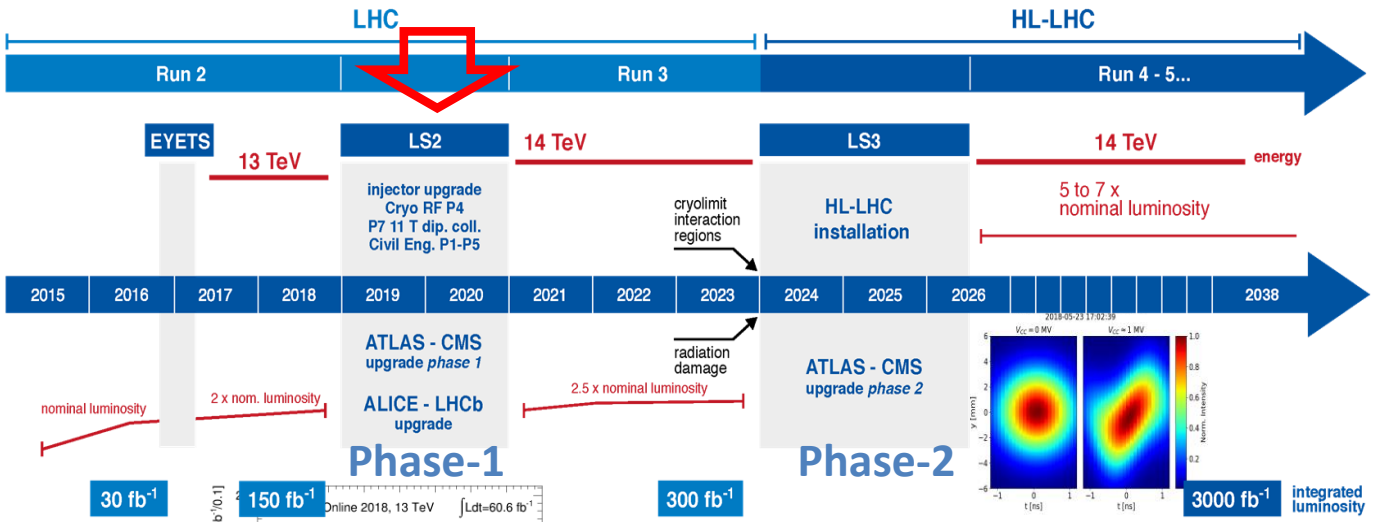
Upgrade of the ATLAS Detector (JINR participation)

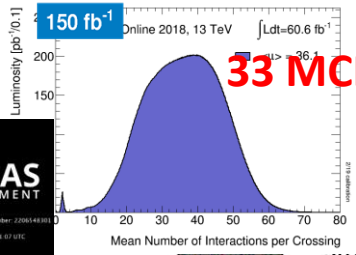
A. Cheplakov

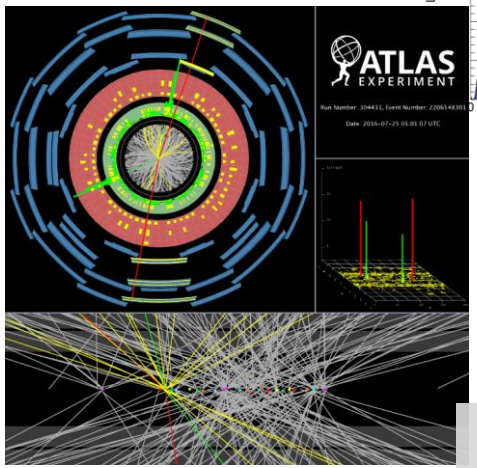
LHC / HL-LHC Plan



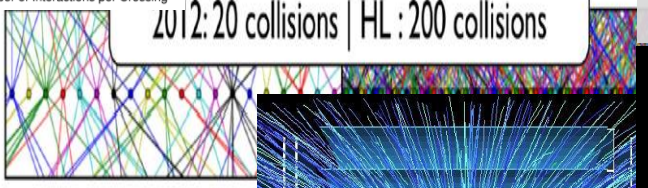
33 MCHF

270 MCHF

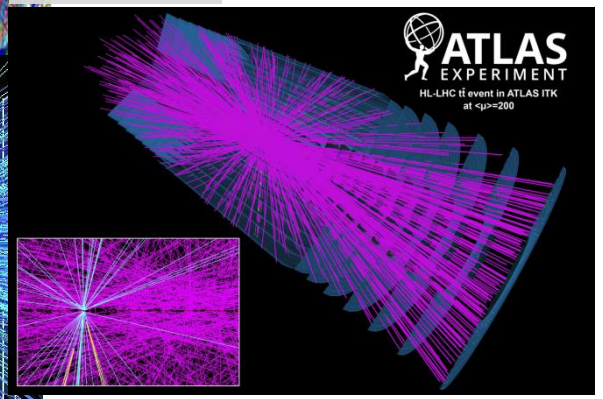




H→μμ ee



<μ>=200



12000 tracks in the tracker acceptance (each 25 ns)

ATLAS Phase-I Upgrade includes five main projects:

- **New small wheel (NSW) for Muon spectrometer**
  - will allow maintenance of good muon tracking performance
  - will also improve the Level-1 trigger performance without raising the p_T thresholds

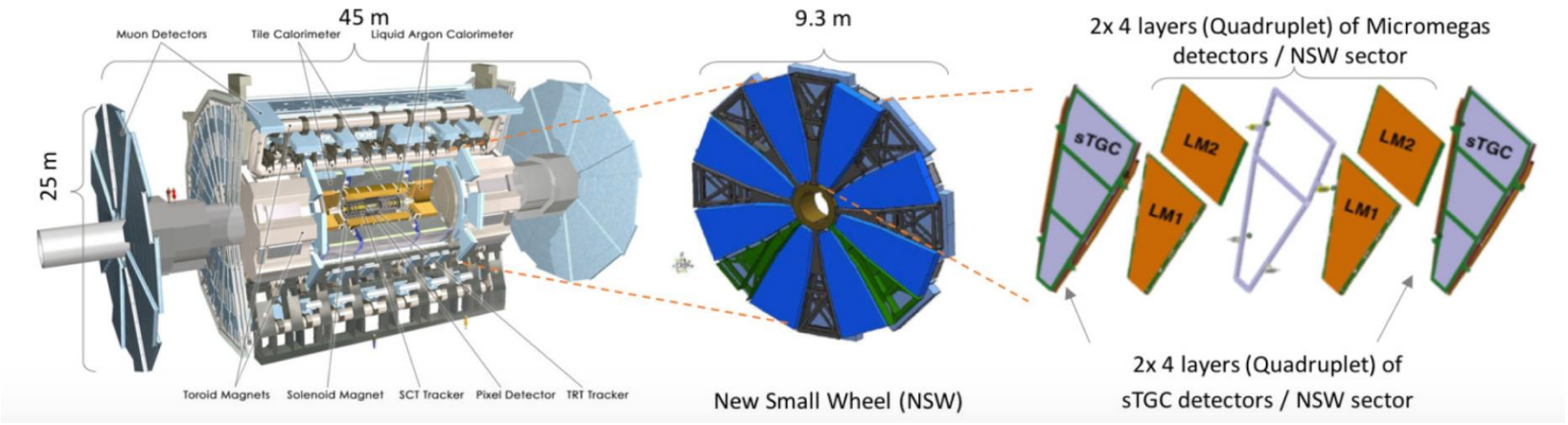
JINR

- **Liquid argon calorimeter (LAr)**
  - aimed at improving the Level-1 calorimeter decision for Run 3 and beyond
  - the trigger decision will be based on information about the jet shape

- **Hardware track finder (FTK)**
  - will provide fast tracking information as input to the high-level trigger
- **TDAQ upgrades**
  - are focused primarily on the Level-1 calorimeter trigger, to take full advantage of the finer segmentation of LAr
- **Forward detector of protons (AFP, ±240m)**
  - registration of pair of protons at small angles

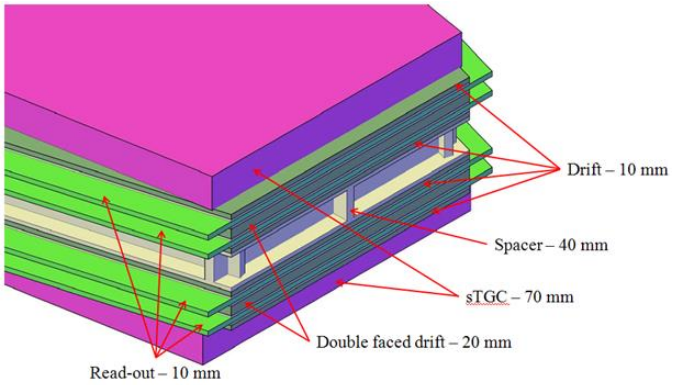
These upgrades are designed to satisfy Phase-II requirements, and will continue operating in ATLAS throughout the Phase-II period. The Phase-I upgrades form the foundation for Phase-II upgrades

Phase-I Upgrade of the Muon spectrometer



MM (Mass-)Production sites:

- **JINR**
- **CEA Saclay**
- **Aristotle University of Thessaloniki**
- **INFN cluster**
- **German cluster (LMU, Wurzburg, Mainz University)**



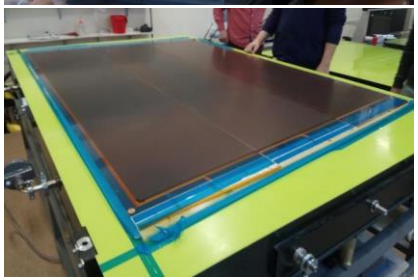
A total of 256 detector planes, 2048 read-out PCBs (each one of 64 pieces) have to be produced with 32 different shapes and dimensions, varying from 2220 x 450 mm^2 to 460 x 450 mm^2. …

JINR (+AUTh):
- **production of LM2 MM RO - 64 pcs (+4)**
- **assembly of 32 quadruplets (+2 spares)**

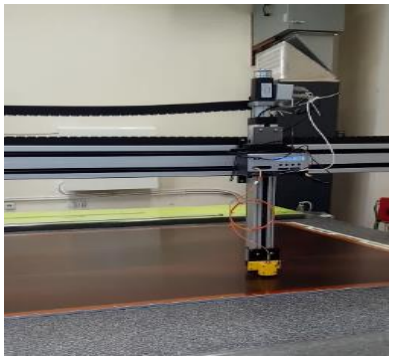
A new technology in Dubna → **second** workshop for domestic experiments (of smaller sizes)

Made at JINR by 2020: 54 MicroMegas readout panels and 14 quadruplets

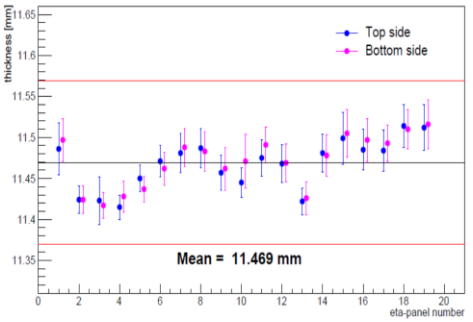


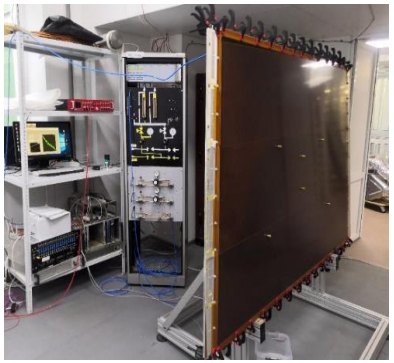



Quality Control:

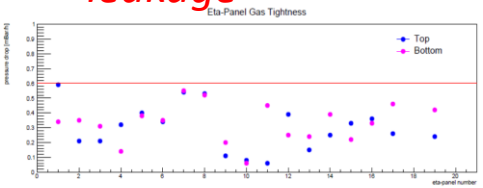


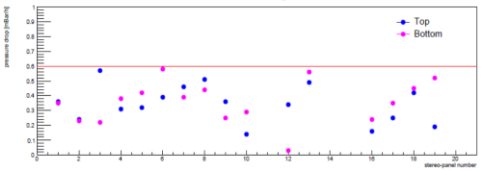
planarity
(6000 pts/side)

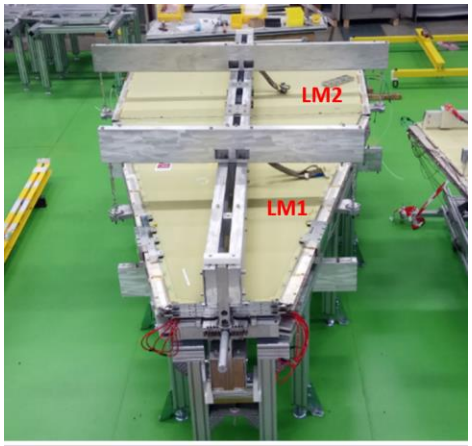




leakage







In mid-November 2019, at CERN, with participation of JINR staff, the first double-sided wedge of large sectors was assembled, consisting of quadruplets manufactured in Saclay (LM1) and in Dubna (LM2).

Phase-I Upgrade - NSW

IT: ”We need 100% openness”

NSW readiness review

(ATLAS internal report) Nov 2019

- MicroMegas (MM) production
  - ➡ Progress in understanding HV issues
    - ▸ **Method of “edge passivation” deployed in all production sites**
  - ➡ Small sector chamber production is well on track while production of chambers for large sectors is on critical path

→ A second construction line in Saclay

- Small strip Thin Gap Chambers (sTGC)
  - ➡ **sTGC chambers production in steady state mode**
  - ➡ Some delay in production of large sector chambers

→ More technical personnel for sTGC assembly at CERN

- Electronics and services
  - ➡ **Most NSW electronics components under production**, low risk, except packaging and testing of second batch of VMM chips
  - ➡ The NSW LV power system has been ordered

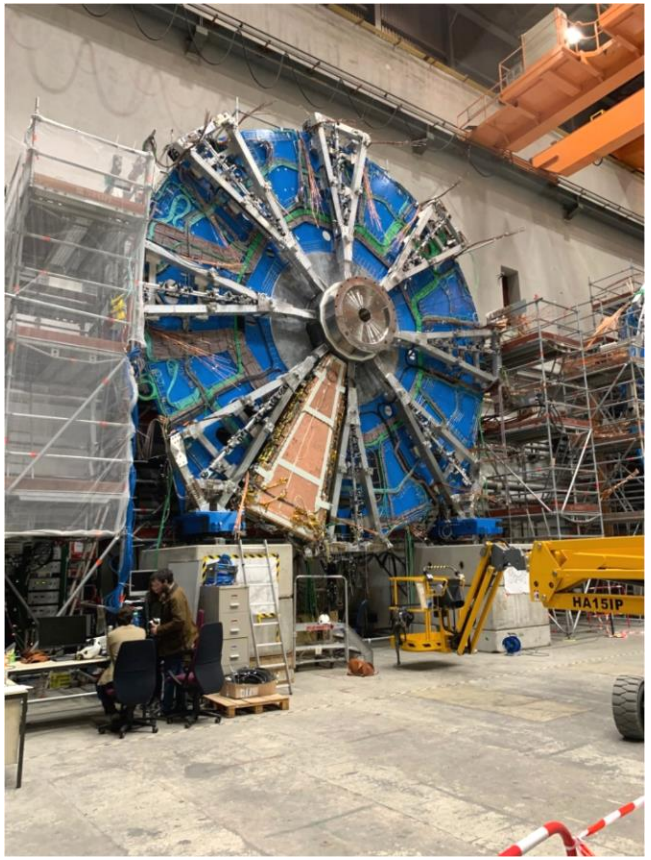
- Muon spectrometer
  - ➡ Fixing RPC of gas leaks (**242 leaks repaired, ~40% of work done**) **by the JINR team**
  - ➡ Upgrade of gas system to mitigate risks of producing new leaks - **racks under production** (available by end of November)
  - ➡ Installation of BIS7/8 chambers in Q1/Q2 of 2020: preparation of the chambers in BB5 well advanced

- Assembly **8** **3**
  - ➡ **MM: 5/8** Small double wedges and **1/8** Large double wedges have already been assembled } **renewed**
  - ➡ **sTGC: 10/16** Small wedges and **1/16** Large wedges have been assembled

13 **3**

- Conclusions
  - ➡ Significant progress on all aspects of the NSW production and installation
  - ➡ **NSW community acquired critical experience in wedge assembly and testing including installation of front-end electronics**
  - ➡ No critical items preventing the installation were identified
  - ➡ **Aiming for installation in fall 2020**
    - ▸ Contingency of 3 to 4 months required
  - ➡ Follow-up review in March and May 2020 (check progress on the critical items and recommendations)

5th Dec 2019: Mounting of 1st Small Sector on NSW



As of today:

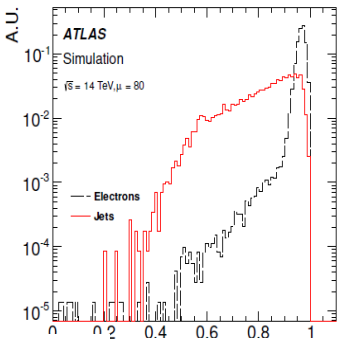
Two wedges of large sectors are assembled, awaiting installation of the FE electronics

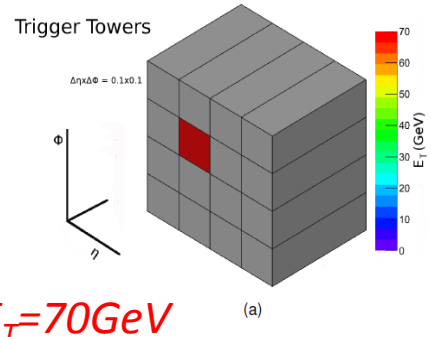
One large wedge is being assembled

Motivations for LAr Phase-I Upgrade

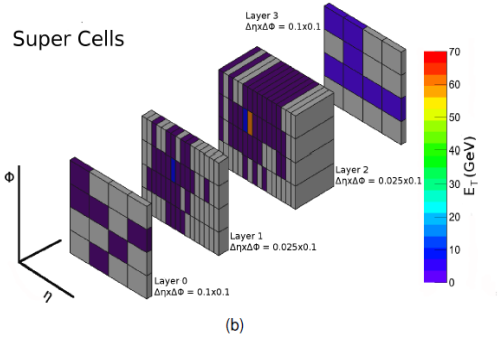
Increasing trigger thresholds with luminosity
→ no margin before hurting physics,
so add more information in the decision of the trigger system.

$$R_\eta = \frac{E^{(2)}_{T,\Delta\eta\times\Delta\phi=0.075\times0.2}}{E^{(2)}_{T,\Delta\eta\times\Delta\phi=0.175\times0.2}}$$



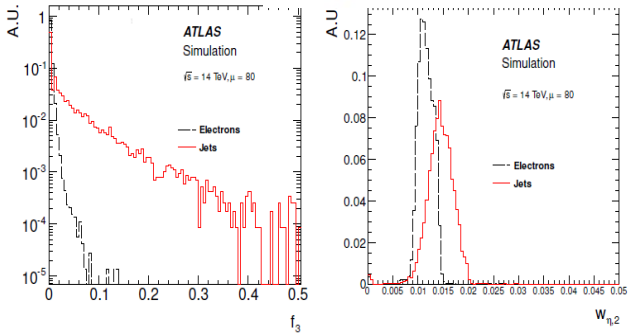


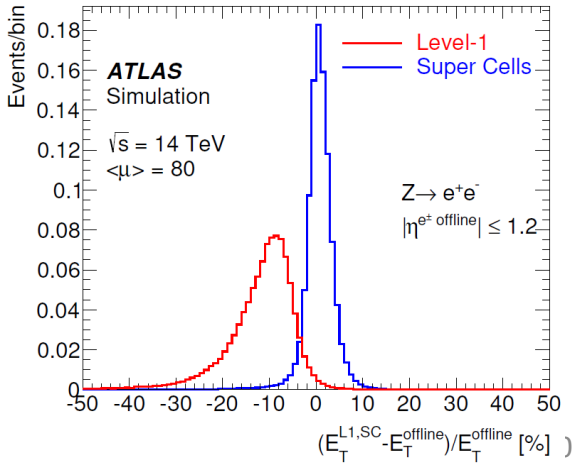
Electron, E_T=70GeV



$$f_3 = \frac{E^{(3)}_{T,\Delta\eta\times\Delta\phi=0.2\times0.2}}{E^{(1)}_{T,\Delta\eta\times\Delta\phi=0.075\times0.2} + E^{(2)}_{T,\Delta\eta\times\Delta\phi=0.075\times0.2} + E^{(3)}_{T,\Delta\eta\times\Delta\phi=0.2\times0.2}}.$$

$$w_{\eta,2} = \sqrt{\frac{\Sigma\left(E_T^{(2)}\times\eta^2\right)_{\Delta\eta\times\Delta\phi=0.075\times0.2}}{E^{(2)}_{T,\Delta\eta\times\Delta\phi=0.075\times0.2}} - \left(\frac{\Sigma\left(E_T^{(2)}\times\eta\right)_{\Delta\eta\times\Delta\phi=0.075\times0.2}}{E^{(2)}_{T,\Delta\eta\times\Delta\phi=0.075\times0.2}}\right)^2},$$





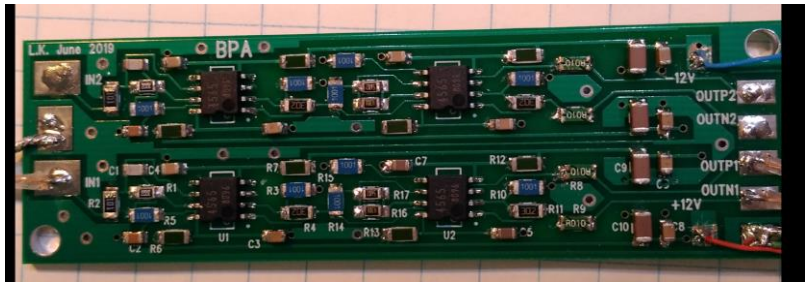
Shower shape estimators can only be built with :

- **Layer information**
- **Fine granularity** **→×10 more signals w.r.t. present system**

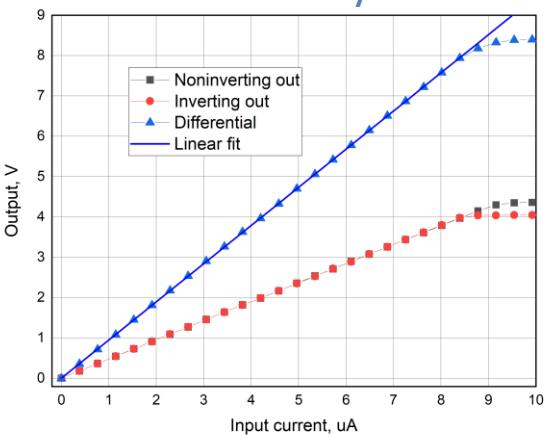
Upgrade of the LAr trigger electronics

LAr Phase-I Upgrade: current activities (also, for Phase-2)

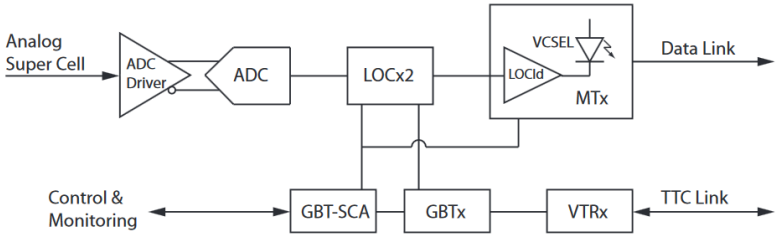
Test-board for high-frequency operational amplifiers of the analog part of LTDB



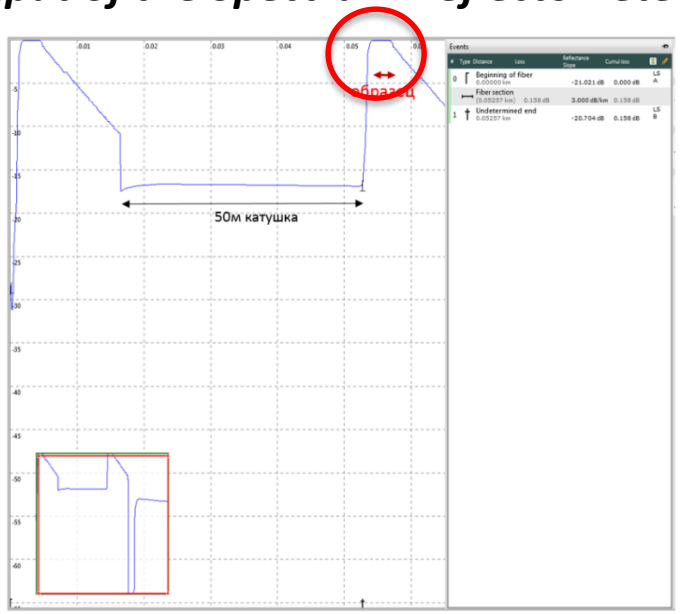
linearity



Signal flow paths of the digital part of LTDB

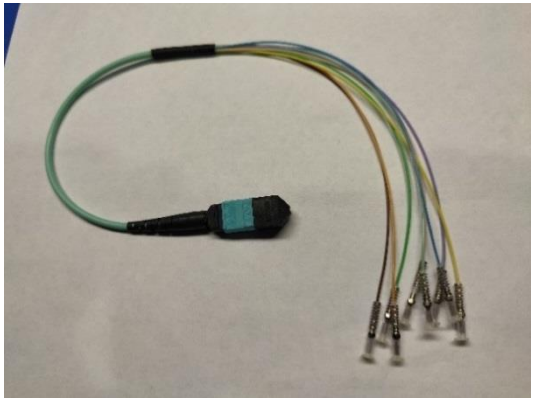


Output of the Spectrum Reflectometer

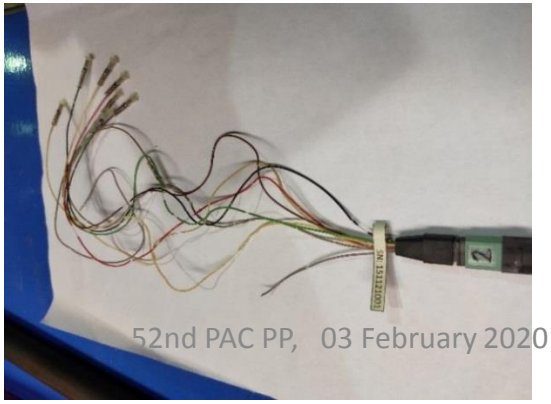


Irradiated pigtails:

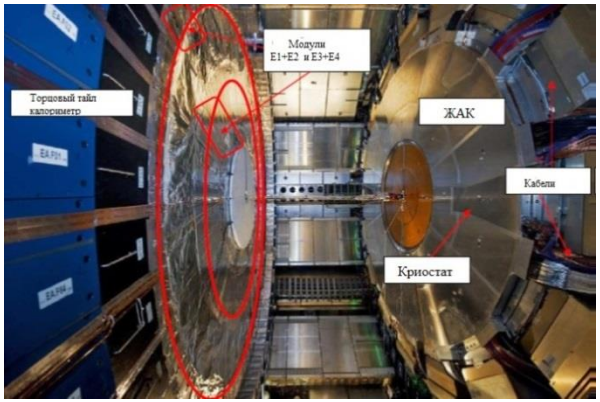
$2 \cdot 10^{15}$ n/cm²

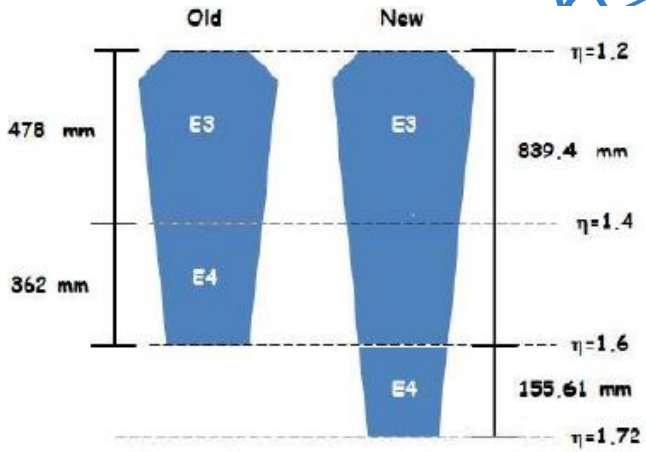


$8 \cdot 10^{15}$ n/cm²



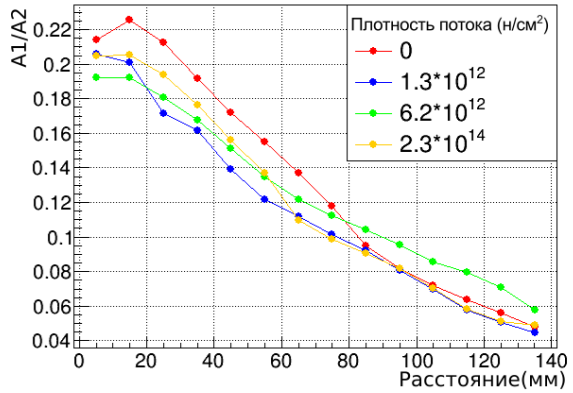
Assembly and installation of the new TILE modules



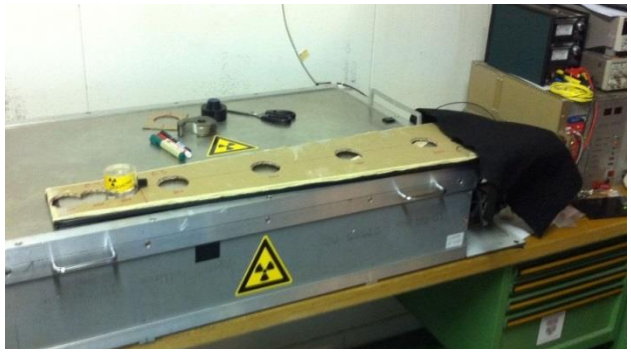


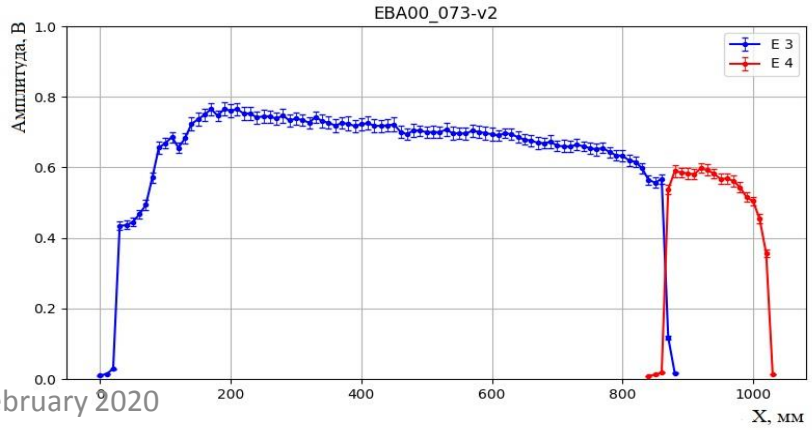
Radiation tests of the new scintillators

Samples from Kharkov, dimensions – 15×4×0.6 cm, doses: 1.3 and $6.2 \cdot 10^{12}$, $2.3 \cdot 10^{14}$ and $1.4 \cdot 10^{15}$ n/cm^2

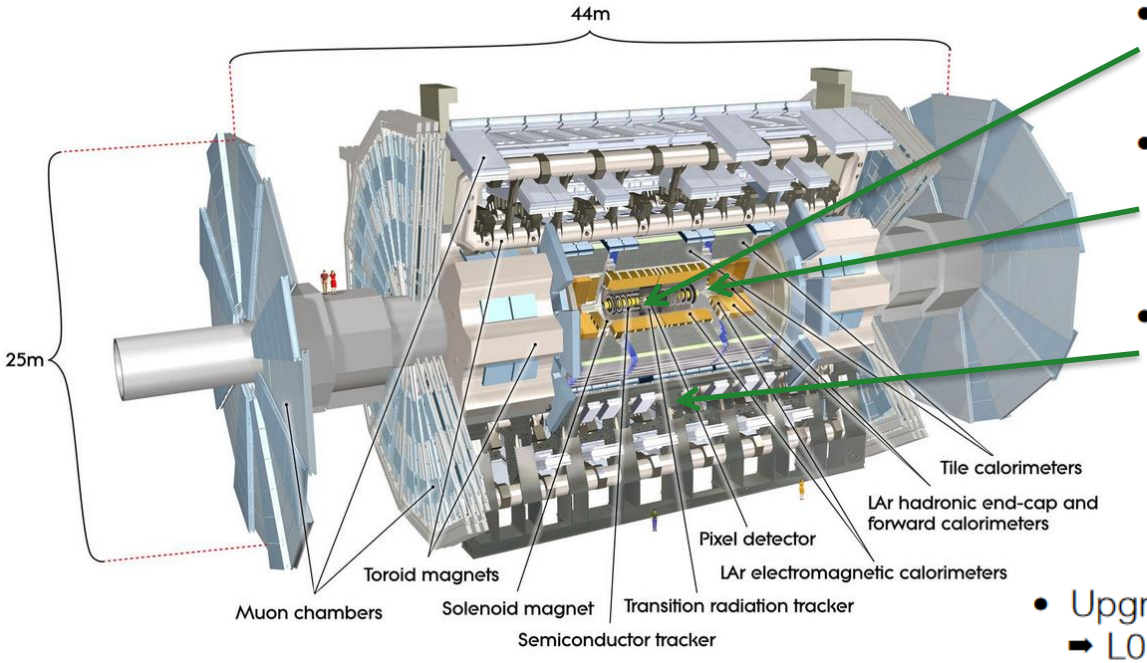


Signal ratio of the "green" and "blue" scintillators (A1/A2) for various doses as function of distance from the PMT (mm)





Phase-II Upgrade



- New Inner Tracking detector (ITk)
  - ➡ All silicon tracker up to $|\eta| = 4$
- High granularity timing detector (HGDT)
  - ➡ **Technical Design Report in preparation expected early in April 2020**
- New muon chambers in the inner barrel region

- Upgraded TDAQ system:
  - ➡ L0: at 1 MHz
  - ➡ Improved Event Filter (output of 10 kHz, hardware tracking as co-processor)
- Electronics upgrade:
  - ➡ LAr calorimeter
  - ➡ Tile calorimeter
  - ➡ Muon system

The Long Road to Phase-2

Starting from LoI in 2012…

The Internal Design Review (IDR) Process (2014 – 2016)

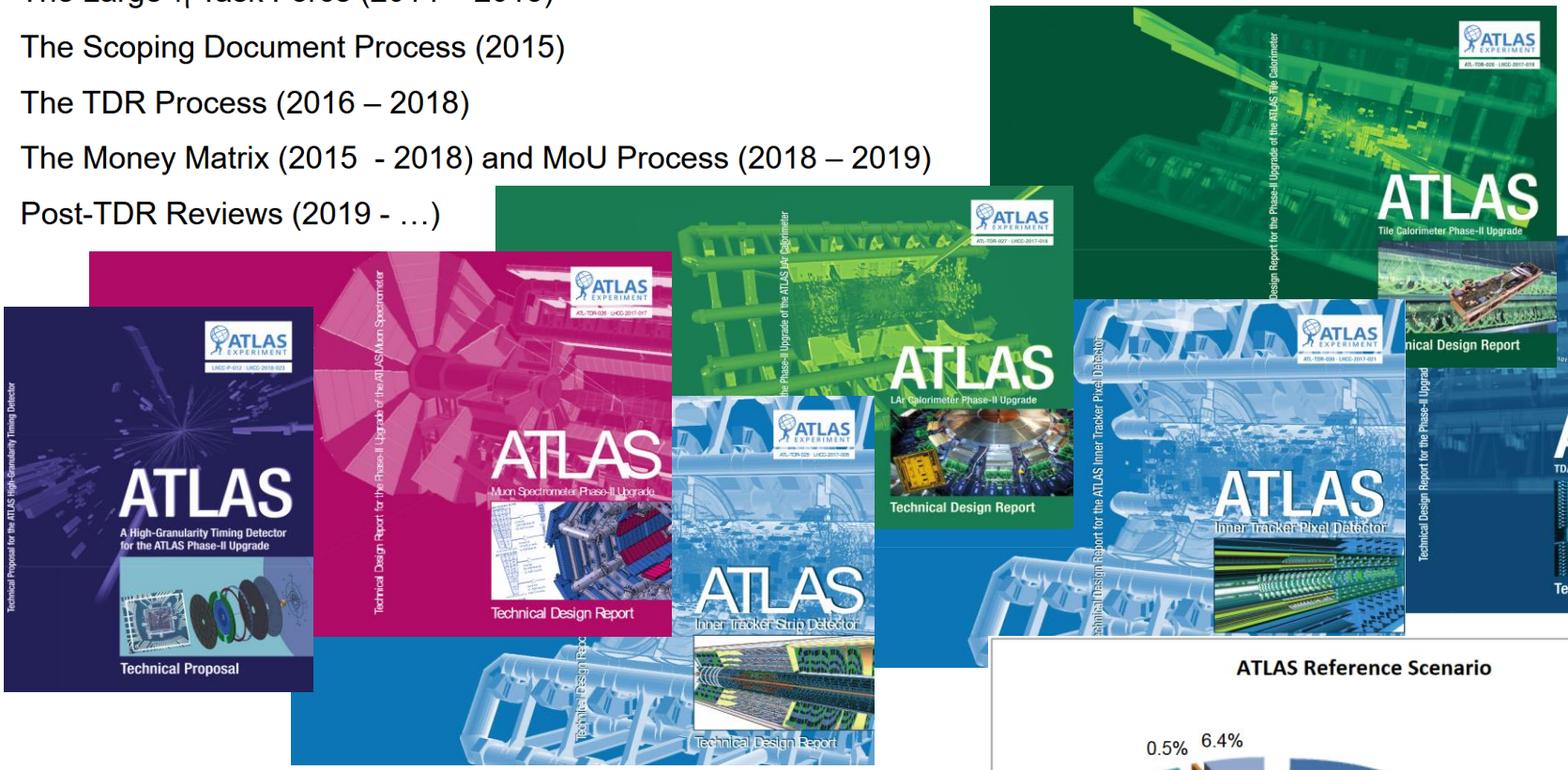
The Large-η Task Force (2014 – 2015)

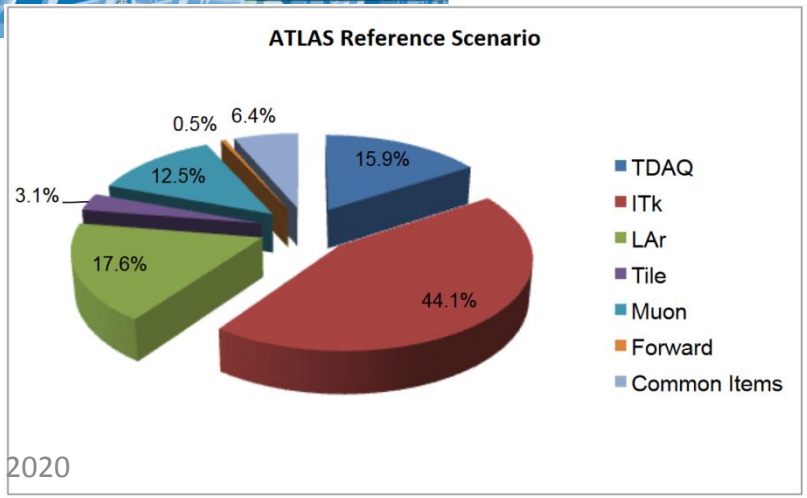
The Scoping Document Process (2015)

The TDR Process (2016 – 2018)

The Money Matrix (2015 - 2018) and MoU Process (2018 – 2019)

Post-TDR Reviews (2019 - …)





These projects are now following the ATLAS technical and schedule review process:

- **Specifications**
- **Preliminary Design Review**
- **Final Design Review**
- **Production Readiness Review**

ATLAS Phase-II MoU's for JINR

ATLAS COLLABORATION CERN-MoU-2019-035

The European Organization for Nuclear Research (CERN)

and

Joint Institute for Nuclear Research (JINR)
Russia

declare that they agree on the Present Addendum to the Memorandum of Understanding for Collaboration in the Construction of the ATLAS Detector

Done in Geneva on 30.4.2019

for CERN

Eckhard Elsen
Director for Research
and Computing

Done in Dubna on 15.05.2019

for JINR

Victor Matveev
Director

JINR Involvements in Phase-2 Upgrade

TDAQ

1.2.1: Readout - *FELIX I/O card. Procurement of components and testing*

1.3.1: Hardware Track Trigger (HTT) Pattern Recognition Mezzanine - *Procurement of components and testing*

1.3.1.6: HTT ATCA Infrastructure - *Procurement, installation and commissioning*

1.3.1.7: HTT Track Trigger Interface - *Procurement of components and testing*

LAr

3.1.1.1 and 3.1.1.2: Preamp-Shaper and HEC Preshaper ASICs - *HEC input stage design and testing;*

3.1.1.4: Optical Link Components - *Production and testing of optical pigtails (**MSHE**+Lebedev);*

3.1.1.5: FEB2 - *Develop analog circuit and testing;*

3.1.4: Front-End Power Distribution System - *Procurement of parts (MES);*

3.2.1: LAr Signal Processor Hardware - *Procurement of parts;*

TILE

4.5.5: LV services: *New Auxillary control boards, cables*

MUON

5.3.3: RPC chambers and FE electronics - *RPC Singlet assembly and testing; Strip panels production and testing;*

5.3.6: Gas System - *Gas system design, production, installation;*

5.8: Power System - *Power distribution design, distribution, production and installation;*

Surface commissioning, installation and commissioning.

… + HGTD

Slides from E. Elsen, Dir. Research & Computing in Open Council meeting, 13 Dec 2019

Summary of requests

	LHC	ALICE	ATLAS	CMS	LHCb
Extend LS2	no	./.	3.5 months	2 months	3 months
Extend YETS 21/22	no	./.	2 months for NSW-C	./.	./.
Extend YETS 22/23	no	./.	./.	1 month for prep of LS3	./.
Delay LS3 by one year	no	yes	yes	yes	yes
highest E	yes, prudently	./.	yes	yes	./.

Summary of Main Decisions

- Extend Run 3 by one year – *such that 2024 is included in Run 3 and LS3 starts in 2025*;
- Extend LS2 by two months – *such that the experimental caverns will be closed on May 1st 2021*
- In early-June 2020, review the New Small Wheel (NSW) detector status, both NSW-A readiness and NSW-C prospects, and fix the NSW installation strategy. Decide on final length of LS2:
  - Decide if NSW-A will be installed in LS2 or LS3
  - If NSW-A is to be installed in LS2 decide if NSW-C will be installed in YETS 2021/2022 – *which will then be extended by two months*
  - Extend LS2 in well-justified circumstances by up to additional six weeks – *ATLAS and LHCb*
- Consider to drop one of the ion runs after 2021 and attach it to the scheduled ion period in 2024 – *to allow cool-down before LS3*
- Decide on the final beam energy after the magnet training at the end of the extended LS2. – *If the training shows that a collision energy exceeding 13.5 TeV will be achievable with high availability then that energy will be chosen, otherwise Run 3 will operate at 13 TeV*

Estimate of the Run 3 integrated luminosity – 180-260 fb^{-1}.

… still uncertainties with the Phase-2 schedule and budget profile.

Project Expenditures

R&D for Calorimetry

development of the front-end readout electronics, new scintillators, testing and products certification

- **Development of the test bench equipped with Optical Time Domain Reflectometer for testing patch-cords, purchase of optical fibers for prototyping (10kUSD);**
- **Irradiation tests at IBR-2 (2 runs per year) – purchase of electronic equipment (5kUSD), materials (rad.hard. cables, connectors, samples) (12kUSD);**
- **Irradiation tests at U-70 (1-2 runs per year) – equipment (4kUSD) and samples (same as for IBR-2M tests) (6kUSD);**
- **HiLum2 experiment at Protvino - HV monitor for beam chambers (3kUSD); CAEN timing unit (3kUSD) and cryogenics (ageing) items (3kUSD).**

R&D for Muon Spectrometer

Intensive production of the MicroMegas chambers and quadruplets assembly for the NSW projects. The chambers are transported to CERN and our team participates in their integration in the NSW structure and final detector commissioning.

- **LM2 quadruplets production, transportation, integration and final commissioning - 120kUSD;**
- **R&Ds for sRPC – 50 kUSD;**
- **Maintenance work on the GaAs:Cr monitors – 30kUSD.**

List of the project participants (including FTE)

Muon spectrometer

A. Gongadze-1, G. Chelkov-1 (DLNP), N. Zimine-1 (VBLHEP) - coordinators
M. Balykina-1, B. Buadze-1, Z. Chubinidze-1, E. Cherepanova-0.3, D. Dedovich-0.9, M.Demichev-1, N. Doroshkevych-1, I. Gongadze-1, L. Gongadze -1, M. Gostkin-0.1, A.Guskov-0.1, N. Kaurcev-1, D. Kharchenko-0.5, N. Koviazina-1, U. Kruchonak-0.4, I. Lyashko-1, I. Minashvili jr. -1, P. Morozov-1, A. Nozdrin-0.1, I. Potrap-1, T. Rudenko-0.9, P. Smolyanskiy-0.8, R. Sotenskii-1, A. Zhemchugov-0.2 (DLNP)
Yu. Filippov-1, A. Ivanov-0.3 (VBLHEP),
I. Titenkov-0.4, A. Zabaluev-0.2 (ATOM)

Calorimeters

A. Cheplakov-1, E. Ladygin-1, (VBLHEP), I. Minashvili-1 (DLNP) - coordinators
V. Kukhtin-1, S.Nagorny-0.3, N. Javadov-0.9, F. Ahmadov-0.2 (VBLHEP)
A. Artikov-0.3, N. Atanov-0.3, V.Baranov-0.3, Yu. Davydov-0.5, V. Gerasimov–0.5, V. Glagolev-0.2, N.Kirichkov-0.3, S. Malyukov-1, V.Romanov-0.3, A. Shalyugin-0.5, A. Simonenko-0.3, V. Tereschenko-0.4, I.Vasilyev-0.3 (DLNP)
S. Kulikov-0.1, M. Bulavin-0.1 (FLNP)

FTE/Person = 34/53 + 29/32 (Physics group) = 63/84 for JINR in ATLAS

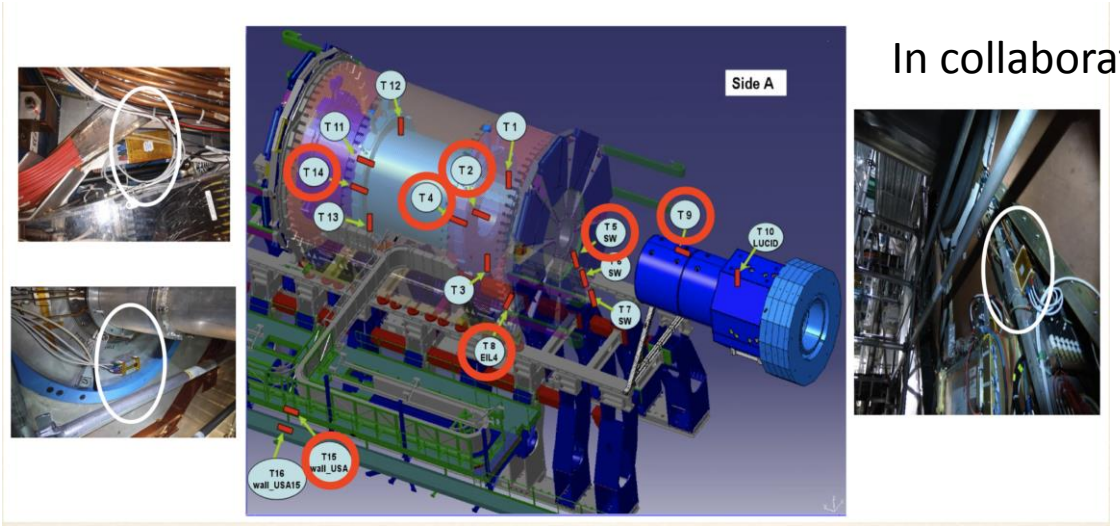
JINR group asks for the project approval for 2021-2023

Back-up slides

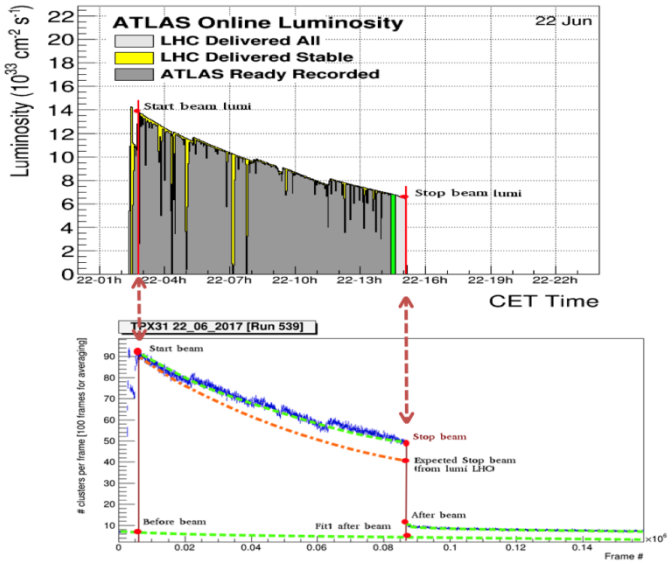
Project expenditures

	Expenditure items	Full cost	1st year	2nd year	3rd year
	Direct expenses for the Project				
1.	Accelerator, reactor	1200h	400	400	400
2.	Materials	110k$	60	25	25
3.	Equipment	150k$	70	45	35
4.	Travel allowance, including: a) non-rouble zone countries b) rouble zone countries c) protocol-based	290k$ 280 10	94 90 4	94 90 4	102 100 2
	Total direct expenses	550	224	164	162

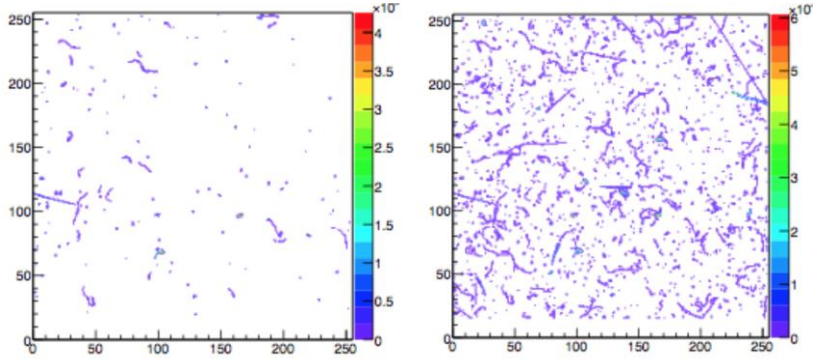
ATLAS GaAsPix monitors



In collaboration with Tomsk



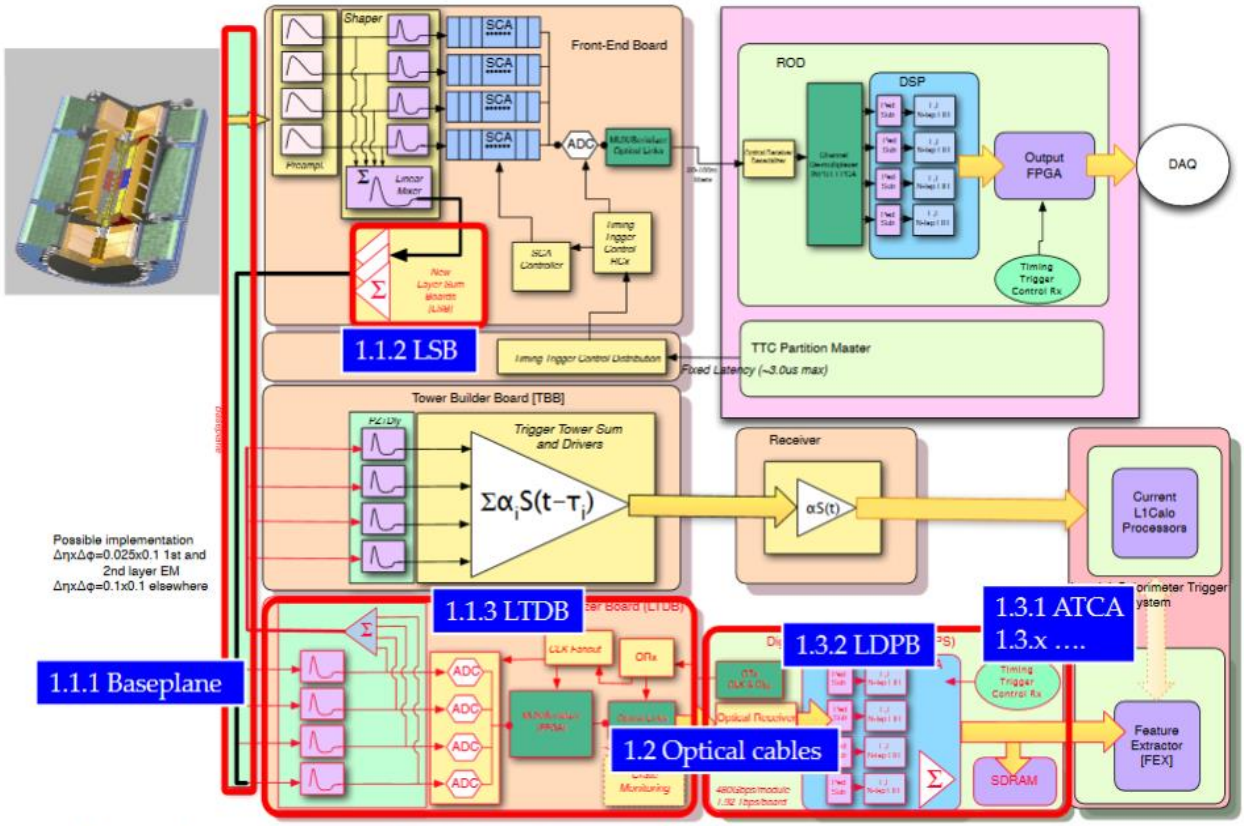
Luminosity measurements



Pictures from one sensor:
1 frame (500μs) and 100 frames

The work is ongoing on development of the effective patter recognition on-line algorithms.

LAr Phase-I Project

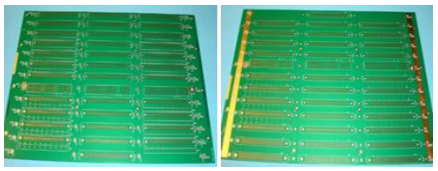


- *New elements are highlighted in RED*

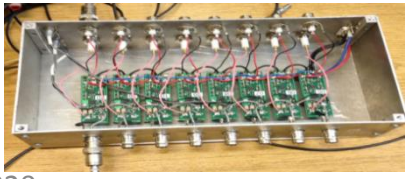
2019/05/23 H. Chen, L. Hervas - Liquid Argon Week

JINR (VBLHEP):

Baseplane design



LTDB Preshaper design

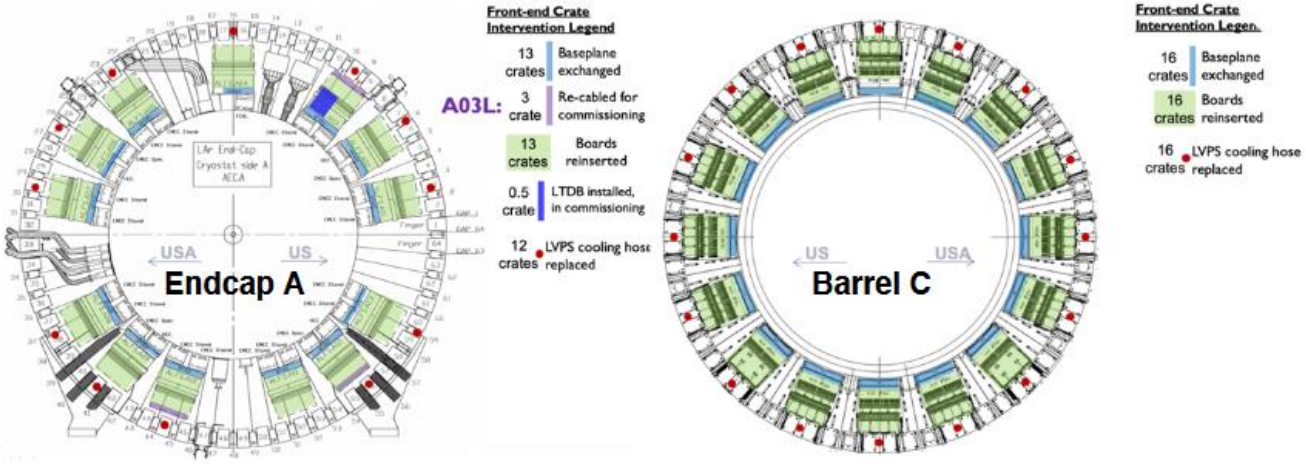


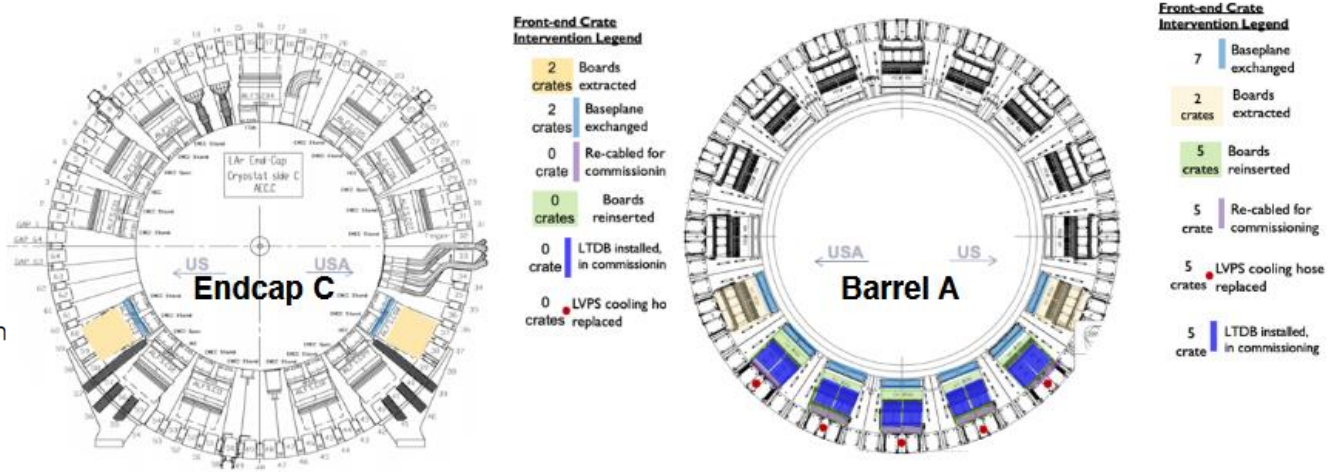
+ Radiation tests of the readout boards and cables at IBR-2M

Phase-I Upgrade - LAr

- Upgrade of the front-end and back-end electronics - **completed on barrel side C & endcap side A**
- Delays on installation of LAr Trigger Digitiser Boards (LTDB) due mechanical nonconformities in power distribution boards, but not on critical path

  - end in January





LS2 Activities - Calorimeters

- Liquide Argon calorimeter (LAr)
  - ➡ Consolidation work on power supplies an system proceeding as planned
- Tile calorimeter
  - ➡ Cooling connector replacement done
  - ➡ Maintenance of electronics well advanced (completed on A-side, nearly done on C-side)
  - ➡ Crack and MBTS scintillators installed on both sides

Phase-II Upgrade Summary and Status

- **All projects (except HGTD) are now following the Phase-II technical and schedule review process of ATLAS**: Specifications, PDR, FDR, and PRR (Prod. Readiness Review), (FDR is required before projects is authorized to spend CORE funds)

- **All projects underwent a re-assessment / baselining effort**, by the ATLAS Project Management Office

- Good progress on all projects:
  - ➡ P2UG review in May 2019: ITk-strips, LAr and Muon
  - ➡ P2UG review in Nov. 2019: ITk-pixel, ITk common items, Tile and TDAQ

- **ITk-strip project: very good progress,** already moving from prototyping into the pre-production phase; sensor pre-production order has been placed

- Areas of concern:
  - ➡ Some technical **options still open in ITk-pixel layout**
  - ➡ **Impact of material in the forward region of ITk** on calorimeter and HGTD performance has to be understood
  - ➡ **Timeline of ITk** (delays, e.g. due to sensor delivery schedule, common electronics (lpGBT))

- Task force to develop strategy for precise luminosity measurement in Run 4 has been set up (proposal for instrumentation)

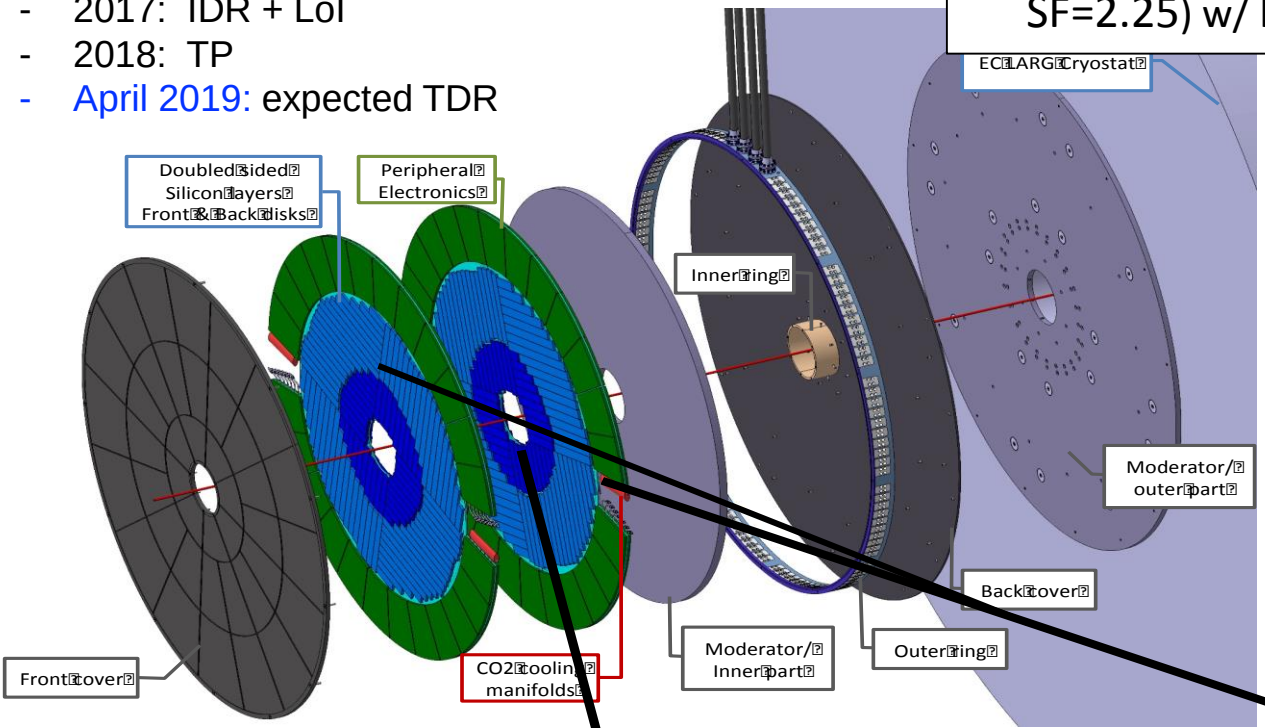
«Road map to the HGTD TDR»

A. Henriques/L.Serin

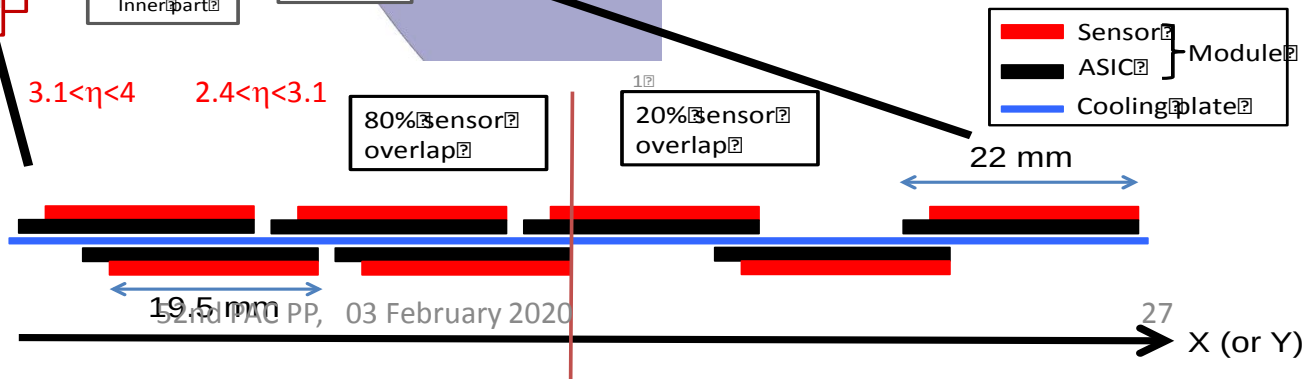
- 2015: Idea in the ATLAS upgrade scoping document (ATLAS Large η TF)
- 2016: start R&D on new sensor (LGAD) + highly demanding ASIC (Altiroc) design.
- 2017: IDR + LoI
- 2018: TP
- April 2019: expected TDR

HGTD in the TDR March circulation

- σ_t ~ 30-50 ps /track (40-85ps/hit) up to 4000fb^{-1}
- ~ 2 (3) hits in 2.4<η<3.1 (3.1<η<4)
- 2 rings; Inner ring (3.1<η<4) replaced at 2000 fb^{-1}
- < 10% occupancy (1.3x1.3 mm^2 cells) with ITK 3.0
- < 5.1x10^{15}n$_{eq}$/cm^2 (w/ SF=1.5);4.7 MGy (w/ SF=2.25) w/ ITK 2.2

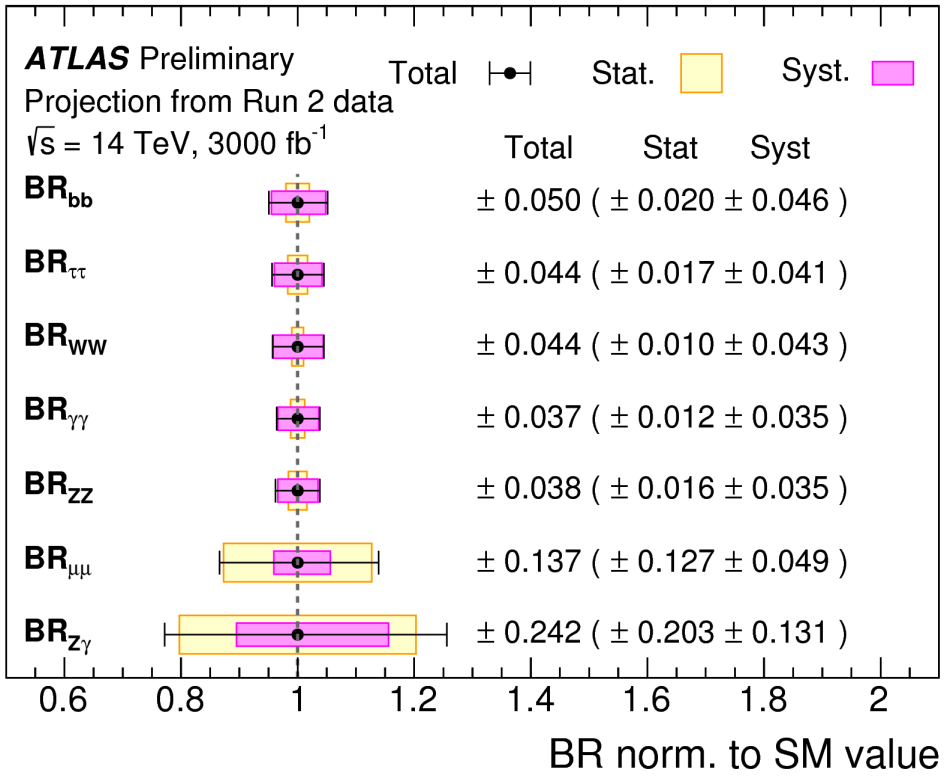


- Detector to be installed on each of two calorimeter extended barrels
- Two instrumented double sided layers (mounted in 2 cooling disks)
- Overlap between modules on inner and outer ring



"It is difficult to quantify how much improvement a decade of thinking and working hard will bring!"

(Sarah Demers, ATLAS Upgrade Physics Group co-convener)



Expected results for the measurement of Higgs boson branching ratios at HL-LHC, normalized to their Standard Model expectation. The size of the bars indicate the **expected** accuracy of the measurements.