JINR group results in the ATLAS experiment

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(on behalf of JINR ATLAS team)

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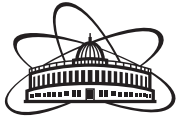
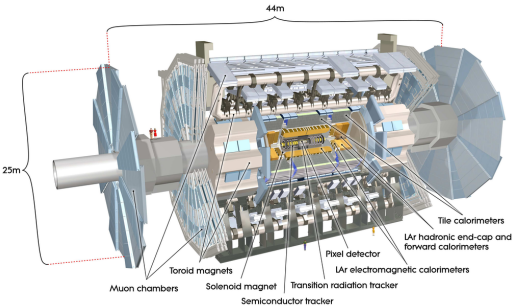


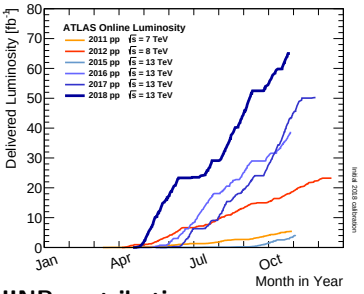
50^{th} meeting of the Program Advisory Committee for Particle Physics

JINR, Dubna

21 – 22 January 2019

Introduction





ATLAS is a general purpose detector at LHC

- Very successful operation in Run-2 (2015–2018)
- $\sim$140 fb^{-1} collected at $\sqrt{s} = 13$ TeV (cf. $\sim$25 fb^{-1} in Run-1 at 7–8 TeV)
- Most of physics results still ahead

JINR is one of the largest participants

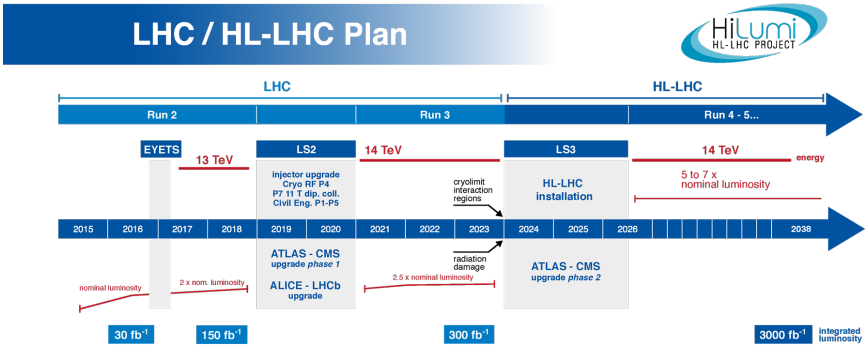
- 127 registered members, 34 authors
- 27 PhD and master students

Main areas of JINR contribution:

- Upgrade Phase-2 (NSW, LAr, Tile calorimeters)
- Higgs physics (VH and $H \to b\bar{b}$ observation)
- Exotics searches (resonances in $Z/W/H + \gamma$, QBH)
- SM precision measurements ($W/Z + b$-jet x-section)
- B-physics (B_c excited states)
- Soft QCD (Bose–Einstein correlations)
- Software support&development (EventIndex, FastSim)
- B-physics trigger
- Theoretical support of analyses

Upgrade activities

LHC and ATLAS upgrade programme



Expect after LS2: $\mathcal{L} = 2.2 \cdot 10^{34}\,\mathrm{cm}^{-2} \cdot \mathrm{s}^{-1}$, 25 ns bunch spacing, $\langle \mu \rangle = 60$

To exploit this increase in luminosity and maintain a low-p_{T} lepton threshold (25 GeV) at the Level-1 trigger keeping the same trigger bandwidth (100kHz), **the development of new detector and readout components are needed**

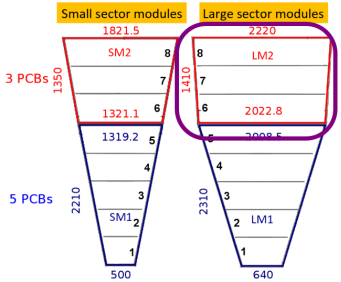
- Requirement and design specifications:
- $\mathcal{L} = 3 \cdot 10^{34}\,\mathrm{cm}^{-2} \cdot \mathrm{s}^{-1}$, $\langle \mu \rangle = 80$

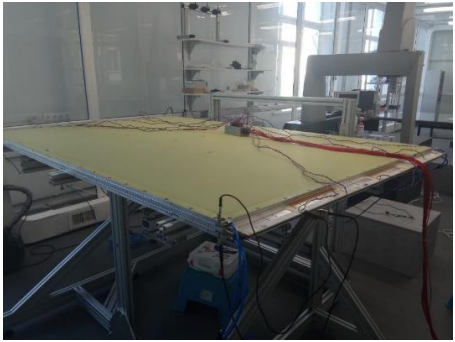
Phase-1 includes

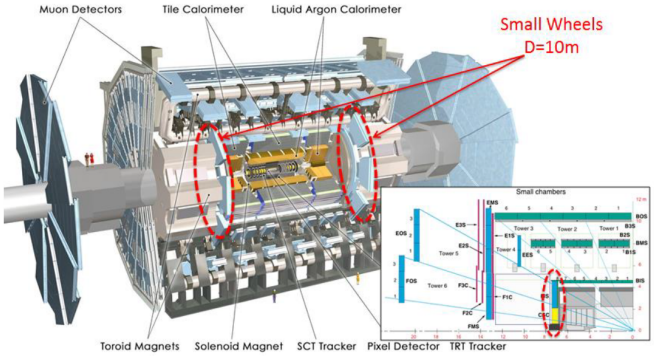
- additional chambers in the forward muon spectrometer
- upgrade of the calorimeter trigger electronics
- new Level-1 trigger processors
- new Level-1 topological trigger processor
- fast track trigger (FTK)

JINR participation in muon New Small Wheels production

- **Motivation:** *degradation of MDT performance* and current *high endcap muon trigger fake rate*
- NSW module = Micromegas panels + sTGC Drift chambers
- LM2 Micromegas modules assembled at JINR
  - 20 panels produced in 2018
  - 5 quadruplets assembled and thoroughly tested
  - 3 quadruplets sent to CERN

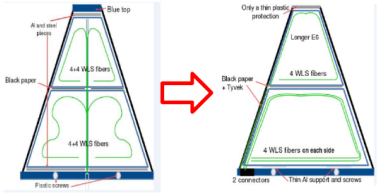






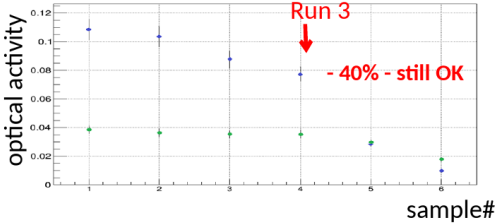
Tile calorimeter in LS1

- **a new layout of the readout fibers was tested**

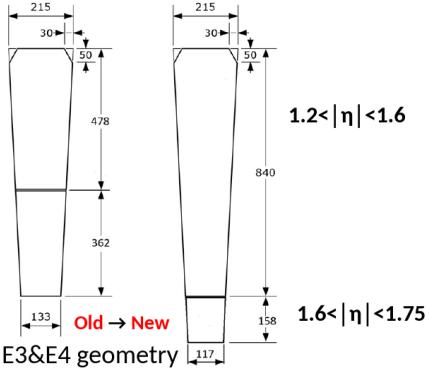


- **Irradiation tests of the new scintillators (Kharkov, Ukraine): UPS-923A (425nm) and (530nm) at IBR-2M**

Sample#	1	2	3	4	5	6
n-fluence, n/cm^2	0	2.1×10^{12}	3×10^{13}	2.8×10^{14}	2.6×10^{15}	1.7×10^{16}



- **a new design of the modules**



- **40 new modules have been produced and transported to CERN**

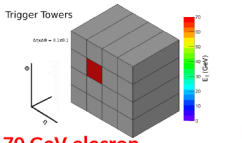
LAr calorimeter: trigger electronics and irradiation tests

Motivation: improvements of the L1-trigger performance by enhancing jet rejection and PU subtraction capabilities.

Shower shape estimators can only be built with :

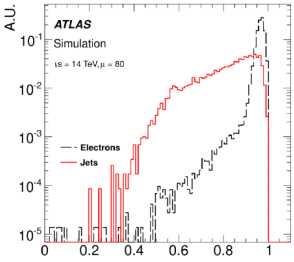
- Layer information
- Fine granularity

→ ×10 more signals (Super Cells) w.r.t. present system (Trigger Tower)



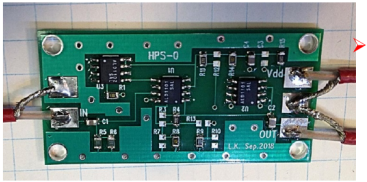
70 GeV elecron

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



JINR in 2018:

Simulation, design and production of the HEC shaper based on CMOS transistors from ADL



The first prototype of the HEC shaper (for the Phase-2 upgrade @ LS3)

Electrical tests of the PCB materials irradiated to $3 \cdot 10^{17}$ n/cm^2

Material	Capacitance (pF)		Impedance (Ohm)	
	before	after	before	after
FR4	1180	620	3.7	3.6
Rogers	730	990	3.6	3.1
Arlon 85N	760	770	2.8	2.8
PI	730	500	3.0	2.9

Physics studies

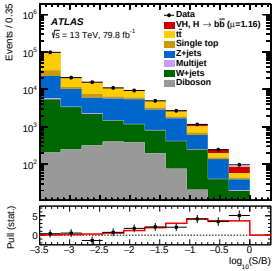
Higgs: observation of VH production and $H \to b\bar{b}$ decay

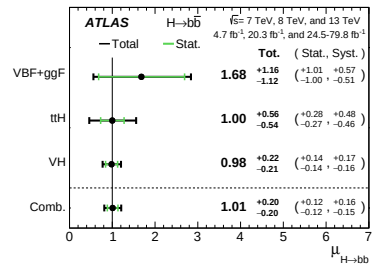
Phys. Lett. B 786 (2018) 59

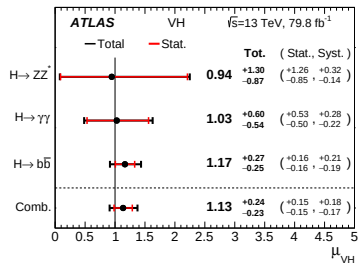
- Search for $H \to b\bar{b}$ in producing in association with W/Z bosons
- Analysis of 79.8 fb^{-1} of $\sqrt{s} = 13$ TeV data + combinations with other production and decay channels and with Run-1 results
- Combination results:
  - $\boldsymbol{H \to b\bar{b}}$ observed with 5.4σ significance (5.5σ expected), $\mu = 1.01 \pm 0.12(\text{stat.})^{+0.16}_{-0.15}(\text{syst.})$
  - $\boldsymbol{VH}$ **production** observed with 5.3σ significance (4.8σ expected), $\mu = 1.13 \pm 0.15(\text{stat.})^{+0.18}_{-0.17}(\text{syst.})$

Channel	Significance	
	Exp.	Obs.
VBF+ggF	0.9	1.5
$t\bar{t}H$	1.9	1.9
VH	5.1	4.9
$H \to b\bar{b}$ combination	5.5	5.4

Channel	Significance	
	Exp.	Obs.
$H \to ZZ^* \to 4\ell$	1.1	1.1
$H \to \gamma\gamma$	1.9	1.9
$H \to b\bar{b}$	4.3	4.9
VH combined	4.8	5.3





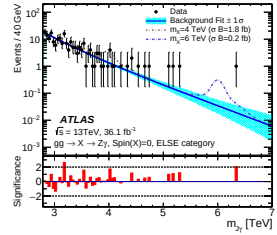


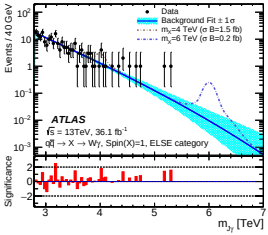
Exotics: search for heavy resonances $Z/W/H + \gamma$ final state

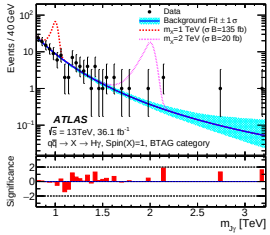
- Search for BSM resonances decaying to $Z/W/H + \gamma$
- $Z/W/H$ identified in their hadronic decays via fat jets
- The data consistent with the expected background
- Upper limits set on the $\sigma(X) \times \mathcal{B}(X \to W/Z/H + \gamma)$
- For 1–6.8 TeV in $W/Z + \gamma$ (various spin hypotheses)
- For 1–3.0 TeV in $H + \gamma$ (spin-1)

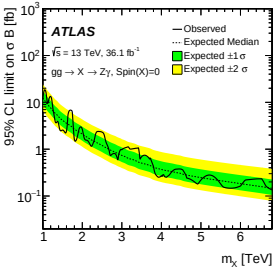
Use 36.1 fb^{-1} of 2015+2016 data

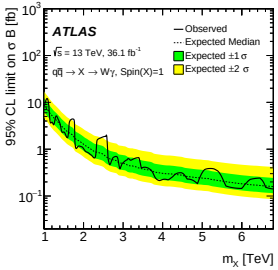
Phys. Rev. D 98 (2018) 032015

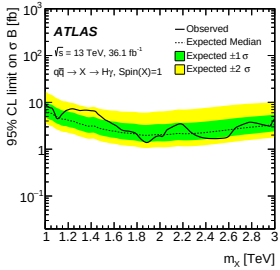






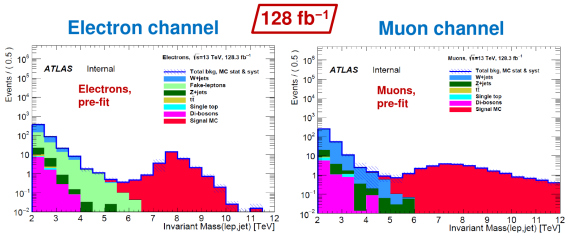




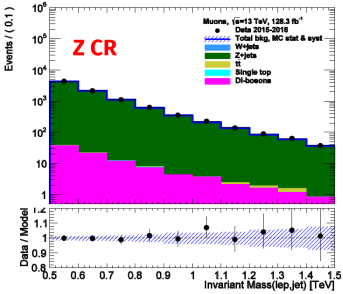


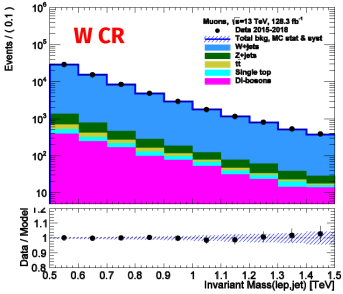
Exotics: search quantum black holes *(on-going)*

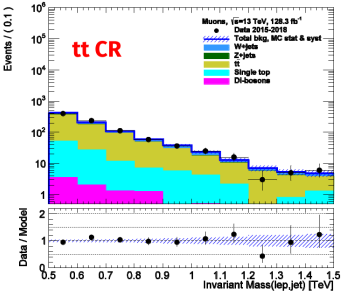
- *Quantum Black Holes* predicted in low-scale quantum gravity theories, addressing hierarchy problem by lowering the quantum gravity scale from $\sim 10^{16}$ TeV to $\sim$TeV region
- Searched in ℓ + jet final state
- Control regions ($m < 1.5$ TeV) defined for Z + jets, Z + jets, $t\bar{t}$
- Data are blinded yet; aim at **full Run-2**
- Expect exclusion at up to $\boldsymbol{m = 7.5}$ **TeV**



Projection of MC in signal region ($m > 2$ TeV)

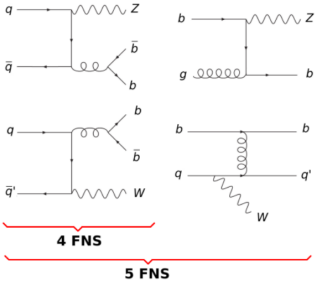


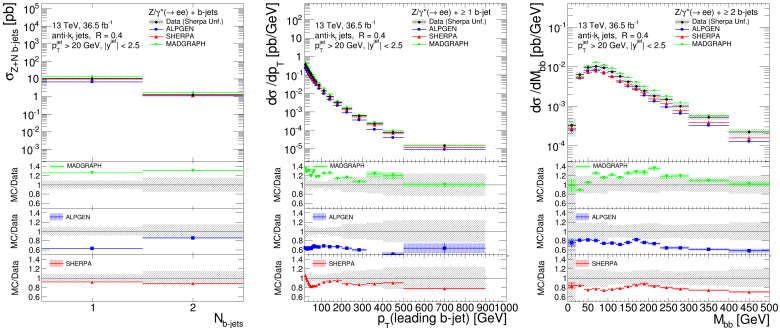




SM: $W/Z + b$-jet production measurement *(on-going)*

- $W/Z + b$ production is a good test for pQCD predictions
- Important background for $H \to b\bar{b}$ and other searches
- Measurement uses 2015–2016 data ($36.1\,\mathrm{fb}^{-1}$)
  - Both electron and muon channels for Z/W
  - Inclusive x-sections for $Z/W+ \geq 1b$, $Z/W+ \geq 2b$
  - Differential x-sections for various observables

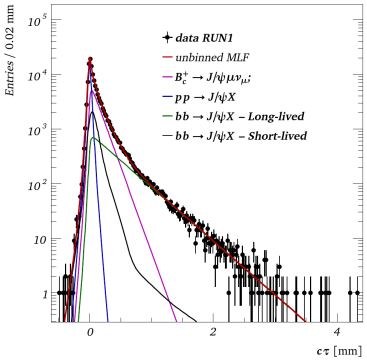


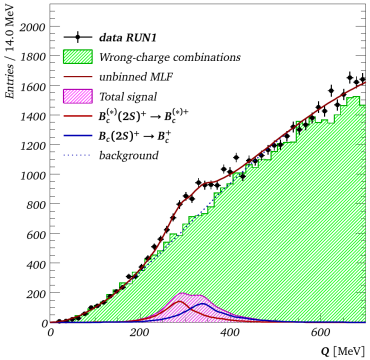


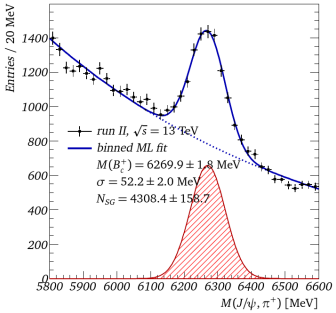
- SHERPA provides best inclusive x-section description
- Various discrepancies in the shape description across the generators

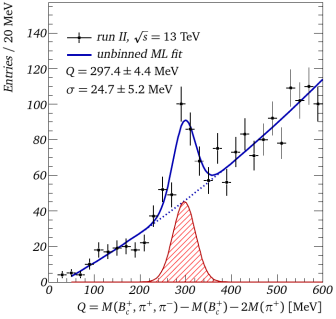
B-physics: searches for $B_c^{(*)}(2S)$ states *(on-going)*

- $B_c^{(*)}(2S) \to B_c^+\pi^+\pi^-$ was first observed by ATLAS in Run-1
  - Later LHCb claimed non-observation → tension with ATLAS
- Run-2 (full dataset) analysis using $B_c^+ \to J/\psi\pi^+\pi^-$
  - Confirmation of the Run-1 result with the new data
- New Run-1 analysis using $B_c^+ \to J/\psi\mu^+X$ mode
  - Incomplete reconstruction → more difficult analysis technique
  - Benefit from ×20 higher $\mathcal{B}$ → ∼50k signal B_c+, ∼2k signal $B_c^{(*)}(2S)+$)

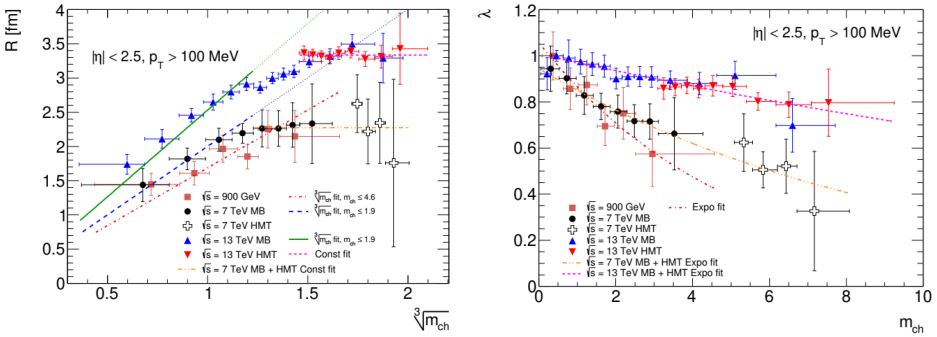








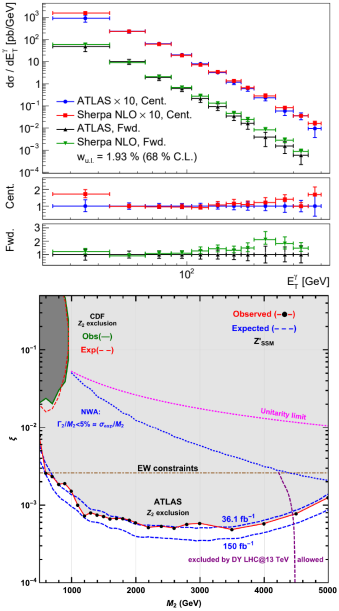
Soft QCD: Bose–Einstein correlations with charged particle pairs at 13 TeV



- Bose-Einstein Correlations (BEC) studied for same-sign charged particle pairs in pp-collisions at $\sqrt{s} = 13\,\text{TeV}$.
  - Using the double ratio correlation function $R_2(Q)$ which eliminates problems with energy–momentum conservation, topology, resonances etc.
- **Saturation effect** in the multiplicity dependence of the BEC source radius is confirmed for high multiplicity.
  - First observation at 7 TeV in EPJC 75 (2015) 466
- The multiplicity and pair transverse momentum dependencies of the BEC correlation strength and source radius parameters on the energy collisions are observed.

Theoretical work in JINR ATLAS group

- Evaluation of intrinsic charm PDF component from ATLAS measurement of $\gamma + c$-jet production at $\sqrt{s} = 8\,\text{TeV}$
  - Upper limit on the IC fraction set at 1.9 % @ 68 % C. L. (arXiv:1712.09096)
  - Plan to contribute to $\gamma + c$ and $Z + c$ production measurement with Run-2 data
- Electroweak process calculations for LHC
  - Adding higher-order $O(\alpha\alpha_s)$, $O(\alpha^2)$, $O(\alpha_t\alpha_s^2)$, $O(\alpha_t^2\alpha_s)$, $O(\alpha_t\alpha_s^3)$ corrections for single W/Z production to *MC SANC* integrator (version 1.30 being prepared)
  - Modelling and calculation for Drell-Yan analyses in ATLAS, contributing to CERN Yellow Reports
- Constraint on $Z - Z'$ mixing parameters from ATLAS search for diboson resonances (JHEP 03 (2018) 042, 13 TeV, 36 fb^{-1})
  - Most stringent limits to date set in (M_2, ξ) plane, much improved w.r.t. earlier results from Tevatron and precision EW data analyses (EPJ Web Conf. 191 (2018) 02006)



Software support and development

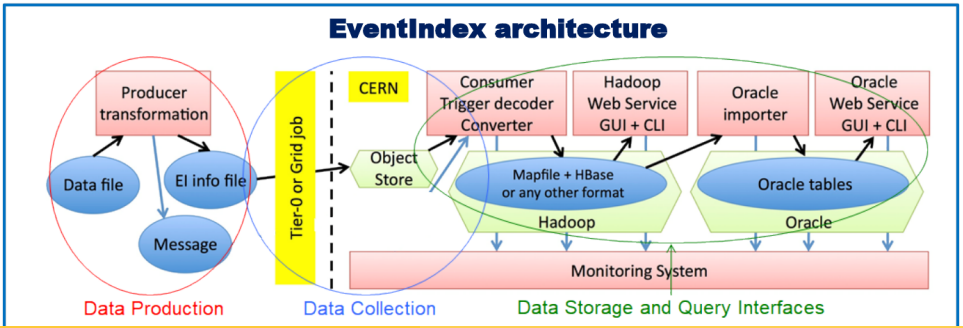
Distributed data management: EventIndex

EventIndex is a system to index the data or Monte Carlo events in the ATLAS experiment

- Full index stored in Hadoop system, an abbreviated version in Oracle DB

Possible use cases:

- Event picking (to get a handful of events in a desired formats)
- Event selection or counting based on trigger decisions
- Checking data consistency/integrity
- Producing trigger chain overlapping matrices
- Producing data stream overlapping matrices
- Quick assessment of datasets content



EventIndex – JINR contribution

On-going activities:

- Management of data indexing at GRID sites
- Decoding the trigger information in MC (trigger bits → trigger chain names, using the DB)
- System performance monitoring
  - Implemented using a modern platform influxDB + Grafana

Development of EventIndex using modern BigData technologies for the Run-3 operation:

- Use HBase as data storage
- Use Spark and Impala to improve the performance of data and queries processing
- Deep modernization of EventIndex, migration to a completely new platform

Participating in EventIndex project opens a window to modern BigData technologies, provides unique experience useful for other experiments or educational projects

Summary

- JINR ATLAS team made a substantial contribution to a number of physics studies
  - 2 ATLAS papers published in 2018 (+3 ATLAS conference proceedings)
  - $>$ 10 physics analyses on-going
- Active participation in the Phase-1 upgrade programme
- Theoretical support of physics measurements
- Distributed data management software support and development
- *Not all areas of activity were presented in the talk!*

- Take a chance to get more details from our team posters tonight:
  - Observation of VH production and $H \to b\bar{b}$ decay (*Faig Ahmadov*)
  - Micromegas production facility (*Irakli Minashvili*)
  - Low-p_{T} (di)-muon trigger efficiency measurement (*Tatiana Lyubushkina*)

Thank you for your attention!

Backup slides

Conference presentations in 2018

- LHC days in Belarus 2018 – several reports from JINR team (*A. Cheplakov*, *Yu. Kulchitsky*, *V. Lyubushkin*, *A. Pankov*, *S. Turchikhin*)
- Beauty'2018 – "Beyond Standard Model searches in B decays with ATLAS", *S. Turchikhin*
- Charm'2018 – "Prospects of Charm Physics at ATLAS", *S. Turchikhin*
- Charm'2018 – "Multiple charm(onium) production at the LHC", *S. Turchikhin*
- QCD@work'2018 – "Probing QCD with the ATLAS Detector ", *Yu. Kulchitsky*
- Talks at local JINR conferences AYSS'2018, Alushta'2018 (*F. Ahmadov*, *O. Koval*)
- Contributions to LHC Electroweak WG meeting and LHC EW Precision Sub-group meeting (*S. Bondarenko*, *L. Kalinovskaya*, *A. Sapronov*)

Papers papers published in 2018

ATLAS publications with major contribution of JINR team

- Search for heavy resonances decaying to a photon and a hadronically decaying $Z/W/H$ boson in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector, PRD 98 (2018) 032015
- Observation of $H \to b\bar{b}$ decays and VH production with the ATLAS detector, PLB 786 (2018) 59

Conference proceedings

- *Y. Kulchitsky*, Probing QCD with the ATLAS Detector, EPJ Web of Conferences 192, 00002 (2018), Proceeding of "QCD@work'2018"
- *S. Turchikhin*, Beyond Standard Model searches in B decays with ATLAS, PoS(BEAUTY2018)048, Proceedings of "Beauty'2018"

Non-experimental works related to ATLAS

- *A. Pankov, V. Bednyakov*, First results on precision constraints on $Z - Z'$ mixing with ATLAS and CMS diboson production data at the LHC at 13 TeV and predictions for Run II, EPJ Web Conf. 191 (2018) 02006, Proceeding of "QUARKS'2018"
- *N. Abdulov et al.*, Employing RHIC and LHC data to determine the transverse momentum dependent gluon density in a proton, PRD 98 (2018) 054010, Proceeding of "QCD@work'2018"
- *V. Bednyakov et al.*, Constraints on the intrinsic charm content of the proton from recent ATLAS data, arXiv:1712.09096, submitted to EPJC

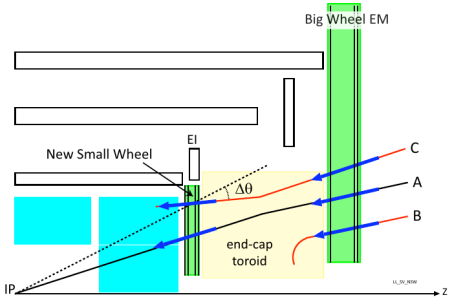
Upgrade overview

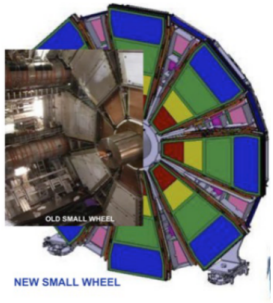
The Phase-2 upgrades for the HL-LHC run are motivated by the aging of the inner tracker (primarily because of radiation exposure), by the increased occupancy of the detector systems and data volumes that would saturate the readout links, by the obsolescence of some of the detector sub-system electronics, and by additional requirements that the trigger system will impose on the detector readout in order to cope with the expected luminosity during the HL-LHC era (5×10^{34} cm^{-2} s^{-1} with $\langle\mu\rangle\approx140$). Specifications of each upgrade component are then defined for up to $\langle\mu\rangle=200$.

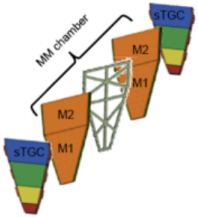
JINR in the Phase-2 Upgrade Programme (from the MoU's):

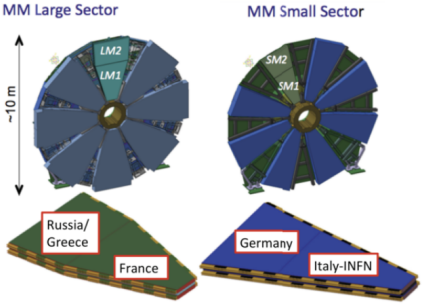
High Granularity Timing detector (HGTD) - *mechanics design and production, assembly.*
LAr trigger electronics – *HEC input stage design and testing, analog circuit development; Production and testing of optical pigtails.*
TILE - *New Auxillary control boards, cables.*
MUON - *RPC Singlet assembly and testing; Strip panels production and testing; Gas system design, production, installation; Power distribution design, distribution, production and installation;*
TDAQ - *FELIX I/O card. Procurement of components and testing*

New Small Wheels





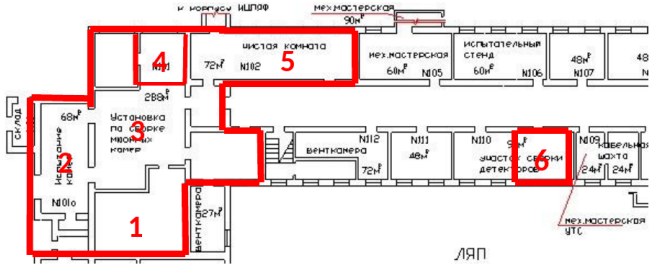




Production at DLNP

2 lines:

- *ATLAS MM for NSW upgrade* – MM from the received materials
- *"Dubna" MM bulk lab* – complete cycle production line for R&D, different experiments and applied studies



1) Assembly clean room (RO panels)
2) "Dubna" MM production Line
3) Hall for cosmic stand

4) MM gas leak testing room
5) Clean room for Quadruplet assembly (+3d machine)
6) Panels cleaning/washing room

ATLAS Calorimetry