Please find below email exchanges dated back in Dec 2022-Feb 2023. After we submitted the eRD112 FY23 proposal that listed the AC-LGAD detector specs, the project office raised some questions related to the TOF material budgets "What material budget is tolerable based on the performance of the detectors sitting behind ToF systems?"

Answers to these questions documented in [1] were discussed at TOF, eRD112/LGAD consortium meetings, and provided to the project office. The answer to the TOF material budget question is attached below:

The material budget for the BToF (FToF) is 1% (8%) X0. A breakdown of the contributions to the material budgets can be found in [10], with the dominant contribution from the cooling and mechanical supporting structure. (Q2) We don't anticipate a significant change in the material budget for the BToF, which is optimized to be around 1% X0 and the impact on the performance of the DIRC and barrel EMC calorimeter is acceptable.

The barrel DIRC detector is designed to provide PID at relatively large momentum, e.g. 3-sigma pi/K separation up to 6.5 GeV/c. To achieve such performance, the track angular resolution at the surface of the DIRC has been assumed to be 0.5 mrad in DIRC simulation. Multiple scattering through 1% X0 material leads to 0.5 mrad smearing for particles with momentum below 3.2 GeV/c [5]. If the BToF material budget increase to 2% (4%) X0, the smearing would be 0.5 mrad for particles with momentum below 4.6 (6.8) GeV/c [5], which could deteriorate the DIRC PID performance. We note that a simulation study for the track angular resolution for DIRC was only very recently completed [11], and more detailed studies are needed involving not only tracking but also DIRC.

The BTOF is placed at the radius around 65 cm, about 15 cm away from the front surface of the barrel EM calorimeter. The impact of the BToF material on the performance of the barrel EM calorimeter is negligible according to [6].

(Q2) We foresee a possible need to reduce the material budget for the FToF, corresponding to 8% X0 material in front of the dRICH and forward EM calorimeter.

The dRICH is designed to provide PID at relatively large momentum, e.g. more than 3-sigma pi/K (e/pi) separation between 3-60 (1-15) GeV/c. To achieve such performance, the track angular resolution at the entrance of the dRICH is assumed to be 1 mrad. Multiple scattering through 8% X0 material leads to 1 mrad smearing for particles
with momentum below 5 GeV/c [5]. If the FToF material budget reduces to 4% X0,
the smearing would be less than 1 mrad for momentum above 3.4 GeV/c [5], which would be consistent with the assumed angular resolution for the dRICH momentum coverage. We note that a simulation study

for the track angular resolution for dRICH was only very recently completed [11], and more detailed studies are needed involving not only tracking but also dRICH.

The FToF is placed at z=190 cm, about 140 cm in front of the forward EM calorimeter. A detailed simulation with ePIC software is still to be done, but according to [6], the impact of the FToF material on the forward EM calorimeter may not be negligible.

As you can see, the argument on 1% BTOF material budget was driven by the 0.5 mrad angular resolution requirement by DIRC. I would like to note that the microgas detector at R~55-60 cm and uRWELL at R=72.5-75 cm are designed to provide better than 150 um single hit resolution and thus improve the angular resolution for DIRC [*]. *However, it seems to me that these two detectors alone are insufficient to constrain the angular resolution for DIRC, as the angular resolution achievable with two points each with 150um resolution and separated by 12.5 cm, is 150 um*sqrt(2)/12.5cm=1.7 mrad, and 1.1 mrad when separated by 20cm.

Best,
Zhenyu

[*] Incremental Preliminary Design and Safety Review of the EIC Tracking Detectors, March 20, 2024

On Jul 31, 2024, at 08:31, Matthew Posik <posik@temple.edu> wrote:

Hi All,

The most recent tracking angular resolutions going into the various PID systems were presented here at the tracking meeting on May 30th (starting at slide 20):
https://indico.bnl.gov/event/23630/contributions/92294/attachments/54845/93843/05-30-2024-TrackingWG_CraterLakeComparisons.pdf

More recent studies (fast and full simulations) have been presented at the MPGD simulation meeting (https://indico.bnl.gov/event/24221/) by Shyam and myself:

Fast simulation update:
https://indico.bnl.gov/event/24221/contributions/94045/attachments/55833/95494/Tracking_Performances_Shyam_15July24.pdf

Full simulation update:
https://indico.bnl.gov/event/24221/contributions/94046/attachments/55823/95470/07_15_2024_DIRCAngleRes.pdf

The 0.5 mrad angular resolution requirement coming from the DIRC group was for a momentum setting of 6 GeV. We do not yet have requirements for other momentum settings. There was some discussion with the DIRC group at the collaboration meeting and my understanding from Sourav is that they are going to look at angular resolution requirements for lower momenta tracks, and update their PID look-up tables (which assume 0.5 mrad track resolution over all momenta) to use the angular resolutions that were presented in the tracking WG meeting on May 30th. Sourav, pleas correct me if I got something wrong.

What we see from simulations is near |eta| < 0.5, we are not too far from the 0.5 mrad @ p = 6 GeV requirement. Slide 29 from the Tracking WG report shows the angular resolution vs eta for 6 GeV tracks propagated to the DIRC entrance. Here we find about 0.6 mrad angular resolutions, and then they degrade as we move to larger |eta| due to tracks crossing more material.

The simulations show that we are dominated in ePIC by multiple scattering effects which prevent us from improving angular resolution based solely on the spatial resolution. We generally find good agreement between full and fast simulations, with the benefit that in fast simulation we can easily separate the contributions coming from the detector spatial resolutions and the multiple scattering. From slide 10 from the Fast simulations, you can see how dominate the multiple scattering contribution is.

With ePIC being dominated by multiple scattering, this means that our angular resolutions will follow our material budget, increasing any material along the path to the PID detector will degrade the resolutions. This effect is much more sensitive at lower momenta and depends on the amount of material being added. For example, slides 25 and 26, show angular resolutions vs. momentum. The black markers represent the current ePIC configuration, while the blue markers represent a 50% decrease in the outer MPGD barrel layer material. Comparing the two markers you see a larger difference in performance at lower momentum (~1GeV), which converges at larger momentum. Larger material changes could also alter performance at larger momentum. To have a complete picture of the impact on DIRC performance we would need to know

1. What is the required tracking angular resolution from the DIRC for tracks less than 6 GeV?
2. What is the max momentum the BToF can reliably reach? If upper momentum reach of the BToF can provide good PID for the lower momentum reach of the DIRC, then maybe the DIRC performance could be relaxed in that region, if tracking is having a difficult time to meet its requirement.

Elke, there is not yet any implementation of the barrel imaging calorimeter in the track reconstruction. I am hoping to have an idea of what its impact could be in the next couple of weeks. However, given that ePIC is already dominated by multiple scattering and that a hit in the imaging calorimeter needs to pass through the full DIRC material budget (~13% X0) I would not expect a significant impact from the detector on the angular resolutions, but its impact still needs to be demonstrated.

Thanks,
Matt

Matt Posik
Research Associate Professor