Proposal Committee Subgroup: Integration & Global Design

Status Report

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October 28, 2021

BROOKHAVEN
NATIONAL LABORATORY

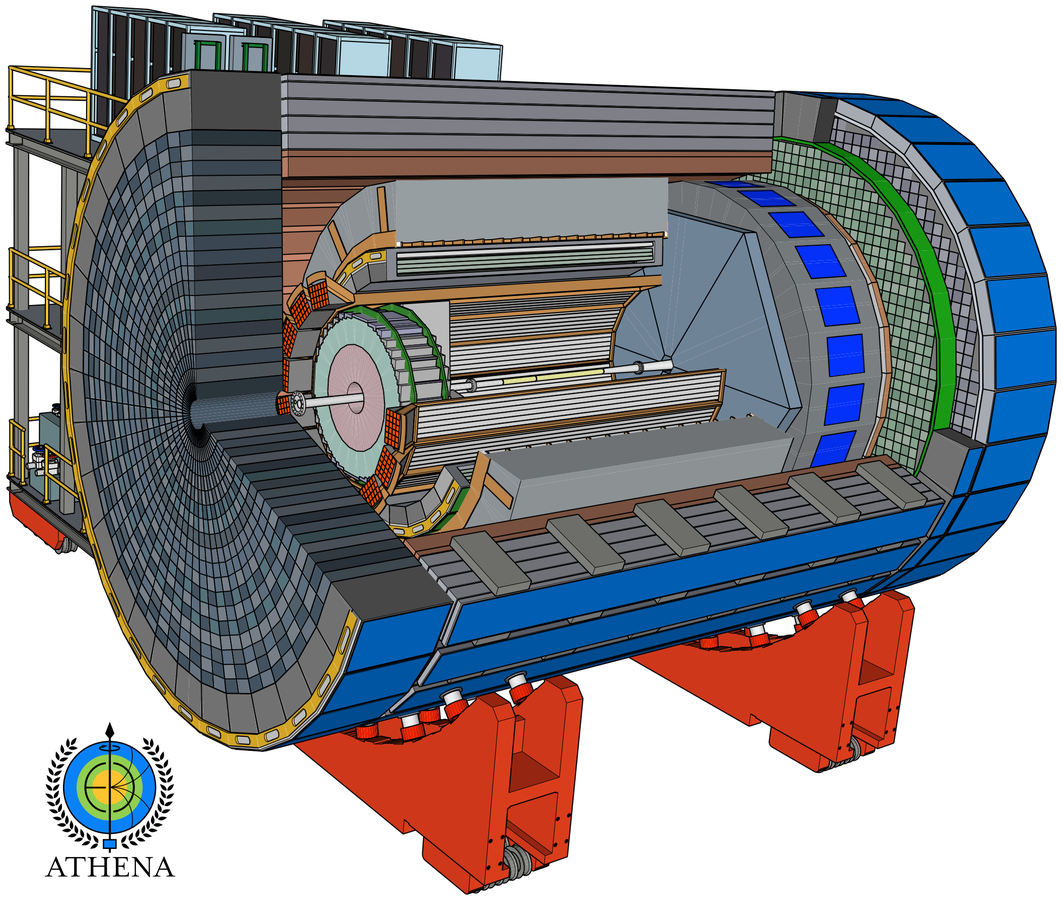
Goal of the I/GD Subgroup

Define ATHENA baseline detector in collaboration with

- Detector Working Groups
- Engineers
- Project
- Software Group
- Physics Working Groups

Guiding principles of ATHENA design

- Maximize tracking capabilities (3T)
- Maximal possible overall size
- Large acceptance
- Performance matching requirements
- Robustness
- Upgrade capabilities
- Cost effectiveness



Organization

- Weekly Meeting on Wednesday 11:00 EDT (17 so far)
  - `https://indico.bnl.gov/category/378/`
  - Committee + Invited Colleagues (varying, DWG & PWG conveners, Software, …)
- Wiki Pages
  - `https://wiki.bnl.gov/athena/index.php/Integration`
- Project Support/Contact
  - Elke Aschenauer
  - See also project relate info at `https://wiki.bnl.gov/athena/index.php/Project`

Status

Status

- Yes, we completed the definition of the baseline detector (10/20/2021)
- We think that the ATHENA design fulfills all physics requirements and the goals we had set for us
- There is plenty of room for optimization - devil is in the detail
  - Much of this will have to happen after December 1
- The proposal is not the end of the design process - work will need to continue

Last Touch to the ATHENA Baseline

The key feature of ATHENA is a large 3 T magnet providing optimal tracking performance but that also has some downsides in some areas that we need to work around

- Operation of photosensors in high-B environment (→ another talk)
- Tracks curl up in barrel region
  - $p_T^{\text{accessible}} > 0.45r$ [GeV/m]
  - Tracking solved compact Si-Tracker
  - Lack of PID in barrel region practically for $p_T < 0.5$ GeV/c
    - Big concern for I/GD group (no such gap in ECCE)
    - Option 1: low-field runs ⇒ sub-optimal, deterioration of overall performance, non-optimal use of run time
    - Option 2: add PID detector at small radii
      - requires no degrading of tracking performance
      - has to have low mass (EMCal !)

Last Touch to the ATHENA Baseline

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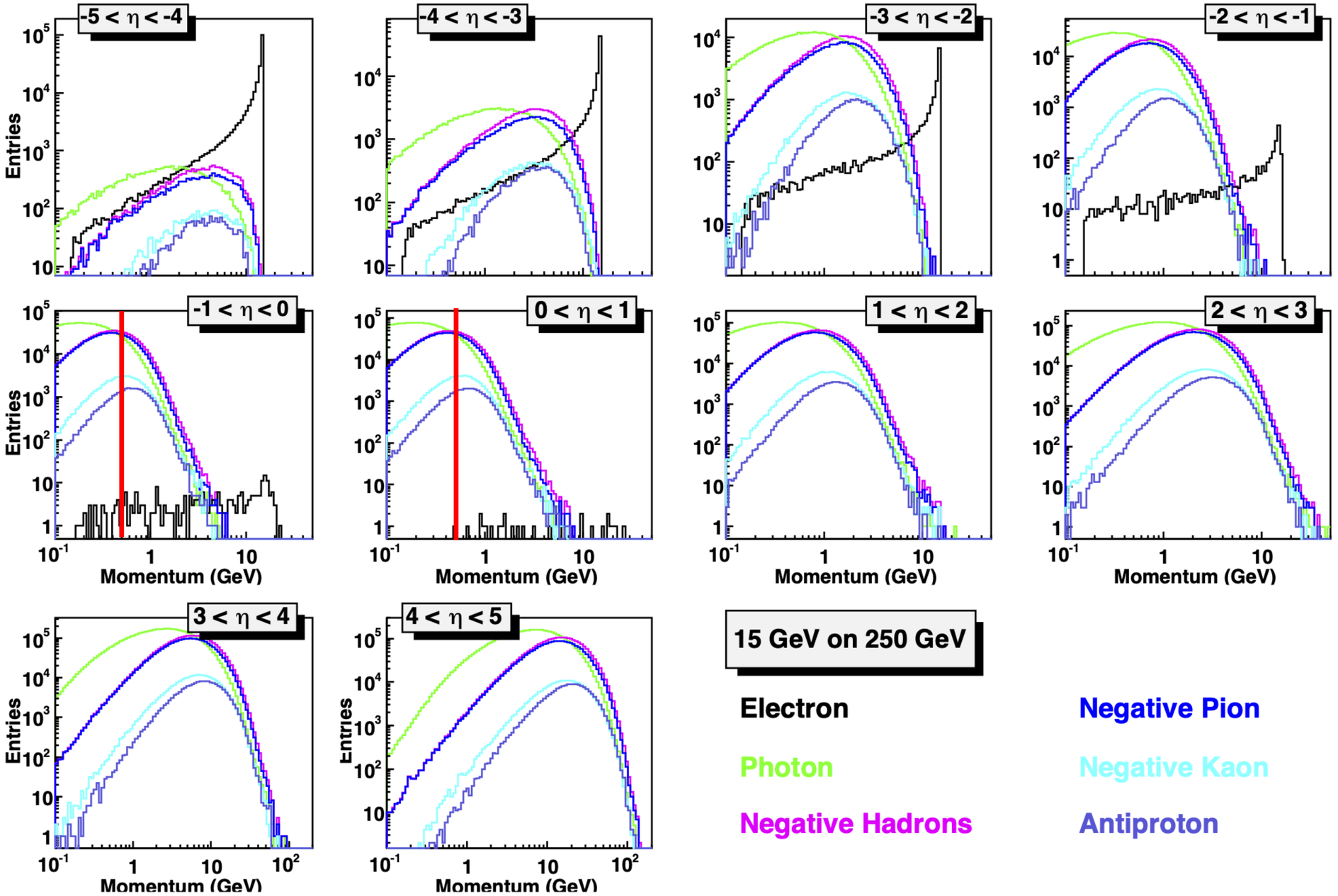

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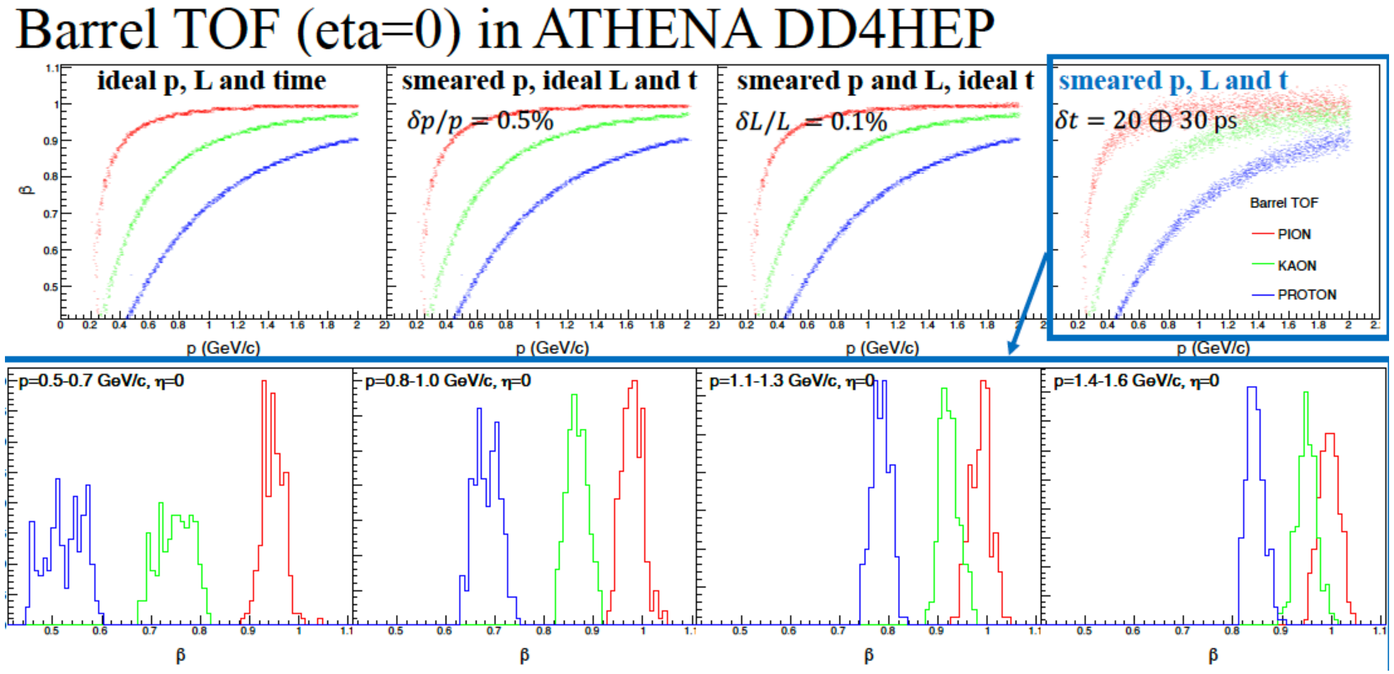
Barrel Time-of-Flight Based on AC-LGAD Sensors

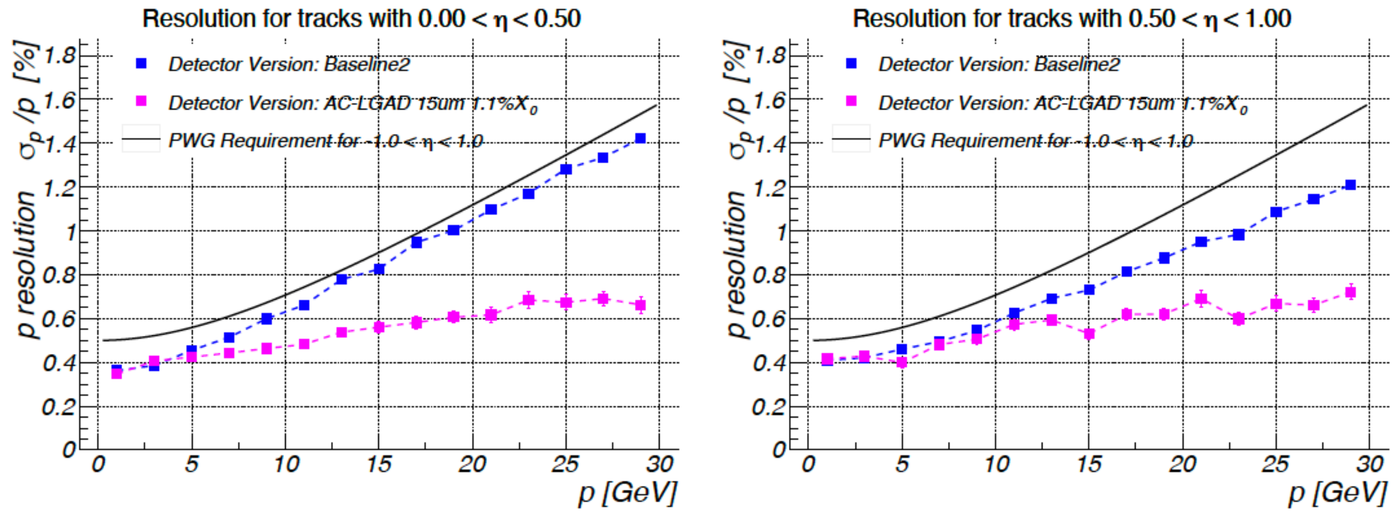
- Proposed by Univ. of Illinois at Chicago, Rice, and BNL groups
- AC-LGAD technology has various applications in ATHENA already
  - Roman Pots in FF region
  - B0 in FF region
  - AC-LGAD is an improvement over LGAD that is used already at LHC
  - Have common designs in sensor technology & ASICs: can combine R&D efforts
  - Requirements:

	Time resolution / hit	Position resolution / hit	Material budget / layer
Barrel ToF (Tracker)	<30 ps	(3-30 μm for Tracker)	$< 0.01\ X_0$
Roman Pots	<50 ps	$< 500/\sqrt{12}\ \mu m$	N/A
B0	<50 ps	$O(50)\ \mu m$	$< 0.01\ X_0$

  - Proposed geometry:
    - -1 < z < 1, R ~ 0.5 m, -1.1 < η < 1.1, A=6.28m^2

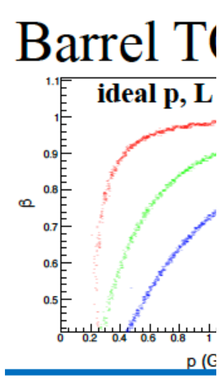
AC-LGAD ToF - Performance

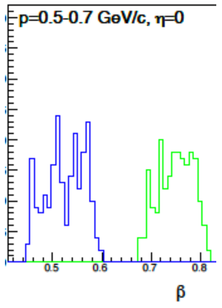


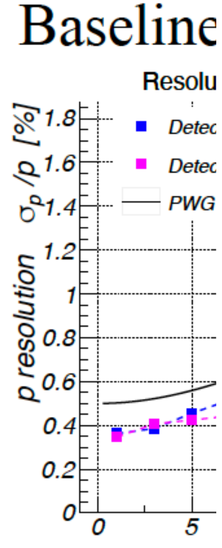


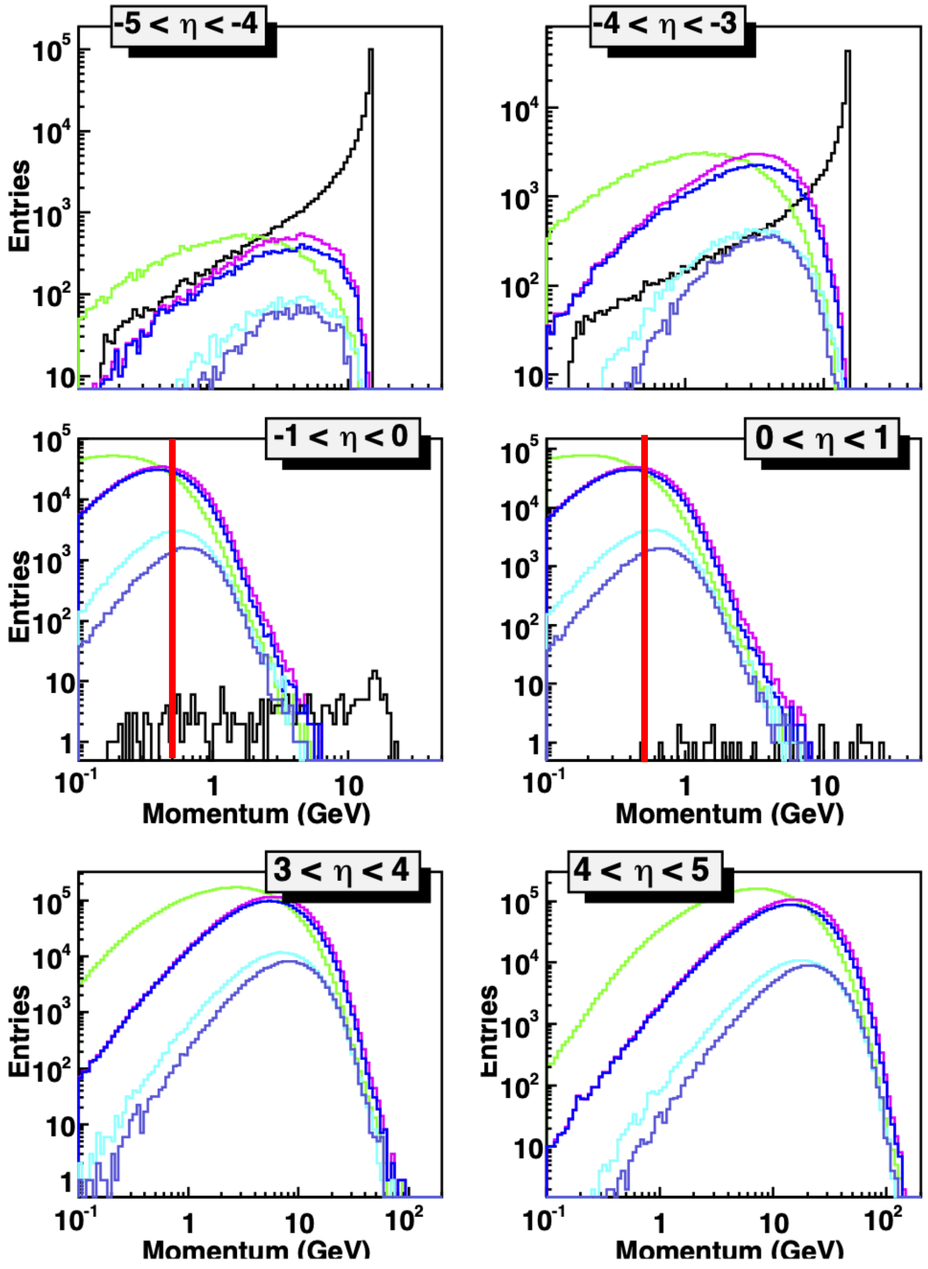
- Delivers needed PID between 0.2 - 1 GeV/c
  - Note that relative $\pi/K/p$ yields are not realistic in sims
- Offers some overlap with DIRC
- Very small impact on the momentum resolution at low momentum and significantly improvement on the momentum resolution at highest p_T (10 GeV/c)

AC-LGAD ToF - Performance









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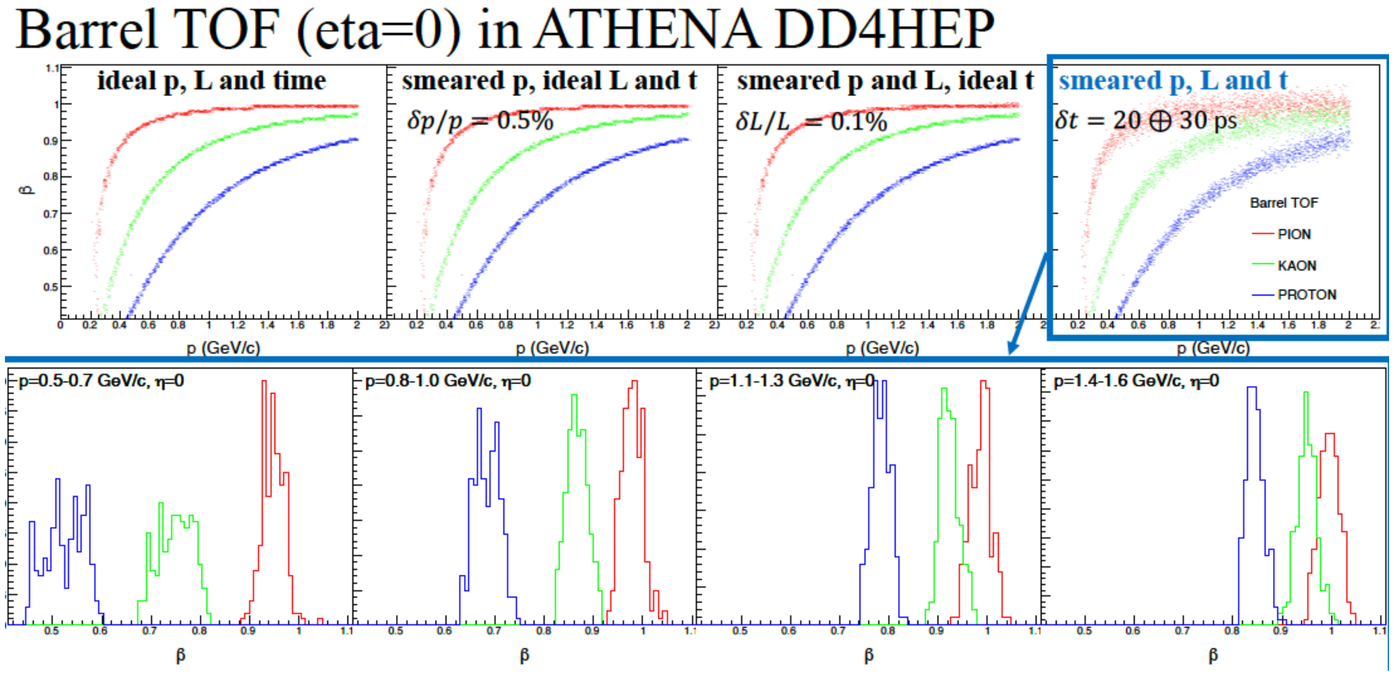
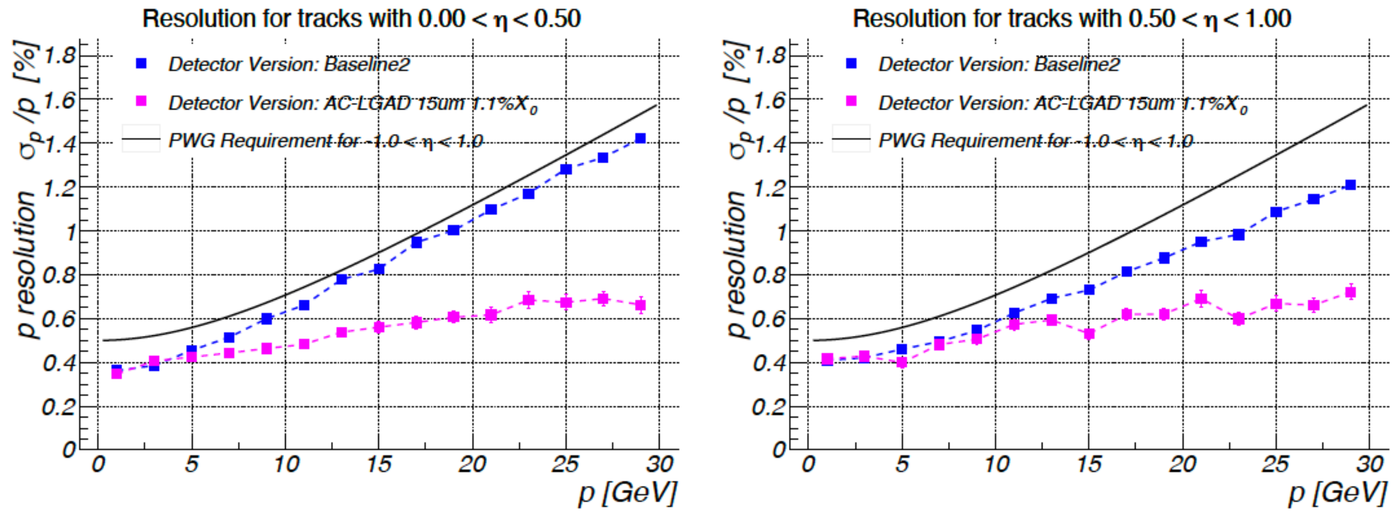
AC-LGAD ToF - Performance





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Our Worries

The I/GD group was (and still is to some extend) worried about several issues

- Fast ToF = Heat
- Proposed position interferes currently with MMG layers
- Effect of thickness on EMCal?
- Routing of services?
- Time-to-proposal
  - Not enough time to optimize B2.0 tracking geometry again
  - Need to run production for physics evaluation
  - Question: Could it replace a MMG layer or do we welcome the additional tracking points for improves pattern recognition?

Barrel Tracker (B-2.0, Numbers from ATHENA Canyonlands_v1.1 Tag)

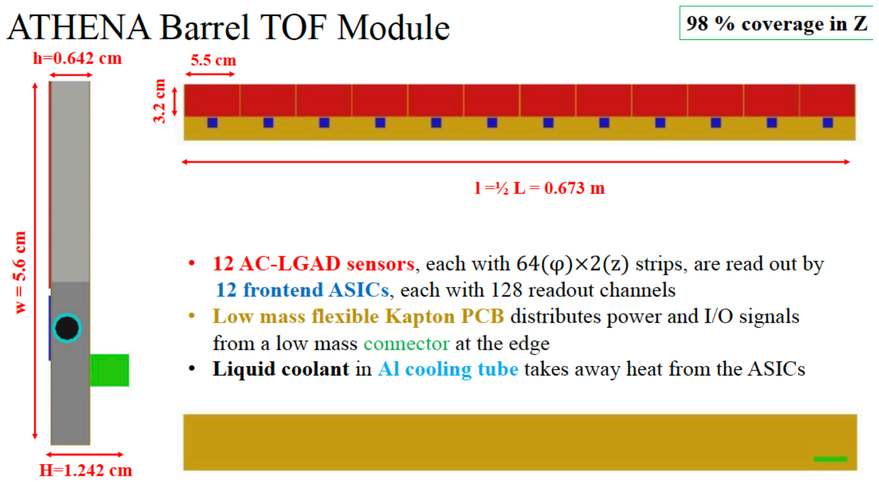
Silicon Tracker (3 Vertex + 2 Barrel Layers)

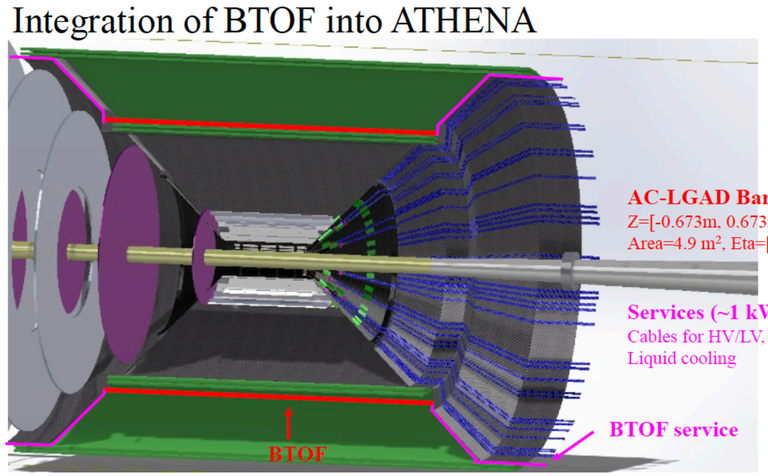
R (cm)	Length (cm)	Resolution	Active Area Material (X/X0 %)
3.3	28.0	10 um pixel pitch	0.05
4.35	28.0	10 um pixel pitch	0.05
5.4	28.0	10 um pixel pitch	0.05
13.34	34.34	10 um pixel pitch	0.55
17.96	46.68	10 um pixel pitch	0.55

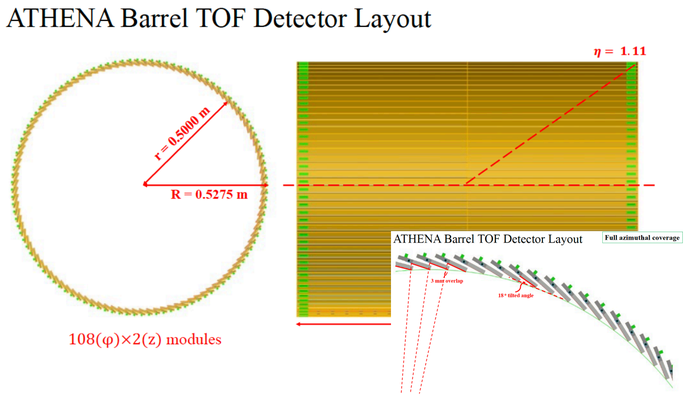
Micromegas Barrel (4 barrel layers)

R (cm)	Length (cm)	Resolution	Active Area Material (X/X0 %)
47.72	127.47	150 um (r-phi) x 150 um (z)	0.4
49.57	127.47	150 um (r-phi) x 150 um (z)	0.4
75.61	201.98	150 um (r-phi) x 150 um (z)	0.4
77.46	201.98	150 um (r-phi) x 150 um (z)	0.4

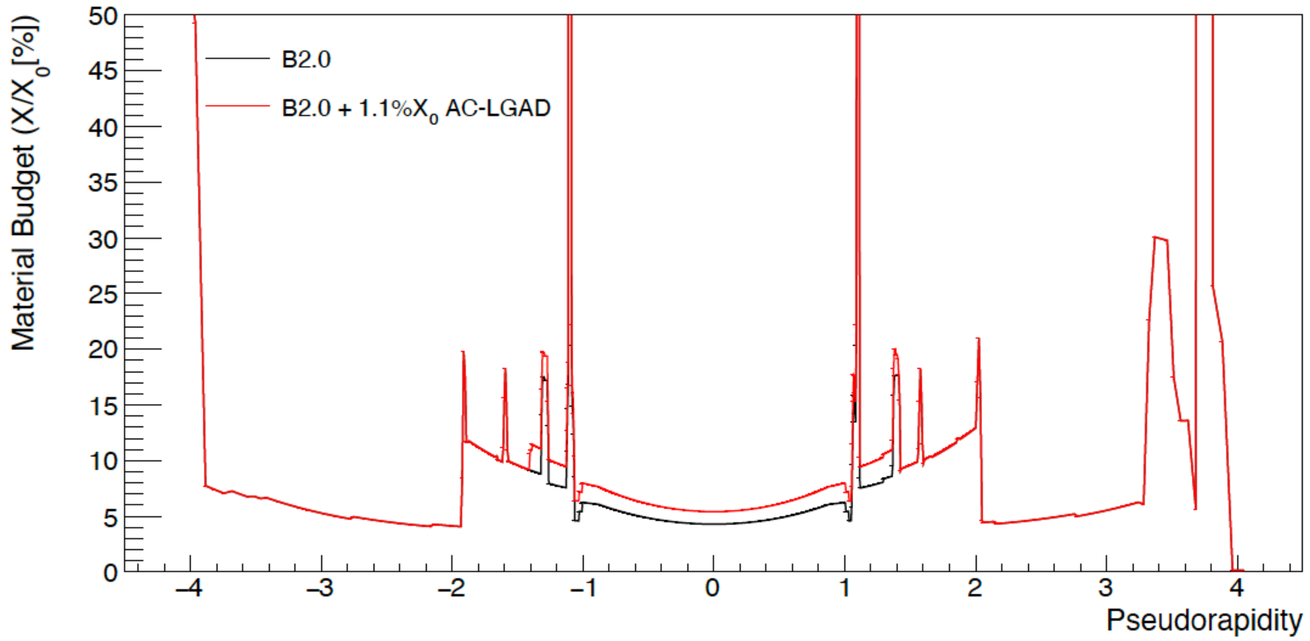
Retiring Some of the Issues







ATHENA Tracker Baseline 2.0 - Material Scan



- Still much work to do but it seems doable and the impact on material and heat production is moderate (pixel → strips)
- Geometric acceptance?
- Integration needs a closer look

Decisions, Decisions

- I/GD group adapted a barrel ToF based on AC-LGAD into baseline
- However, we will not change the current tracking baseline B2.0
- In the proposal we have to balance the fact that the ATHENA baseline detector has a bToF but that its performance was evaluated separately
  - Puts burden on
    - I/GD writing the intro/design part and the risk evaluation
    - PID WG and ToF proponents to produce the main text for this
- Much work to be done after December 1. Expect homework questions on this after December 13-15 review. Need to get B3.0 out running with optimized tracking and integrated bToF once the proposal is submitted.
- N.B.: I/GD sees no need/motivation for a forward ToF at the moment

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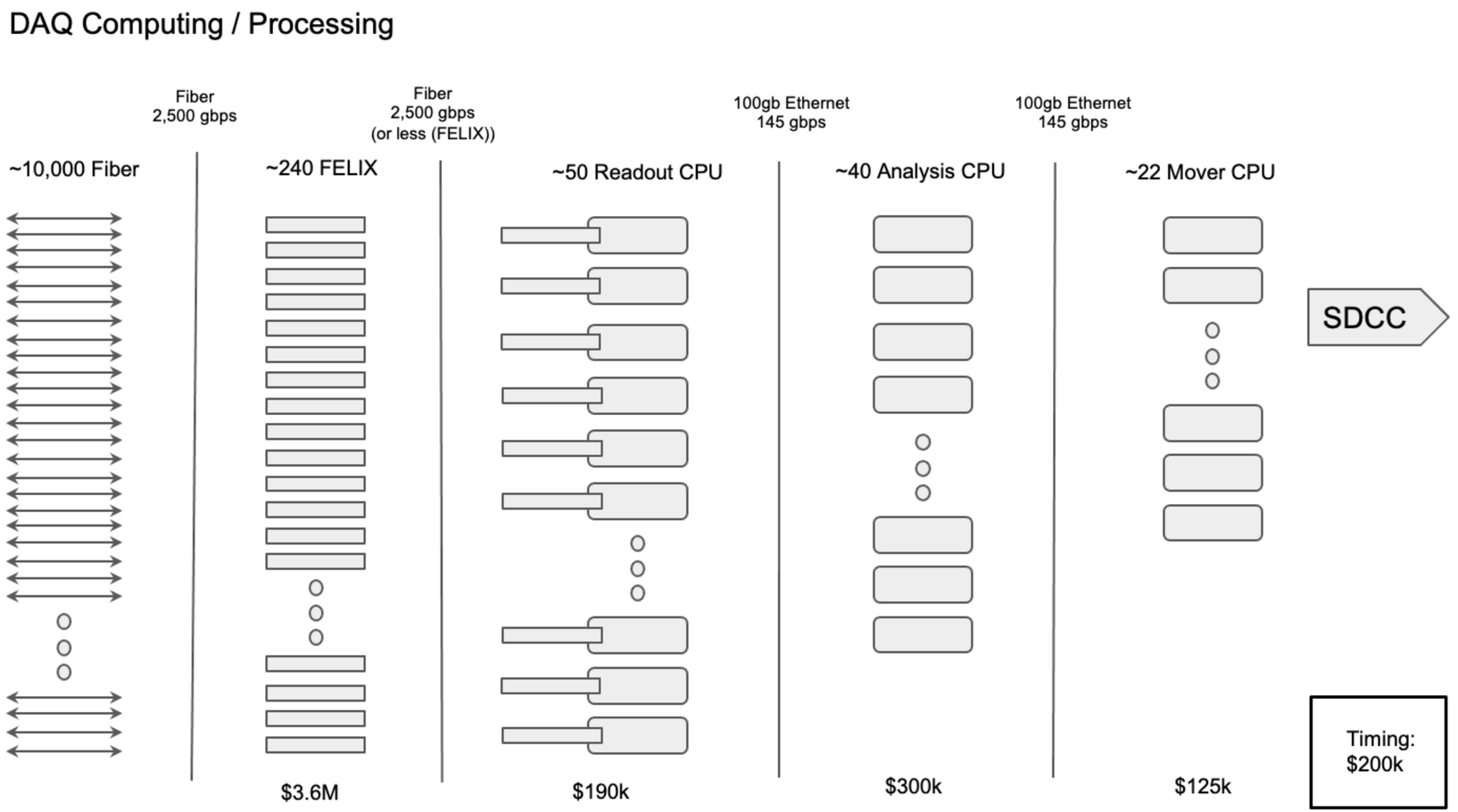
We understand that this decision was a bit controversial and created some nervousness in the collaboration so shortly before the deadline **but we felt that the benefit outweighs the disadvantages**. We simply cannot write a proposal for a detector that does not ID 50% of the hadrons in the barrel. We would not do our job properly if not attempting to eliminate a severe weakness of the current design.

Now for Something Completely Different: DAQ

- Current Design ➟

- Specific Challenges
  - Knowing the data volume to DAQ / to tape (Simulation / People to interpret simulation)
  - Low utilized links
  - SiPM detectors sensitive to single photons → very large dark count rates increasing with radiation exposure
  - Streaming model



Cost Optimization & Aggregation Scheme

The aggregation for most detectors is not yet fully designed, but as currently understood, many have very low fiber utilization! This adds to FELIX cost.

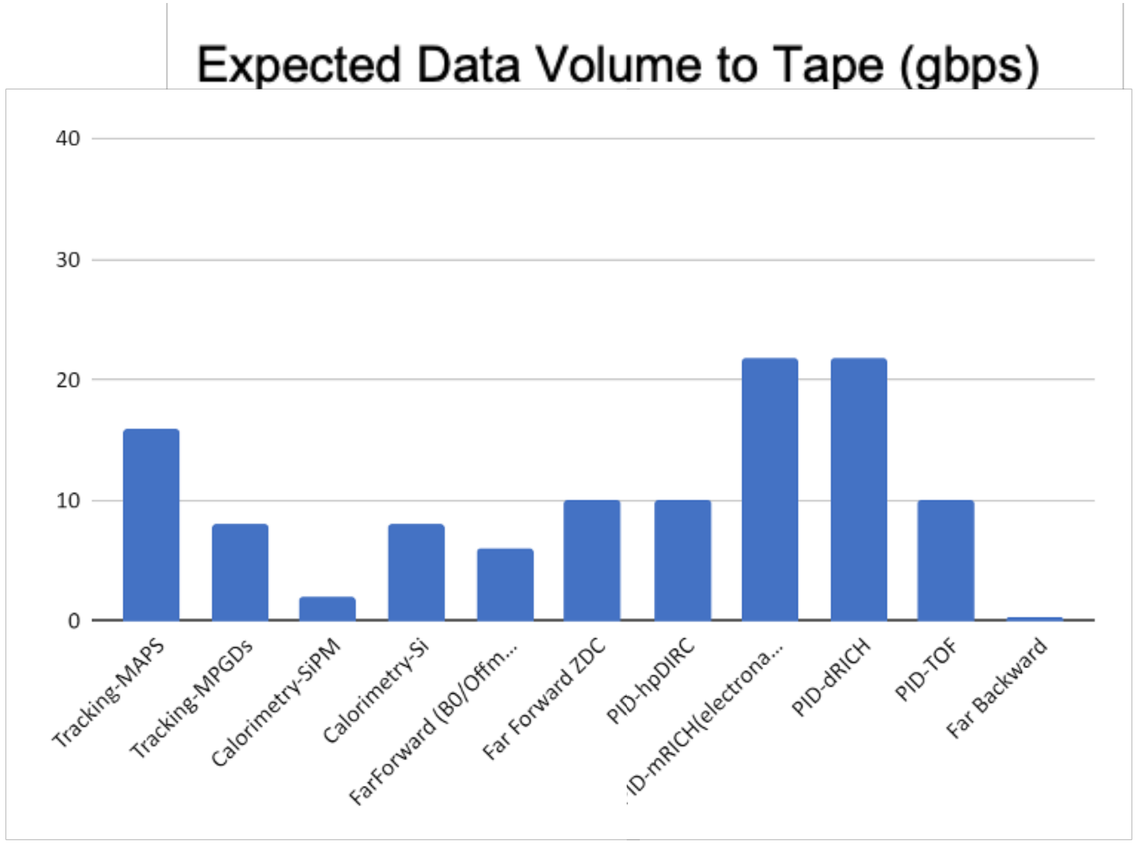
With a cheaper aggregation scheme we could reduce number of FELIX boards by ~x2 freeing ~$2M, however we would then have a design and construction project for aggregating ~5-10k fibers, which could easily cost O($2M)

Detector	Data Rate (gpbs)	Fibers	Rate/fiber (gbps)
Tracking-MAPS	16	600	0.03
Tracking-MPGDs	8	132	0.061
Calorimetry-SiPM	2	568	0.004
Calorimetry-Si	8	12	0.667
FarForward (B0/Offm/RP)	6	1393	0.005
Far Forward ZDC	10	102	0.099
PID-GridPix	32	144	0.223
PID-hpDIRC	10	1024	0.01
PID-pfRICH	1168	144	8.112
PID-dRICH	1168	144	8.112
PID-TOF	10	2442	0.005
Far Backward	72	15	4.8

Choosing option to be done soon after proposal selection:

- Use FELIX straight out
- New design
- Modify (simplify) FELIX for generic aggregation

DAQ Computing & Processing



Detector	CPUs	Rate/CPU (gbps in)	Rate/CPU (gbps out)
Tracking-MAPS	1	16	16
Tracking-MPGDs	1	8	8
Calorimetry-SiPM	1	2	2
Calorimetry-Si	1	8	8
FarForward (B0/Offm/RP)	1	6	6
Far Forward ZDC	1	10	10
PID-hpDIRC	1	10	10
PID-eRICH	15	78	1.5
PID-dRICH	15	78	1.5
PID-TOF	1	10	10
Far Backward	1	72	0.4

Readout CPUs must reduce the data volume for RICH detectors!

Requirements: up to 100gbps in, ~2-5gbps out.

Streaming Model

Definition of Streaming	Discussion as applies to proposed Athena System
No Trigger Electronics	This is the plan, but 1.The FELIX allows for trigger, and we hope to advocate for the capability in FEE, particularly SiPM based RICH Detectors 2.Strategically with regard to Proposal reviewers, also as debugging & fallback capability. 3.We must and will be able to assert deadtime via the timing subsystem
Detectors are self-triggered	Reasonable definition
Trigger on data present	Equivalent definition, certainly not “no selection is applied”, we need zero suppression
No deadtime	This is the goal, but may be impossible / be detector dependent
No Trigger	Our baseline is “software based trigger/filter” for SiPM based RICH and for FB detectors, (which implies need to consider trigger definitions, understand detectors, pre-calibrate some detectors, design, understand, and account for bias etc…)
Blurring of offline/online	True, but sloppy, very little blurring is due to streaming. But the new concept is valuable towards rethinking computing model: 1.Move calibrations earlier in reconstruction → even to data taking itself (specific cases?) 2.Move reconstruction tasks towards DAQ (ie. reconstruction done online) (vs) 3.Move reconstruction tasks towards offline (ie. event building → offline) 4.Move triggering (event selection) to offline

DAQ: Summary of Concerns

- DAQ group not happy with current level of understanding of data volumes
- Need to clarify, now that the detector baseline is complete, the expected number of fibers/data rate of fibers for each detector
- SiPM RICH detectors present significant data volume challenges due to dark currents
- Priorities after proposal selection include:
  - Define aggregation at the level of electronics design, with cooperation of DWG
  - Define timing system at the level of electronics design.
  - Define software trigger and/or AI/ML techniques for the dRICH/pfRICH
  - The streaming model is very much up in the air.
  - At the moment we have the need for at least software triggering
  - AI/ML techniques as regard Athena are not well defined, but are potential projects
  - Reconstruction / Calibration challenges & opportunities exist, but are not actually tied to “streaming”

I/GD Writing Efforts for Proposal

Proposal Outline (Updated)

Introduction (2 pages)
- Global Design Principles
- Physics Highlights

done

Detector (25 pages)
- Design Considerations
- Magnet
- Tracking
- Electromagnetic Calorimetry
- Hadronic Calorimetry
- Particle Identification
- Far-forward detectors
- Luminosity and low-Q^2 tagging
- DAQ and Readout
- Software Framework
- Risk in Technologies
- Integration Principles
- Upgrade Path

done

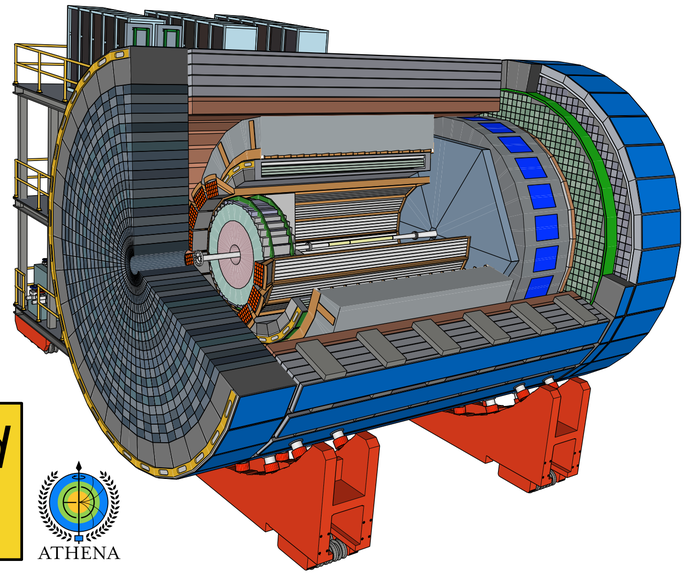
done this weekend

Physics (16 pages)
- Reconstruction Capabilities
- Origin of Spin
- Origin of Mass
- Gluons in Nuclei
- Other Opportunities

ATHENA collaboration Cost and schedule

Detector Graphics/Illustration:

- ATHENA Sketchup model (with help of project engineers and Elke)
  - I/GD will use it in intro
- CAD Drawing from project engineers will be available for subsystems (→ Elke)
- DD4hep graphics (Sylvester et al.)



Text will be submitted on Monday

Summary

- We have an ATHENA baseline detector
- A last minute change was the addition of AC-LGAD based ToF to overcome the lack of PID at low-p_T
  - Definition of B2.0 does not change
  - bTOF has to included and studied more after submission of proposal
    - Optimization of barrel tracking with bTOF in setup
    - Engineers need to have a new look at whole barrel integration
- DAQ work is progressing
  - WG not happy with current level of understanding of data volumes
  - Cost optimization: Felix cards versus cost of aggregation of fibers
  - Long list of action items after proposal selection
- Good progress in writing material for proposal

Note on ATHENA Wiki (I)

- A unexpected flaw has been discovered a few days ago in our Wiki configuration which allowed unauthorized creation of accounts and pages.
- This resulted in numerous spam pages placed on our site by bad actors.
- Didn't affect legitimate ATHENA content
- Immediate action has been taken by Maxim and BNL ITD to rectify the situation.
- It was determined that the most efficient way to proceed is to migrate all valid content to a new server and retire the existing one
- The migration has been completed yesterday and should be transparent to users

Note on ATHENA Wiki (II)

- The cleaned up Wiki: `https://wiki.bnl.gov/athena/index.php`
  - It is important that this new site is checked for consistency
- The old page with the original material is `https://wiki.bnl.gov/athena-old/index.php`
  - Will be available until Nov 3 and then deleted
- Accounts on the new site will be recreated by Maxim on request from working group leaders. As before, there will be one authorized account per working group. Please do so soon since the Wiki pages are important for the proposal process.
- A note from Maxim:
  - Too many are using the syntax reserved for external links in Wiki, to refer to internal pages. It works but creates problems during migrations and also produces the "link" symbol which semantically is "external".
  - Example of an external link: [http://www.cnn.com CNN]
  - Example of an internal link: [[My_WikiPage | My secret Wiki page]]