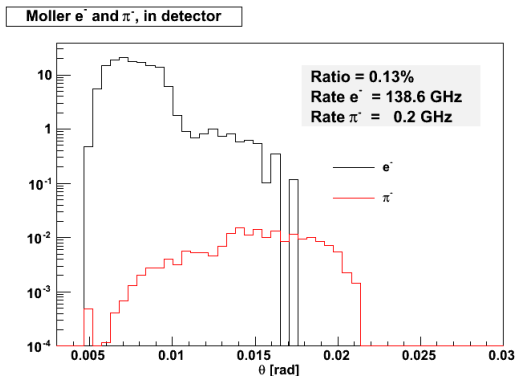


Some Random Notes on Pion Detector and Backgrounds for MOLLER
Mark Pitt, Wed. Oct. 5, 2016

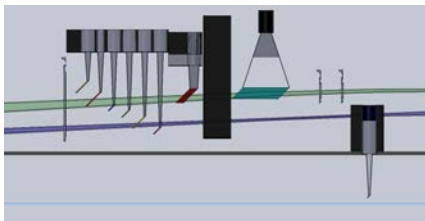
These are mostly based on a phone conversation with KK of his description of the parameters that define the needs for the pion detector in MOLLER.

- MOLLER 2014 MIE document says pion contamination in MOLLER ring $\sim 0.1\%$. Agrees with Seamus simulation which gives $\sim 0.13\%$.
- The thickness of the shower-max detector plus lead shielding likely to be ~ 30 radiation lengths, resulting in pion detection efficiency at back detector of $\sim 10\%$. The anticipated (?) remaining charged particles from the showering of the high energy electrons is $\sim .01\%$, resulting in a desired pion to electron ratio at the back detector of $\sim 1:1$, so that the measurement of the anticipated ~ 0.5 ppm = 500 ppb pion asymmetry in integration mode is not significantly diluted.
- The pion dilution factor will be measured by confirming they are pions with a coincident MIP in the shower-max detector and pion detector. At full beam current the pion rate is ~ 200 MHz, so the resulting rate (per pion detector) at 100 nA in tracking mode is a manageable ~ 3.6 kHz (assuming the 10% detection efficiency).
- The budget (for both GEM planes associated with the pion detector and the pion detectors) estimated in the 2014 MOLLER MIE proposal assumed 6 (not sure why it wasn't 7?) pion detectors. So it was always assumed that there would be nearly full coverage. KK suggested we might get away with half coverage if cost is an issue, but we'll need to think hard before going down to covering just one septant due to the transverse asymmetry issues.
- In doing simulations for determining the optimum lead wall thickness it will be important to have the shower-max detector (or some dummy with equivalent radiation lengths) in place upstream of it. The shower-max detector is still being developed, but it is anticipated that it will be ~ 10 -15 radiation lengths. If we don't have it in the simulation at the moment, we could perhaps get a default design from Dustin to have in there as a placeholder.
- Overall, just as a reminder, the pion dilution is expected to be $\sim 0.13\%$ with a ~ 0.5 ppm asymmetry (based on E158 experience) resulting in a 0.7 ppb correction in the main MOLLER thin quartz ring that we would like to measure to about 20% of itself. The correction is anticipated to be a factor of 3 smaller in the shower max detector.
- Seamus' simulation slides on this from the 2014 Science Review are attached.



- After optics and detector taken into account, contamination is $\sim 0.13\%$

Detector Setup



- Use lead filter to shower/stop e^- , pions more likely to punch through
- Use quartz/tungsten + shower to measure pion contamination and asymmetries

Detected pion rate/width made worse by:

Smaller azimuthal coverage	Rate $\times 0.5$
Pions stopped in lead	Rate $\times 0.1$
Showers into detector	Width $\times 2.0$
δA_π	148 ppb

Uncertainty from pion correction has uncertainty from ability to measure A_π and knowledge of N_π/N_{ee} :

$$A_{ee} = A_{\text{meas}} \left(1 + \frac{N_\pi}{N_{ee}} \right) - A_\pi \frac{N_\pi}{N_{ee}}$$
$$\delta A_{ee}|_\pi = \delta A_\pi \frac{N_\pi}{N_{ee}} \otimes (A_{\text{meas}} - A_\pi) \delta \left(\frac{N_\pi}{N_{ee}} \right)$$

Assuming no uncertainty in N_π/N_{ee} :

Detector	N_π/N_{ee}	$\delta A_{ee} \pi$
Quartz	0.13%	0.2 ppb
Quartz shower	0.04%	0.06 ppb

If A_π is 1 ppm, uncertainty in N_π/N_{ee} needs to be relative 10%

For Hyperon decays:

$$N_{\Lambda}/N_{\pi} \sim 10^{-5}, A_{\pi} = 1 \text{ ppm} \rightarrow 10 \text{ ppm}$$

Assuming $A_e = 35 \text{ ppb}$

Detector	$\Delta A \text{ [ppb]}$		$\delta A \text{ [ppb]}$	After Run 1
	$A_{\pi} = 1 \text{ ppm}$	$A_{\pi} = 10 \text{ ppm}$		
Moller Quartz	1 ± 1	13 ± 1		3
Moller shower	0.3 ± 0.3	4 ± 0.3		3
Pion Shower	1000	10000		825

Shower detector will pick out presence of hyperons to high precision in only run 1