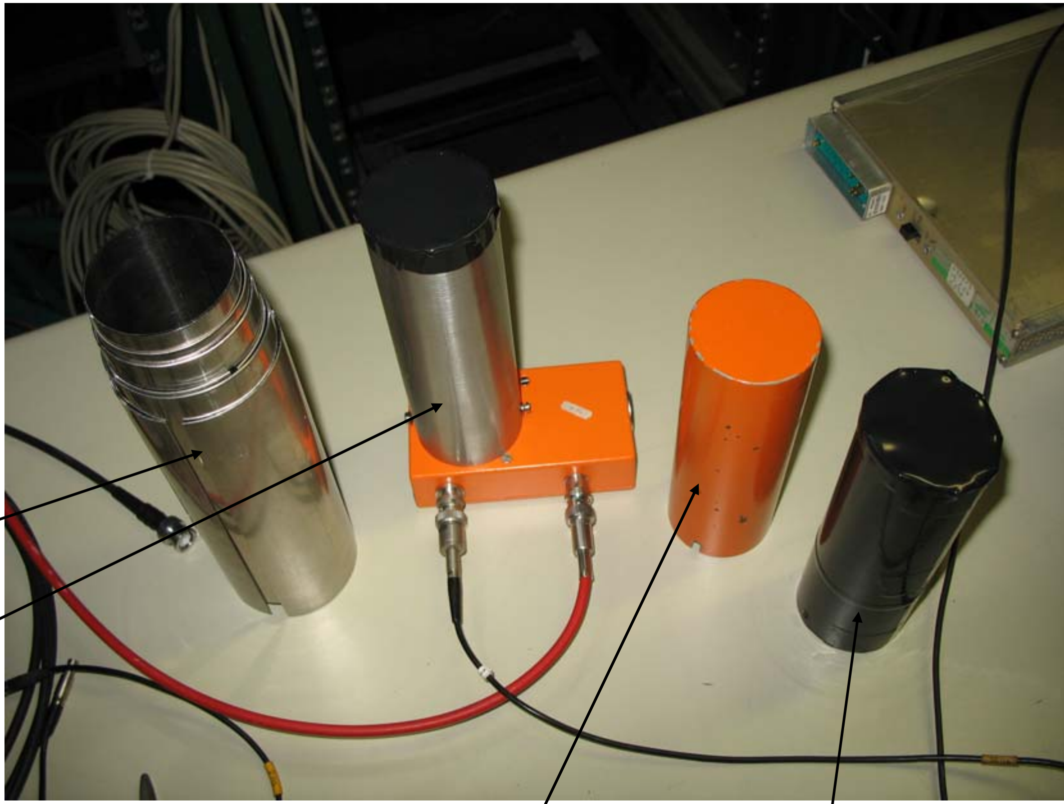
- Motivation: 3 meters from the interaction region we have a magnetic field of ~300 Gauss. The detector must still function in this environment. Placing the detector closer to the solenoid should not be necessary.



Performance in magnetic field

- In general, a photo-multiplier does not work beyond 50 G.
- To shield the ACEM from the B-field, we used up to 6 layers of μ-metal around the tube.

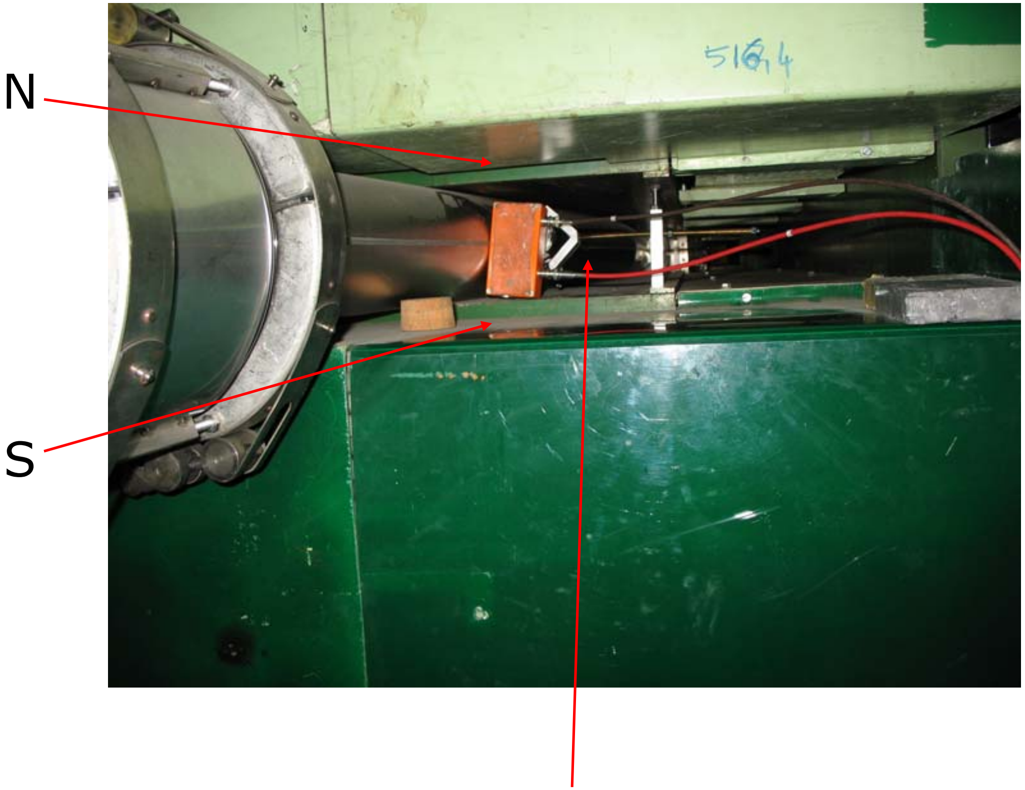
  Thickness: 1 mm/layer.



- Sheets of μ-metal
- Stainless steel-cylinder with taped top (used in magnet testing)
- Original tube (slightly ferromagnetic)
- Tape-covered paper tube (block day-light)

Performance in magnetic field

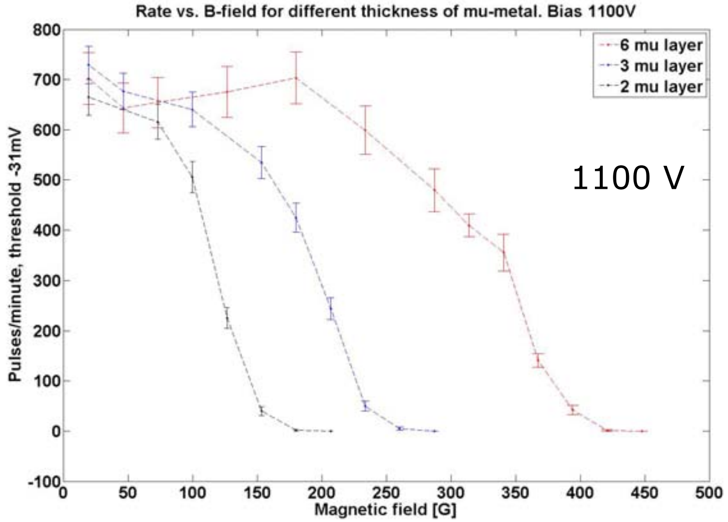
- Setup
  - To verify that the μ-metal shielding works, the detector was placed inside a dipole magnet in a secondary beam line from SPS.
  - We used ^{90}Sr as radiation source (β^-). Since the original tube cover blocked too much of the radiation, it was replaced with a stainless steel cylinder covered with black PVC-tape.
  - The detector signal was sent to a discriminator (threshold -31 mV) connected to a counter in order to see how the pulse rate decreases as the magnetic field gets stronger.

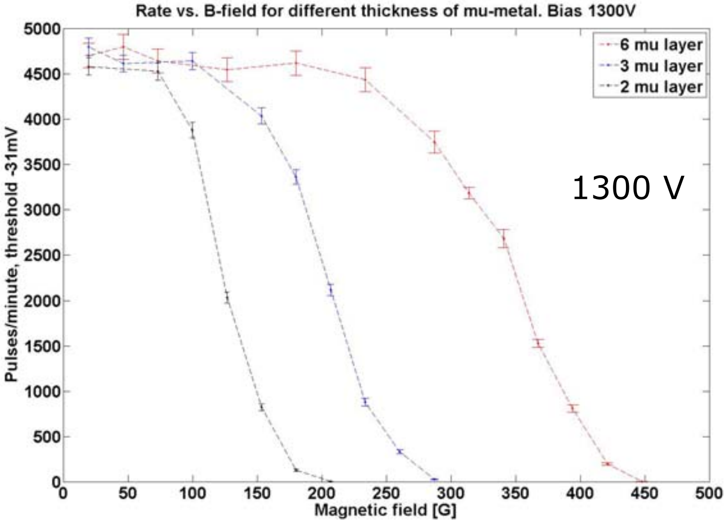


Detector (radiation source barely visible here, but attached to the top)

Performance in magnetic field

- Results
  - Undisturbed by magnetic field up to ~200 G with 6 mm μ-metal
  - The rate is halved at ~350 G independent of the bias voltage (with 6 mm μ-metal).
  - This is not necessarily a disadvantage, since the general problem with particle detection in MERIT is that the particle flux is extremely high.
  - Otherwise, we can just put more shielding around the tube.


Rate vs. B-field for different thickness of mu-metal. Bias 1100V


Rate vs. B-field for different thickness of mu-metal. Bias 1300V

Conclusions

- Detector functions as expected in beam. Long term accuracy ~1%.
- Magnetic field from solenoid not an issue up to 300 Gauss. Use more μ-metal if we want to be closer to the interaction region.
- Good backup detector for use in MERIT.

Outlook:

- Investigate how much HV to use in MERIT and detector behavior at this voltage level.
- PCVD-diamonds as particle detectors…