Brazilian Participation in the ALICE Experiment

USP: *Marcelo Munhoz, Alexandre Suaide, Marco Bregant, Tiago Silva*

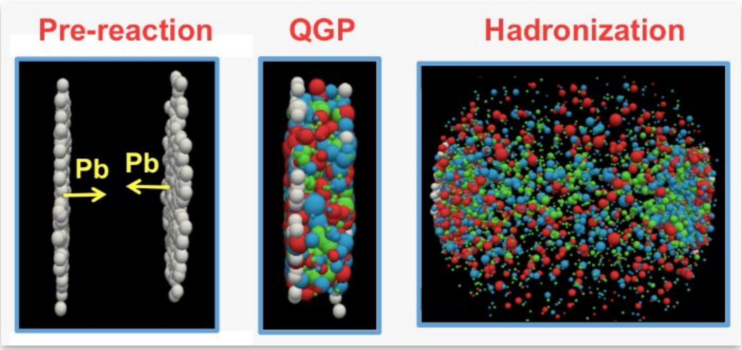
UNICAMP: *Jun Takahashi, Cristiane Jahnke*

UFABC: *Mauro Cosentino*

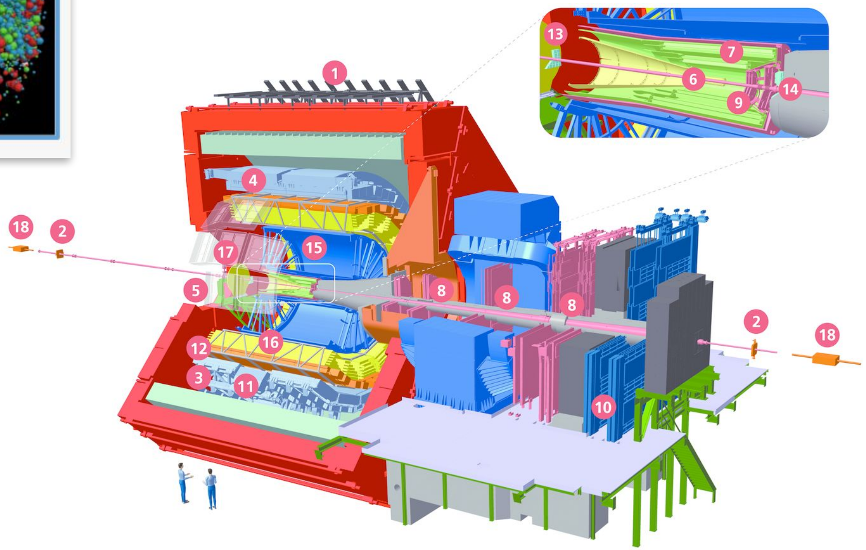
UFRGS: *Maria Beatriz Gay, Cristiano Krug*

ALICE Goal

- The study of matter under extreme conditions: Quark-Gluon Plasma



- Optimized to study collisions of nuclei at the ultra-relativistic energies



ALICE Global view

- World: 40 countries, 169 institutes, 1947 members
- Brazil:
  - 4 Institutes: UNICAMP, USP, UFABC, UFRGS
  - 9 faculty researchers + 2 postdocs (1.8% of ALICE)
    - M&O – A: ~ CHF12.000,00 per person per year
  - 10 PhD students (2.5% of ALICE)
  - 3 master students (1.8% of ALICE)

Brazilian participation

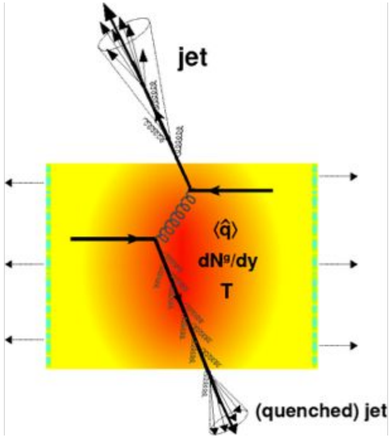
Contribute to the ALICE program through a relevant participation in

- Physics data analysis
  - Hard probes (heavy-flavour and jets)
  - Strangeness

- Development of state-of-the-art instrumentation
  - TPC aging and degradation studies
  - Forward Calorimeter (FoCal)
  - ALICE 3
    - TOF

Data analysis

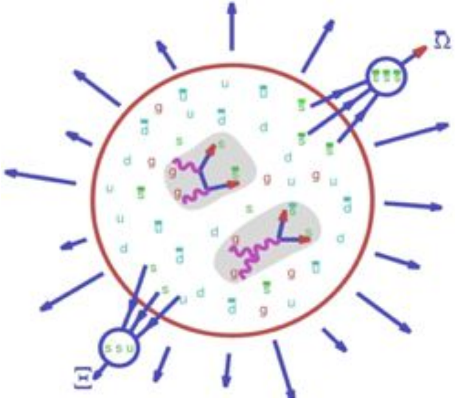
- **J/ψ in jets**
- **Jets from heavy-flavour (electrons)**

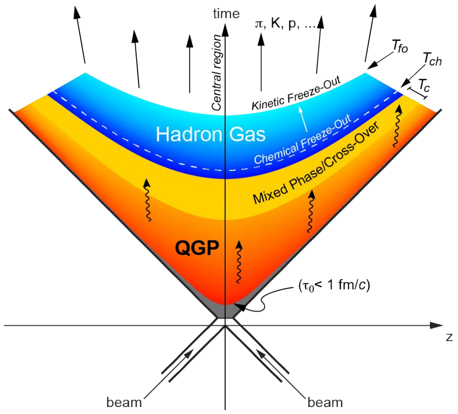


- **X(3872)**

Diquark–diantiquark

- ***Strangeness:***
  - ***Ksi: Ξ^-***
  - **Sigma: Σ^0**

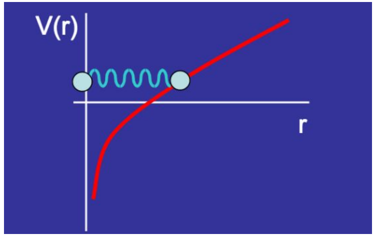




Data analysis: quarkonia

Vacuum potential between q qbar pair grows linearly at large distances

$$V(r) = -\frac{4}{3}\frac{\alpha_s}{r} + kr$$

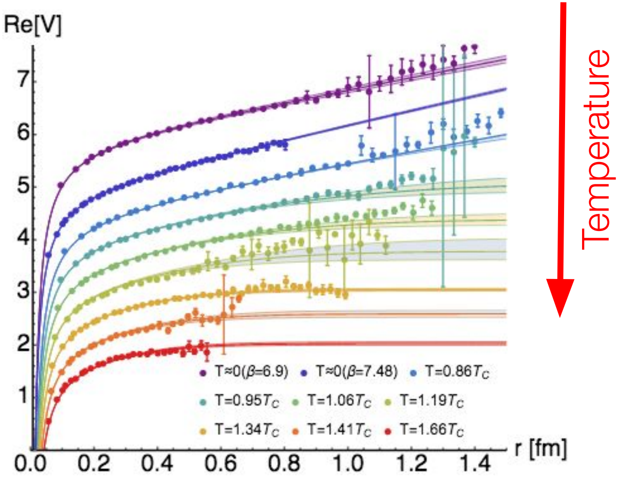


Heavy quark potential

In a deconfined medium the potential is modified:

$$V(r) = -\frac{\alpha_s}{r} e^{-r/\lambda_D}$$

- Coulomb potential is Debye screened
- Quarkonium states will be melted if r > λ_D
  → Quarkonia suppression = QGP signature
- Maximum distance allowed for formation of a bound pair decreases with T
  → Differents states melts at different energies



https://arxiv.org/pdf/1606.06211.pdf

Data analysis: quarkonia

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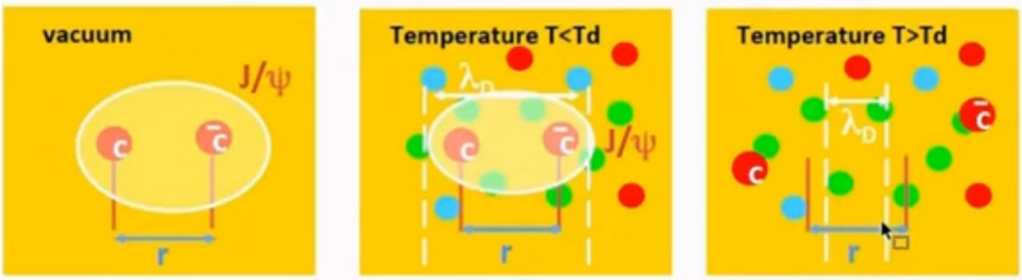

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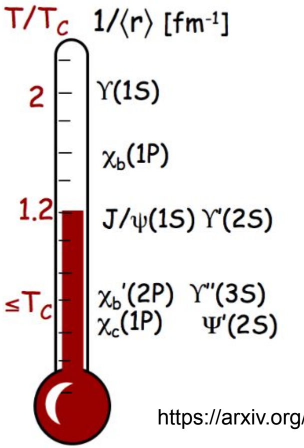

https://arxiv.org/pdf/0811.0337.pdf

Data analysis: quarkonia

Sequential melting observed at RHIC

But at LHC energies, an additional effect was observed and called as Regeneration

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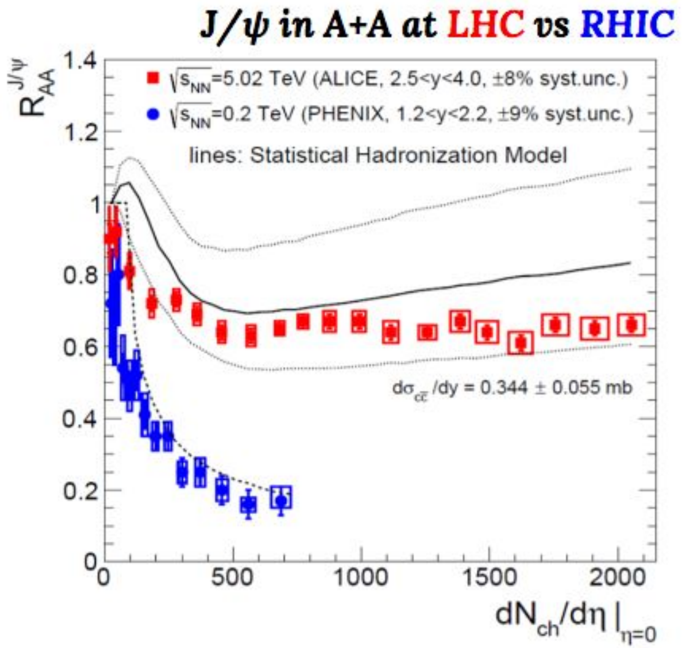
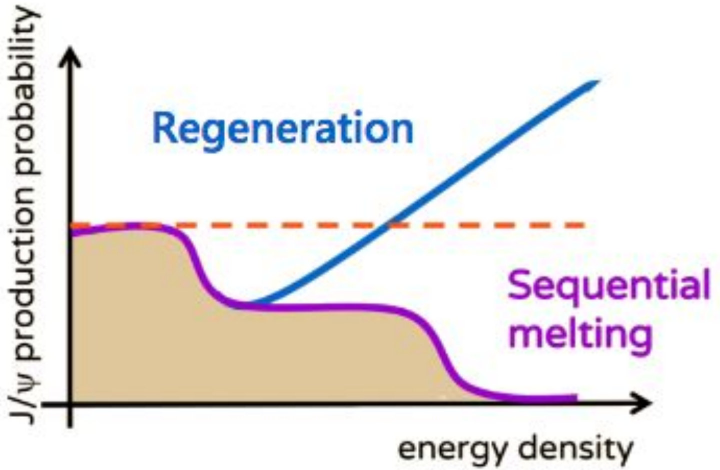
PHENIX, PRC 84 (2011) 054912



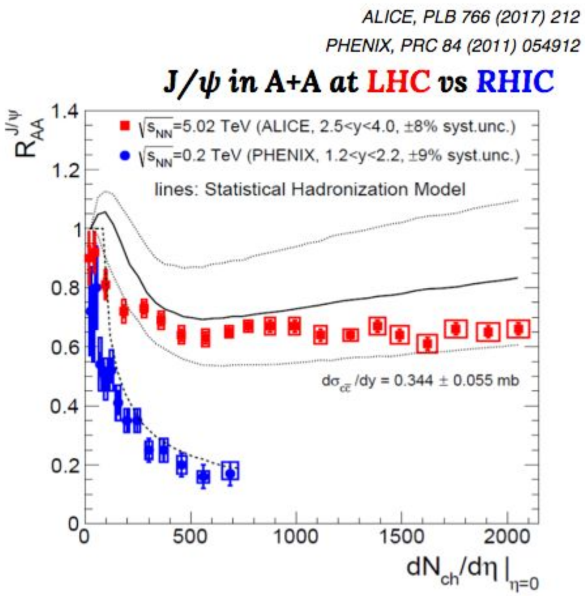


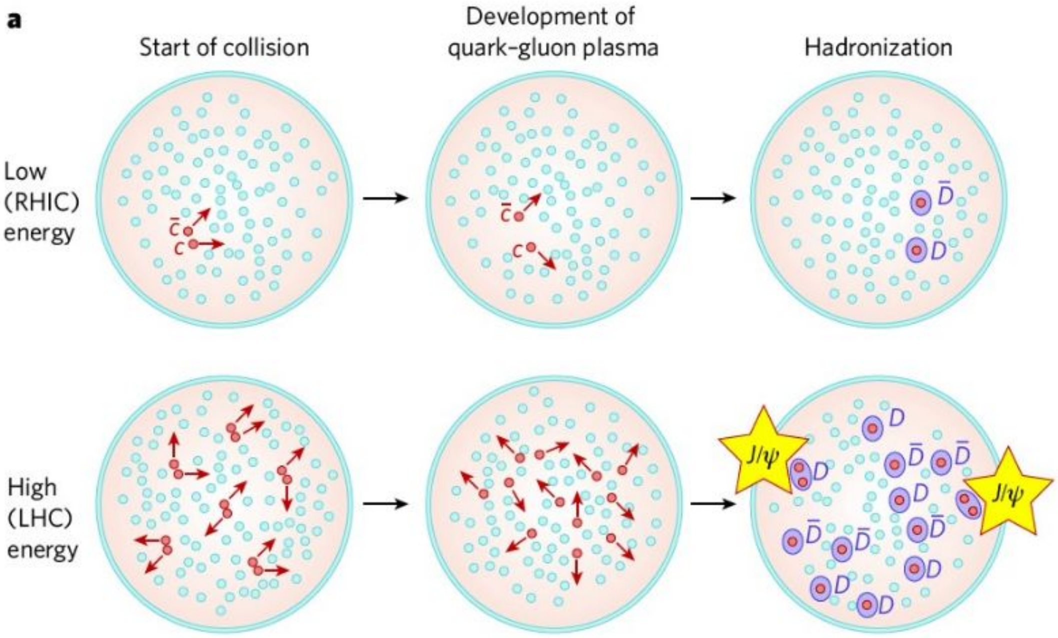
Data analysis: quarkonia

At RHIC/LHC energies, large amounts of c cbar pairs are created

→ Possible to create charmonium on a statistical basis

→ More pronounced at LHC energies





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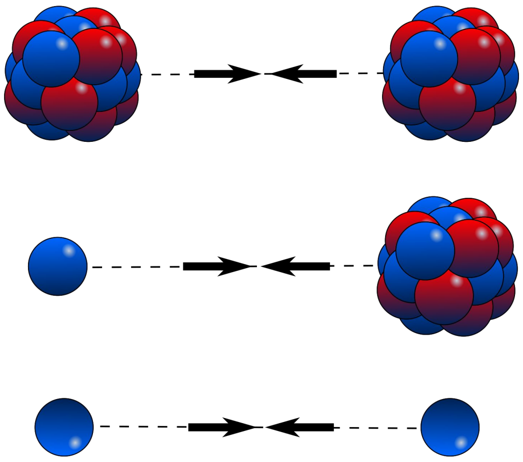
Data analysis: collisions systems

- To understand QGP formation in Pb-Pb collisions, we need references!
- How good is the description of quarkonia in proton-proton and proton-Pb collisions?

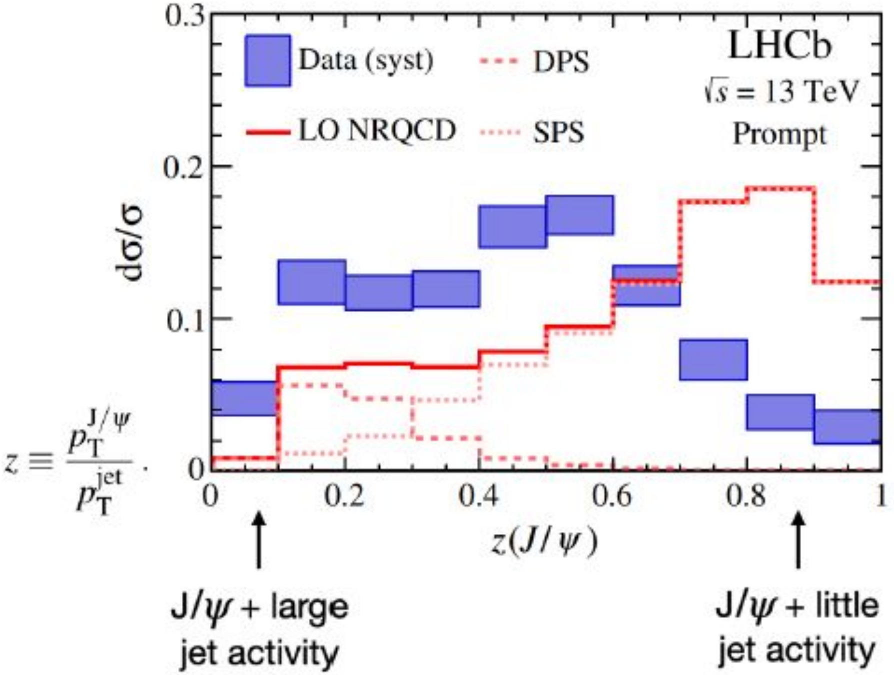
  - Heavy-ion collisions:
    - Quarkonium as a hint of deconfinement (QGP)
  - p-Pb collisions:
    - Cold nuclear matter effects
  - pp collisions:
    - Quantum Chromodynamics (QCD)



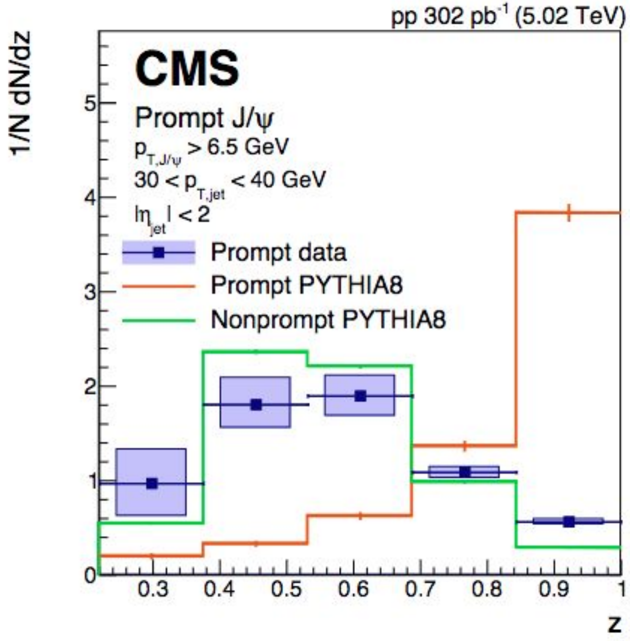
Data analysis: J/ψ in jets

- Motivation: J/ψ produced isolated or in parton showers?
- Prompt J/ψ produced with larger jet activity than predicted by models.

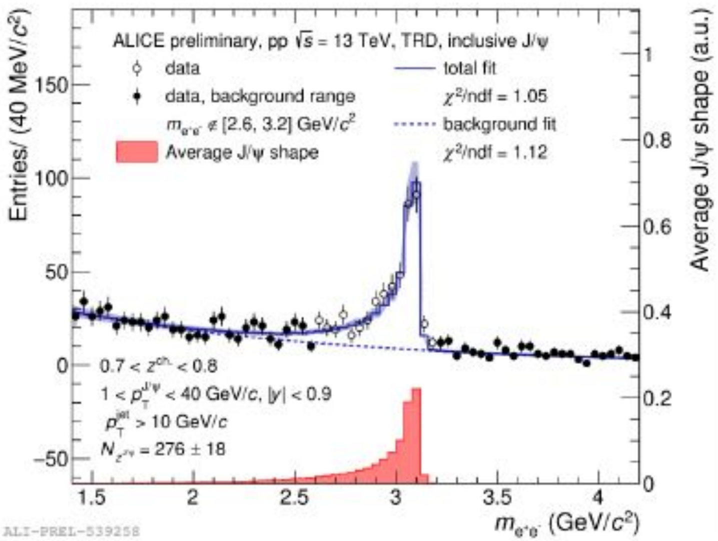
https://arxiv.org/pdf/1701.05116.pdf

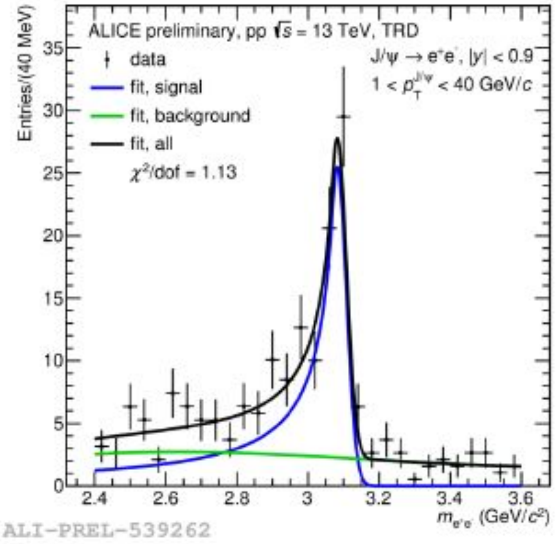


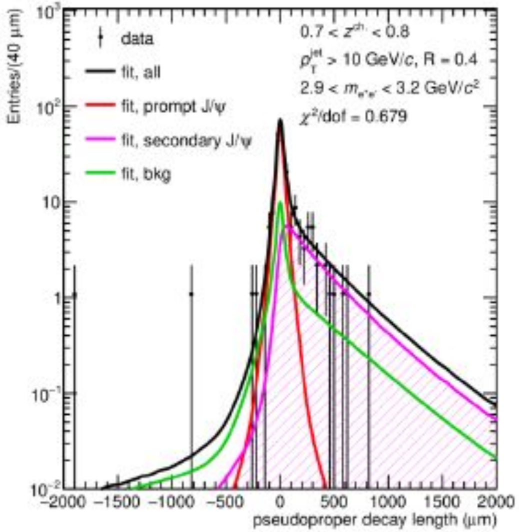
Phys. Lett. B 825 (2021) 136842



Data analysis: J/ψ in jets

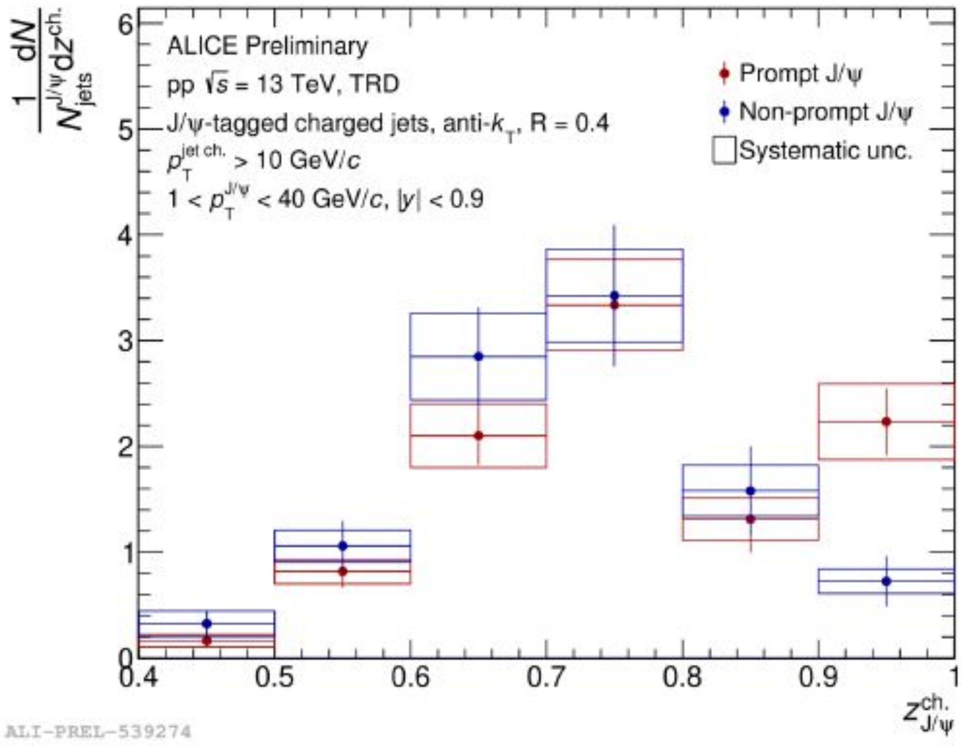






- Jet reconstruction by using anti k_T algorithm with the FASTJET package.
- Extract J/ψ signal in jets with different z(J/ψ)
- Separation of prompt and non prompt J/ψ using pseudo proper decay length

Data analysis: J/ψ in jets



Prompt and non-prompt J/ψ fragmentation functions similar within uncertainties.
→ very large systematic errors.

- Jet p_T smaller than LHCb and CMS
- Different rapidity range when compared to LHCb

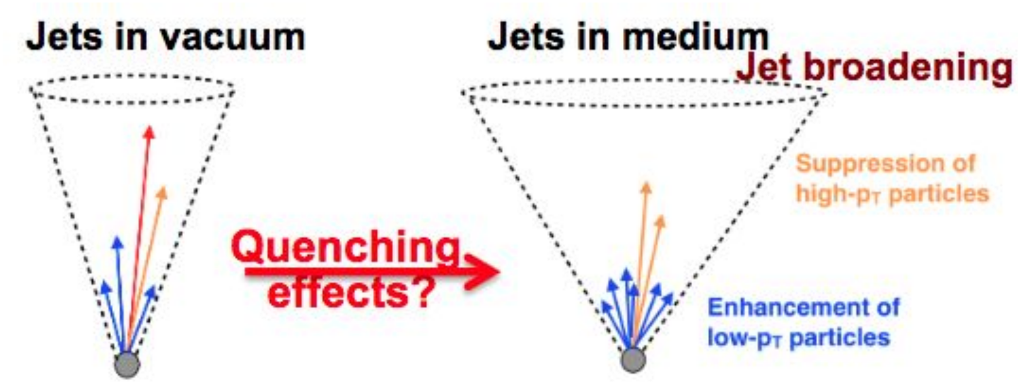
→ Ingrid Lofnes (Oslo)
→ Students working with high multiplicity triggers (Fabio)

Data analysis: Jets from heavy-flavour

Motivation: Address possible modification of jet properties and parton fragmentation in the medium

- Is the jet internal structure modified?
- What are the kinetic properties?

(Leonardo)

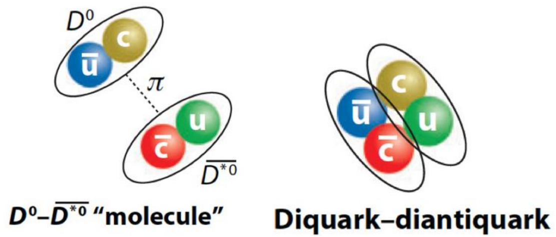


Can HF-jet provide complementary information to inclusive jets?

- HF-jet: (heavy) “quark tagging”
    - Smaller background of “fake” jets from combinatorics at low p_T
    - Better jet-energy scale (depending on observable)?

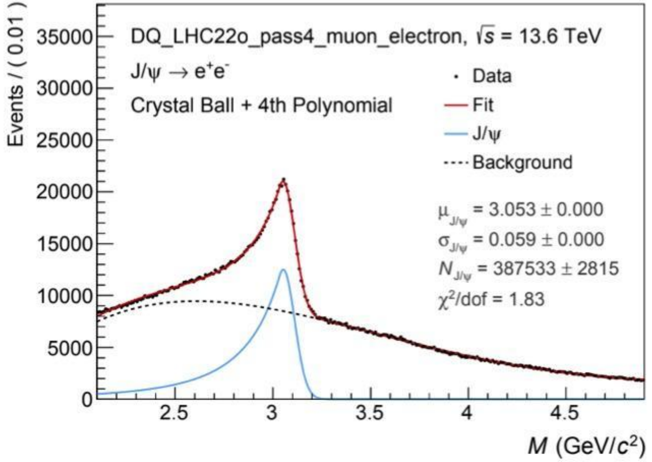
Data analysis: X(3872)

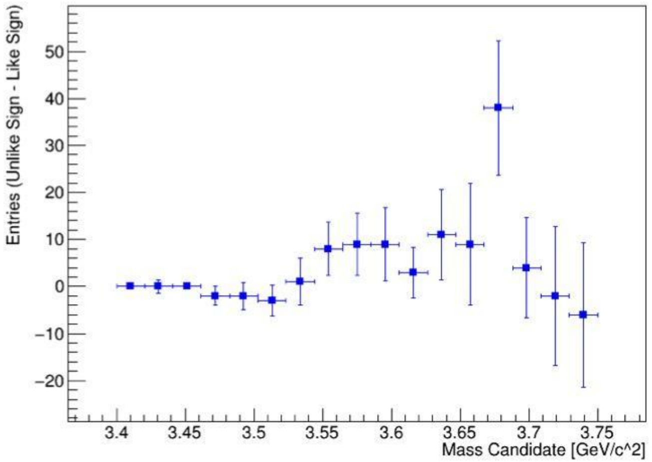
$X(3872) \rightarrow J/\psi\, \pi^+\pi^-$



(Leopoldo)

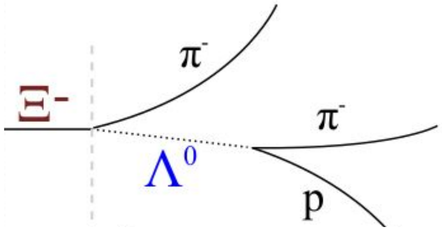
- Different hadronic structures can affect the interaction with the medium formed.
  → In Pb-Pb collisions, the production of X(3872) may increase via coalescence or decrease due to dissociation (similar to quarkonia states).
  - Processes depend on spatial configuration.

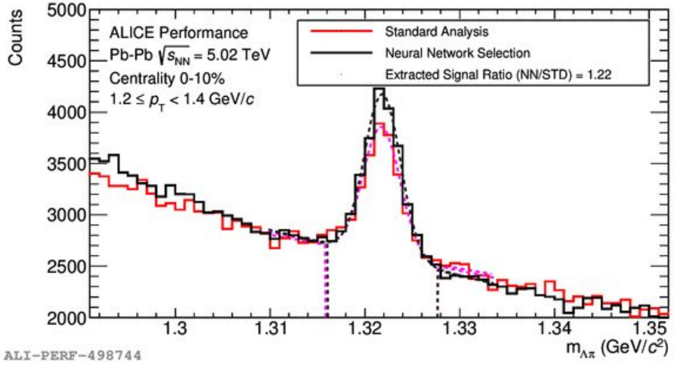




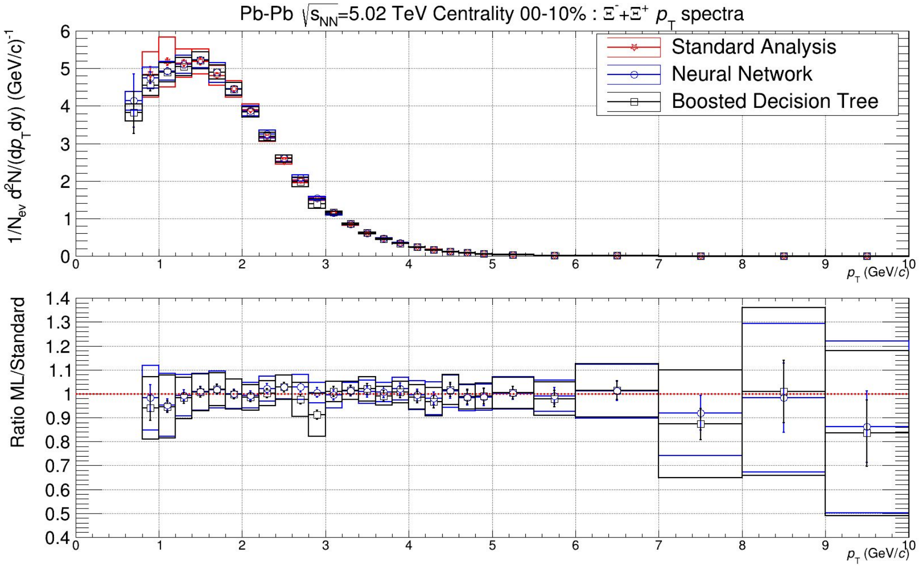
Data analysis: strangeness

Application of ML techniques to improve the signal-to-background ratio (Gabriel)





Invariant mass spectra of Ξ^- particle, showing the improvement of a Neural Network selection



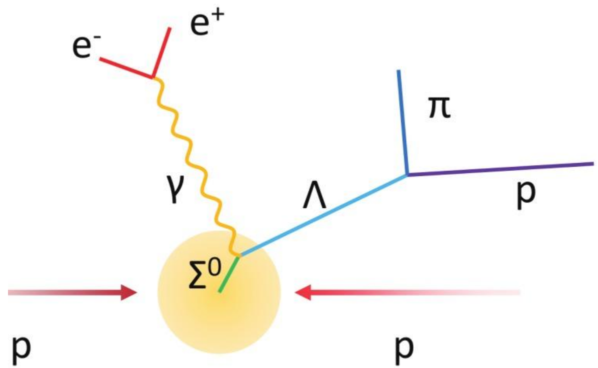
→ Additional p_T bin

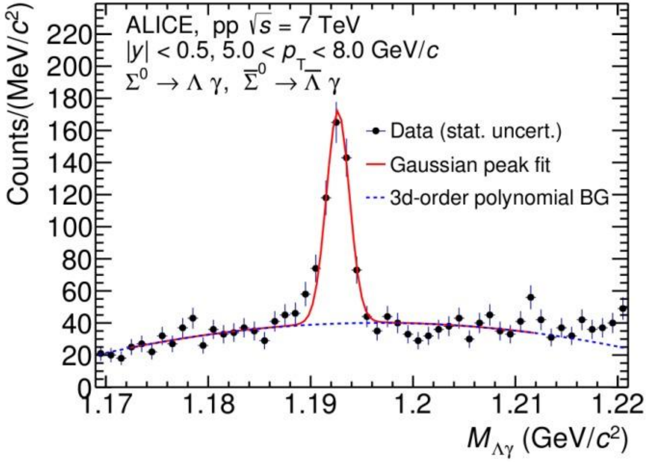
Data analysis: strangeness

- Measurement of Σ^0 baryon in pp and Pb-Pb collisions (Gianni)
- Development of analysis codes for V0s/Cascades selection using ML

  → applicable for $\mathbf{\Lambda}^0$, $\mathbf{\Sigma}$, $\mathbf{\Omega}$, $\mathbf{\Xi}$, $\mathbf{K}^0{}_S$

- BDT for gammas and lambdas





Coordination of PWG-DQ

PWG

Cristiane JAHNKE

Luca Micheletti

JPsi2ee

Victor FEUILLARD

Xiaozhi BAI

QQ2mumu

Maxime GUILBAUD

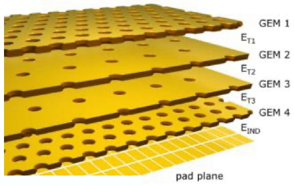
Batoul DIAD

Some of the conveners tasks

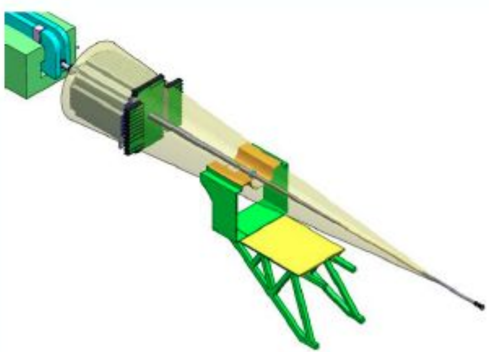
- Coordinate and review analysis from both PAGs
- Prepare abstracts for big conferences
    - Eg. SQM and ICHEP
- Review proceedings/slides/abstracts submitted by PWG-DQ members
- Indication of possible speakers of conferences
- Review and participate of the rehearsals
- Participation on the Physics Board of the ALICE Collaboration

Upgrade

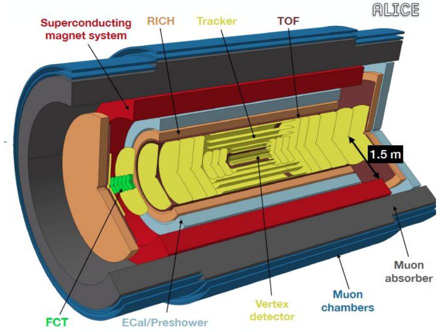
- TPC aging and degradation studies



- Forward Calorimeter
  - Simulations of trigger
  - Physics performance
  - Electronics

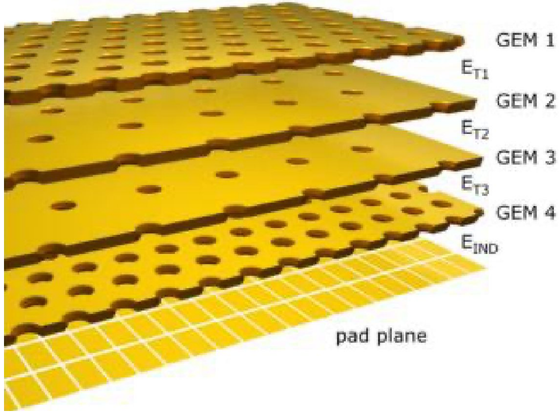


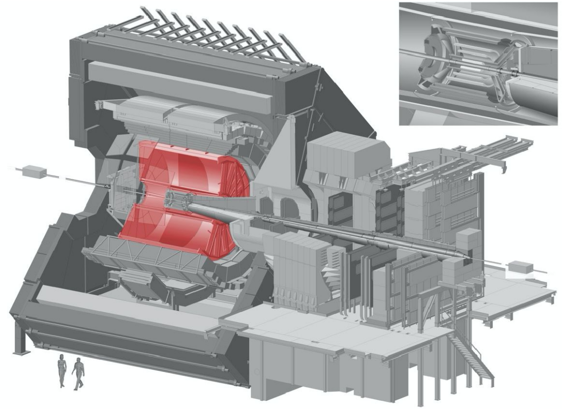
- ALICE 3 TOF

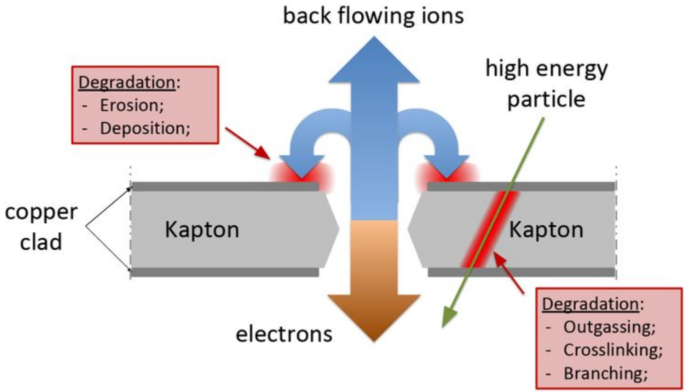


Upgrade: TPC aging and degradation studies

- ALICE TPC Aging Studies:
  - Better understanding of aging and degradation effects

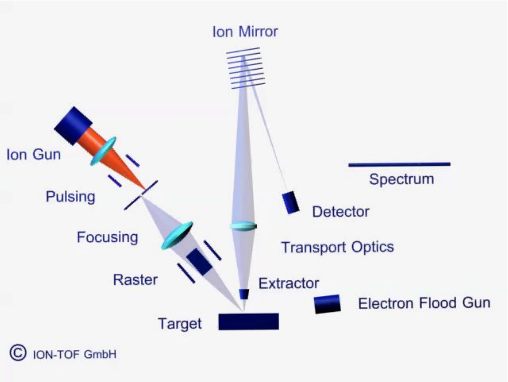




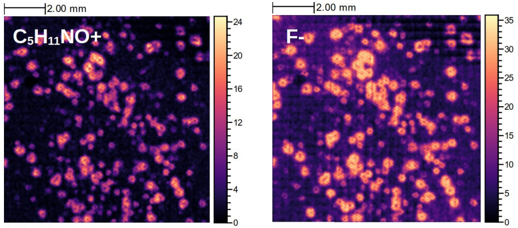


Upgrade: TPC aging and degradation studies

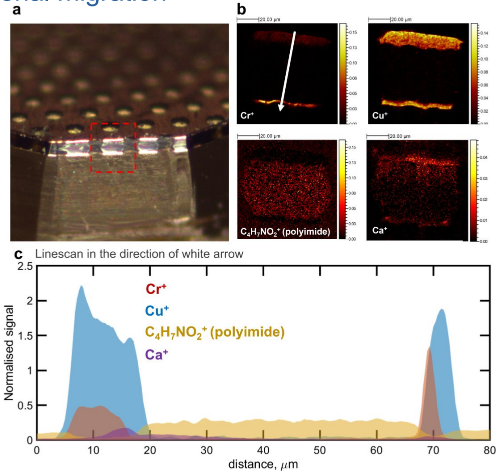
Innovative contribution in using high chemical specificity analytical techniques: ToF-SIMS!



Polyimide redeposition



Material migration



Participation in the 3rd International Conference on Detector Stability and Aging Phenomena in Gaseous Detectors. (Thiago Badaró)

Results obtained in collaboration with NPL and University of Nottingham in UK.

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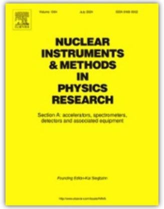

ISSN 0168-9002

Evidence for polyimide redeposition and possible correlation with sparks in Gas Electron Multipliers working in CF4 mixtures

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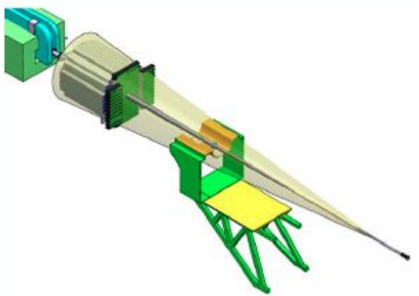
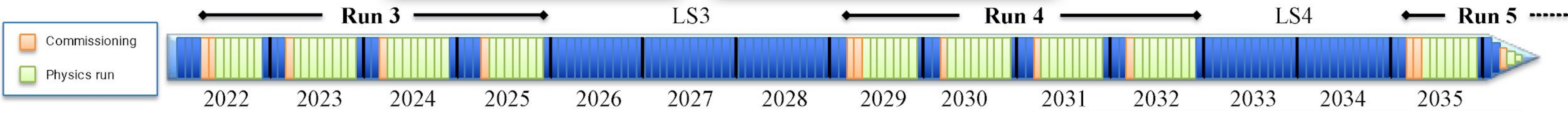
29 Jun 2024

Upgrade: Forward Calorimeter

→ Approved project
→ Published TDR in May



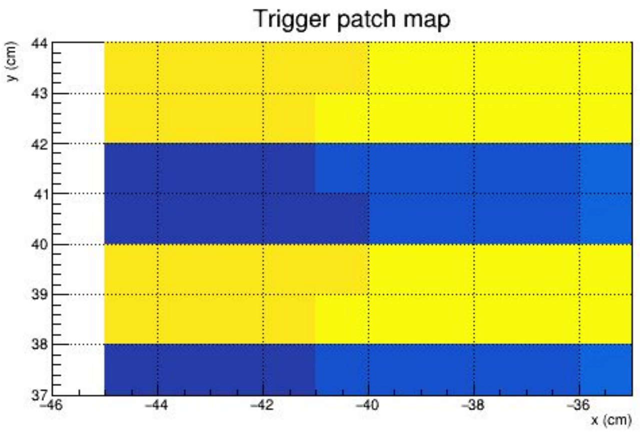


- Forward Calorimeter (FoCal)
  - Explore the small-x parton structure of nucleons and nuclei
  - Electromagnetic and hadronic calorimeters at the very forward region ($3.4 < \eta < 5.8$)

Upgrade: trigger simulation for FoCal

- The issue: very high occupancy events may lead to busy violation in the reading of the pixel layer data
- To mitigate the issue triggering PADs in the 2 layers immediate in front of the pixel layer
- We use some pre-produced simulations and emulate the patch geometry of layers 8 and 9

Hardware configuration



Software configuration

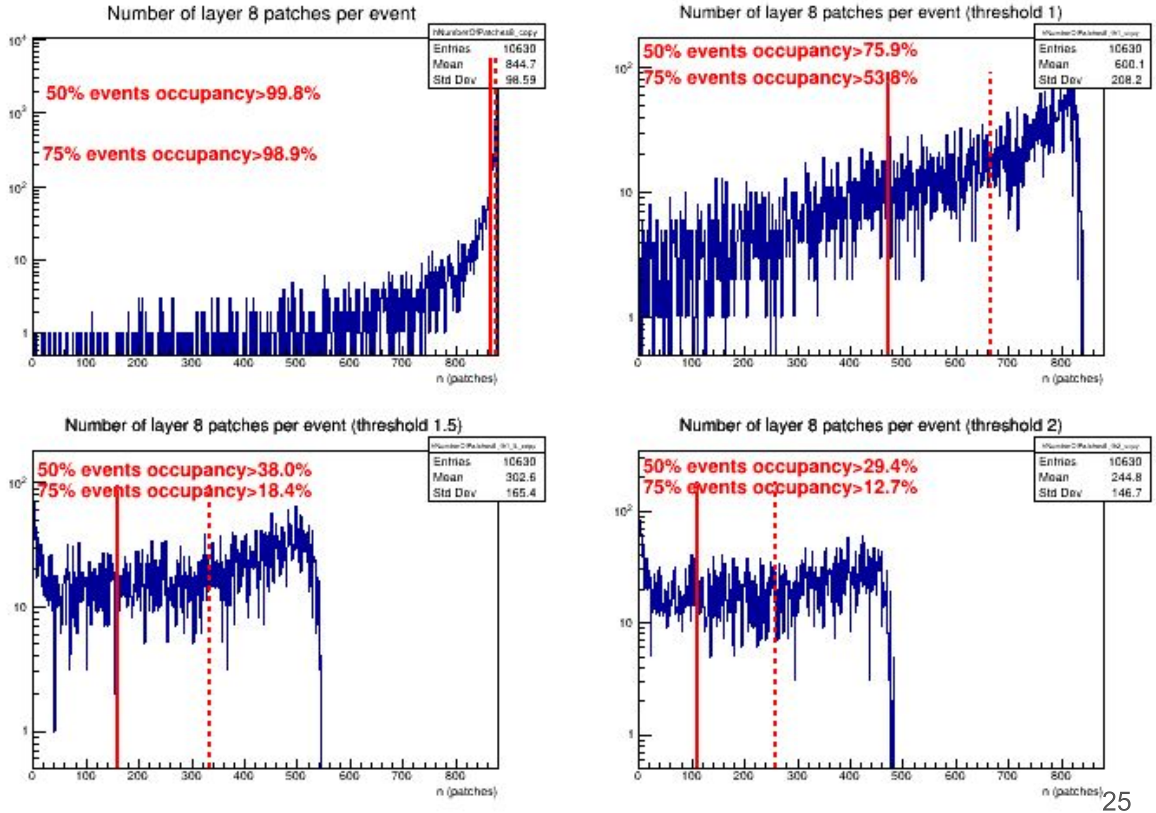
Upgrade: trigger simulation for FoCal

- First calibrate the (GEANT3) energy deposited in layers 8 and 9

- Then choose some patch thresholds corresponding to p_T^{γ}=1.0, 1.5 and 2.0 GeV/c

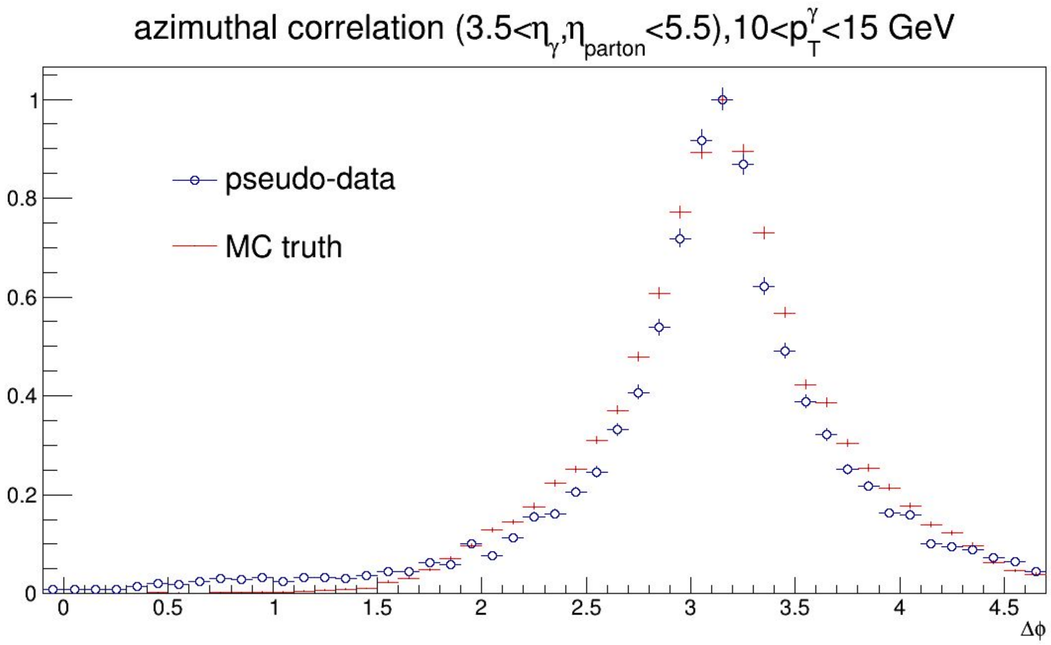
- Apply thresholds to pp MB collisions

- Clearly a trigger is needed!



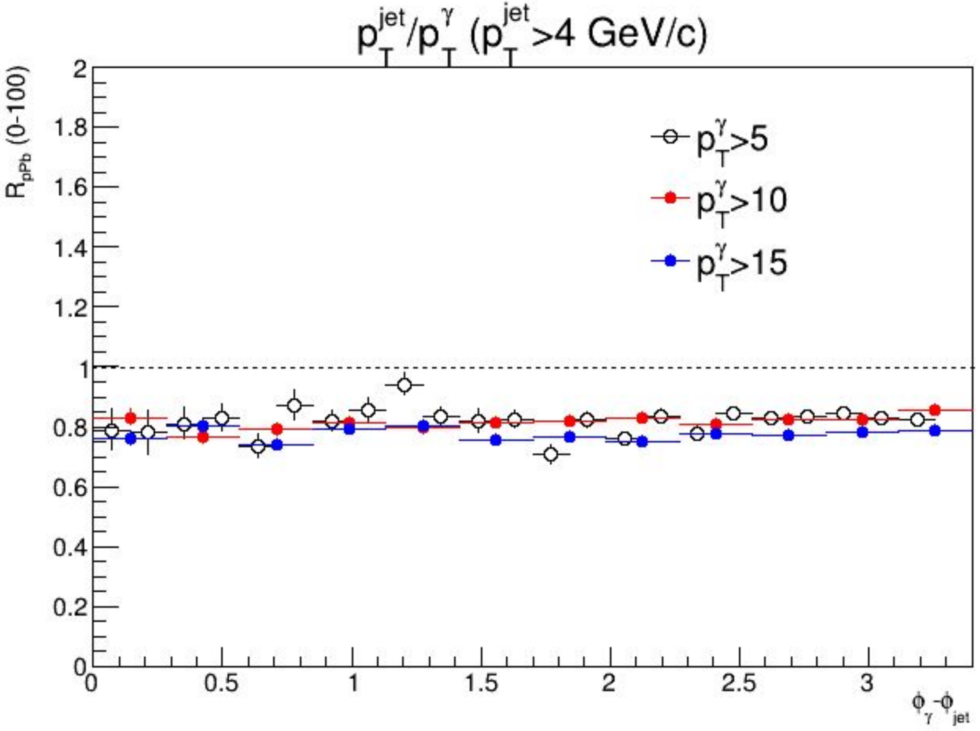
Upgrade: physics performance using FoCal

- Isolated photon-jet correlations (both in FOCAL)
- Access to low-x



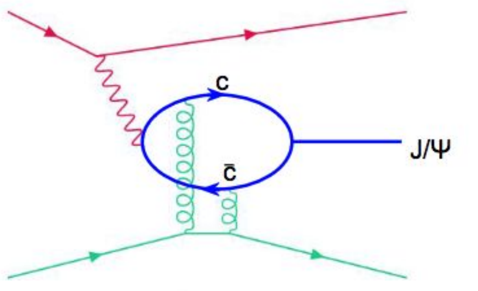
Upgrade: physics performance using FoCal

- K_T: ratio between jet p_T and photon p_T can give information on gluon density
- Ratio between p-Pb and p-p k_T could probe gluon saturation in the Pb nucleus



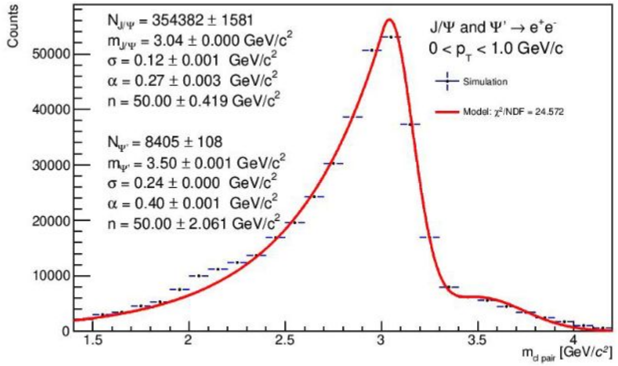
Upgrade: simulations of J/Ψ using FoCal

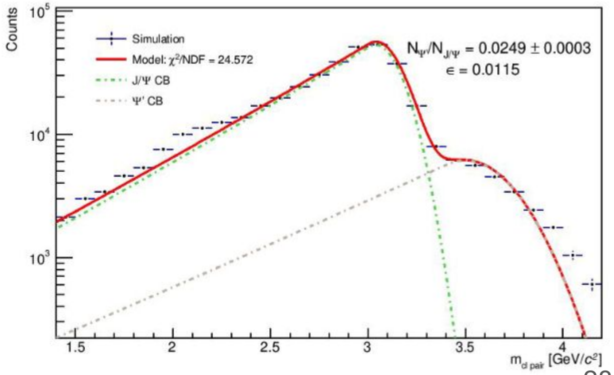
- Exclusive vector meson production in UPC provides access to the PDFs and allows for checking the gluon density.
- Low rapidity measurements are sensitive to particles with small-x.



$$x = \frac{M_{J/\psi}}{\sqrt{s_{NN}}} e^{\pm y}$$

- Simulation using STARlight to generate J/Ψ and Ψ’ events.
- The data is grouped into superclusters and matched with the physical primary particles.
- (incoherent production)





FoCal: photoproduced J/Ψ phenomenology

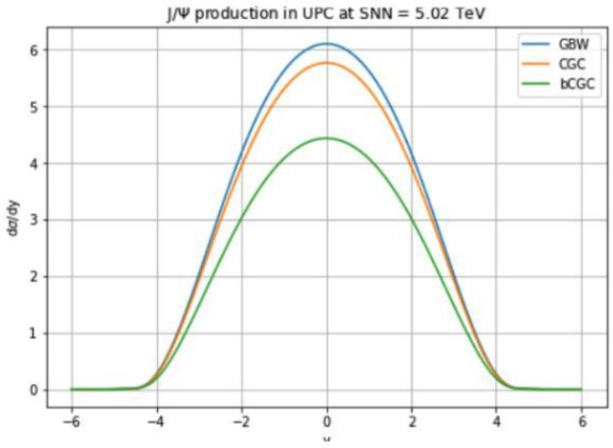
UPC:
Coherent photoproduction of J/Ψ:

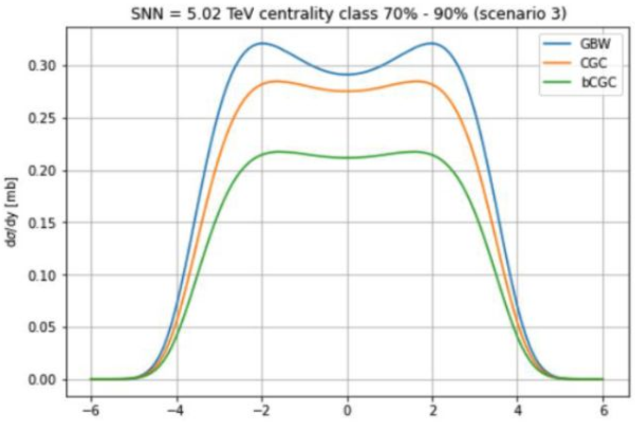
$$\frac{d^3\sigma_{AA\to AAV}}{d^2bdy} = \omega N(\omega, b)\sigma_{\gamma A\to VA} + (y \to -y)$$

Peripheral approach:
Consider only photons that reach the geometrical region of the nuclei-target

$$N^{eff}(\omega, b) = \frac{1}{A^{eff}(b)} \int b_2 db_2 d\alpha N(\omega, b_1)\theta(R_A - b_2)\theta(b_1 - R_A)$$

Calculations included in the ALICE papers for the photoproduced J/Ψ

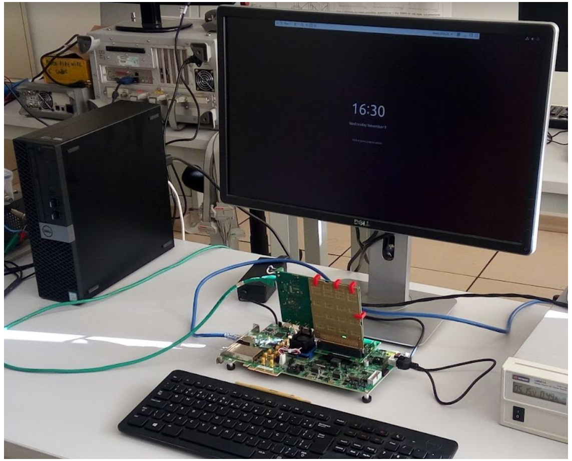




Upgrade: FoCal electronics

The future ALICE Forward Calorimeter will use the HGCROC readout ASIC:

- 10^3 dynamic range
- 72 channels
- 7900+ parameters to be set!

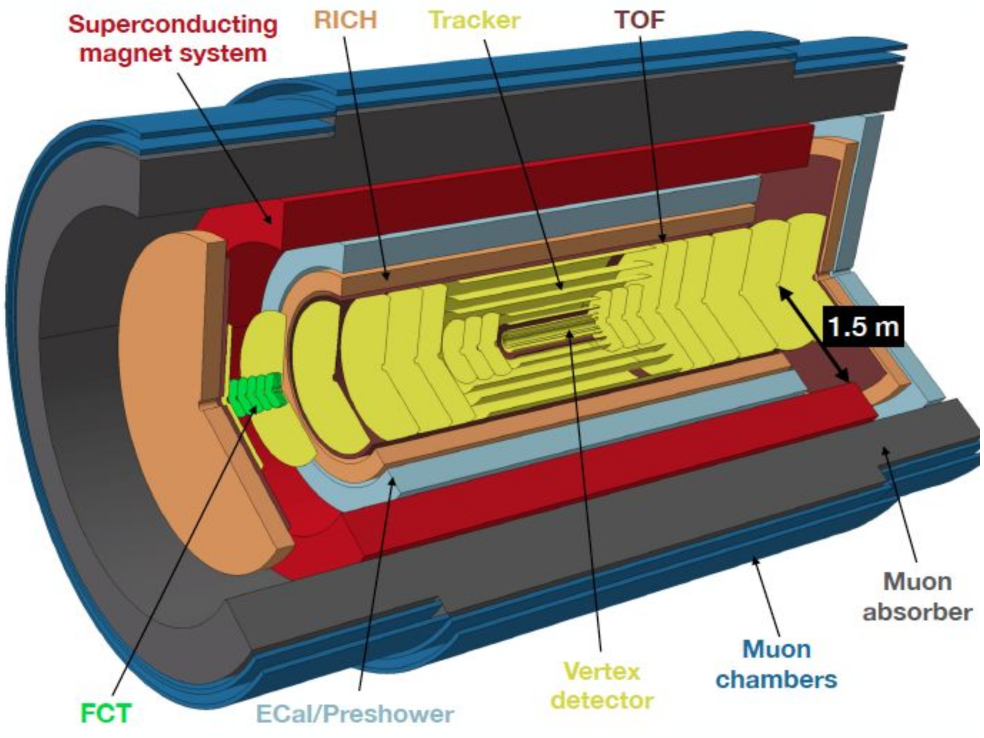


- We have positive results from a test bench set up in HEPIC featuring the HGCROC V1
- HGCROC V3 (final version) en route to Brazil will be addressed next

- Pedestal trimming and setting
- Trigger latency setting
- Pre-amplifier gain setting

Upgrade: ALICE 3 TOF

- Detector R&D (Geovane)
  - Characterization of sensors, test prototypes
  - Measurements of time resolution at CERN's PS
  - Development of an analysis tools based on PyROOT
- Simulation/O2 (Levi)
  - Geometry studies to implement segmentations
  - Occupancy vs PADs dimensions



Summary

- Brazilian group participated in several scientific results
- Brazil has a crucial role in the upgrade of ALICE
  - GEM's studies
  - FoCal
  - ALICE3
- Run 3:
  - New results and high precision data coming soon!

Backup

ALICE future perspectives (Run 5 - 2035)

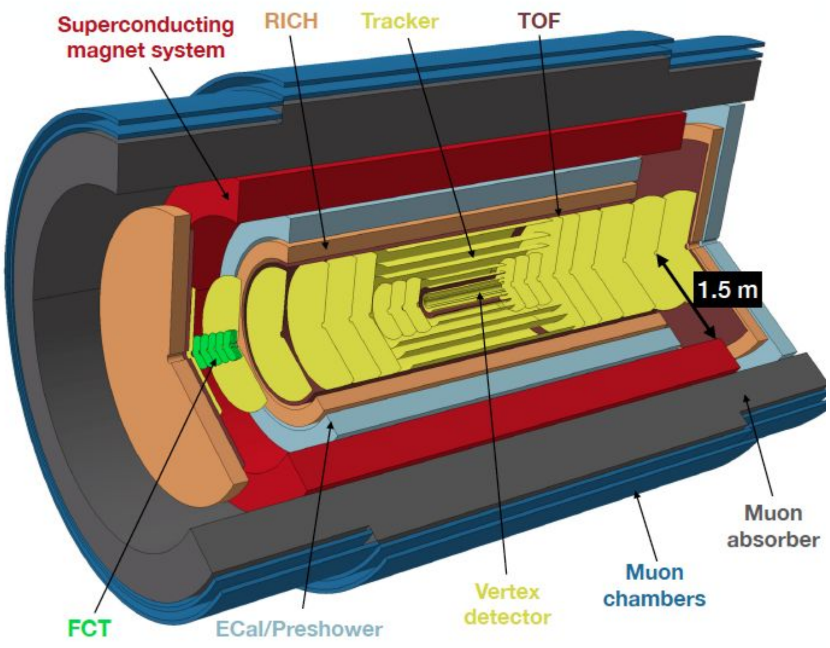
ALICE3:

➔ Compact all-silicon tracker with high-resolution vertex detector
➔ Superconducting magnet system
➔ Particle identification over large acceptance
➔ Fast readout and online processing

- Studies of A–A collisions at luminosities a factor of 5-10 times higher than possible now.

- The excellent timing resolution (≃ 20 ps) will provide particle identification information.

- Ultrasoft region of phase space
  - Production of very low transverse momentum lepton pairs, photons and hadrons.
  - Heavy-flavour, quarkonia, multi-charm hadrons and heavy-flavour correlations
  - Low-mass dileptons
  - Soft and ultra-soft photons



arXiv:1902.01211v2
https://indico.cern.ch/event/1063724/

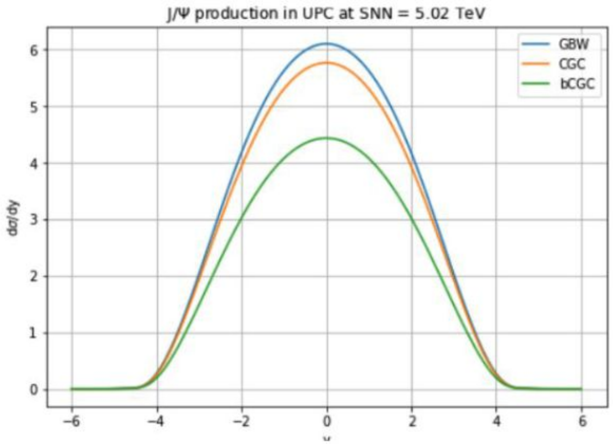
FoCal: photoproduced J/Ψ phenomenology

For UPC:

The rapidity distribution for the coherent photoproduction of J/Ψ is given by

$$\frac{d^3\sigma_{AA\to AAV}}{d^2bdy} = \omega N(\omega, b)\sigma_{\gamma A\to VA} + (y \to -y)$$

where N(ω, b) is the photon flux with dependence in energy dependence ω = Mv/√s and impact parameter b.



Peripheral Approach:

- Effective Photon Flux:

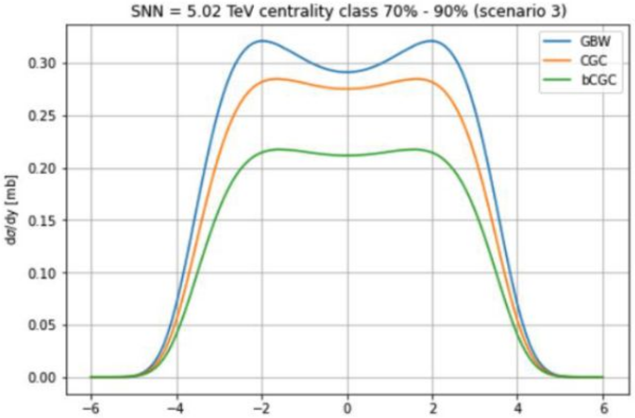
◊ Consider only photons that reach the geometrical region of nuclei-target;

◊ The photons that reach the overlap region are disconsidered

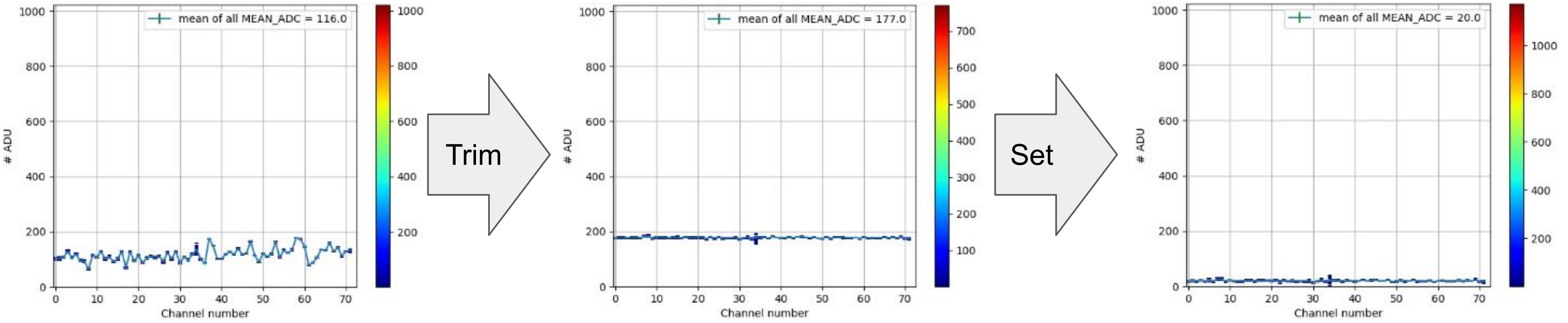
$$N^{eff}(\omega, b) = \frac{1}{A^{eff}(b)}\int b_2 db_2 d\alpha N(\omega, b_1)\theta(R_A - b_2)\theta(b_1 - R_A)$$

- Effective Photonuclear Cross Section

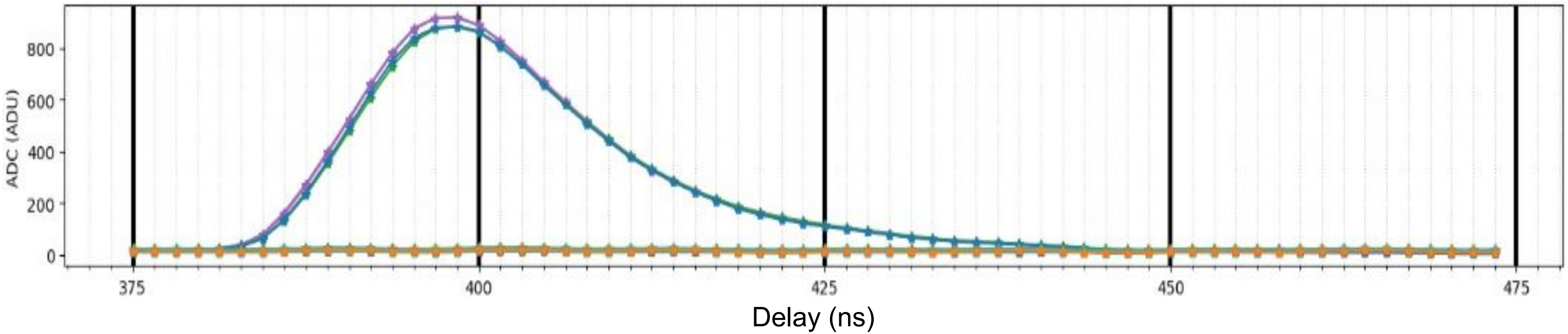
$$\sigma_{dip}^{nucleus}(x, r) = 2\int dbd\alpha b\theta(b_1 - R_A)\{1 - \exp[-\frac{1}{2}T_A(b)\sigma_{dip}^{proton}(x, r)]\}$$



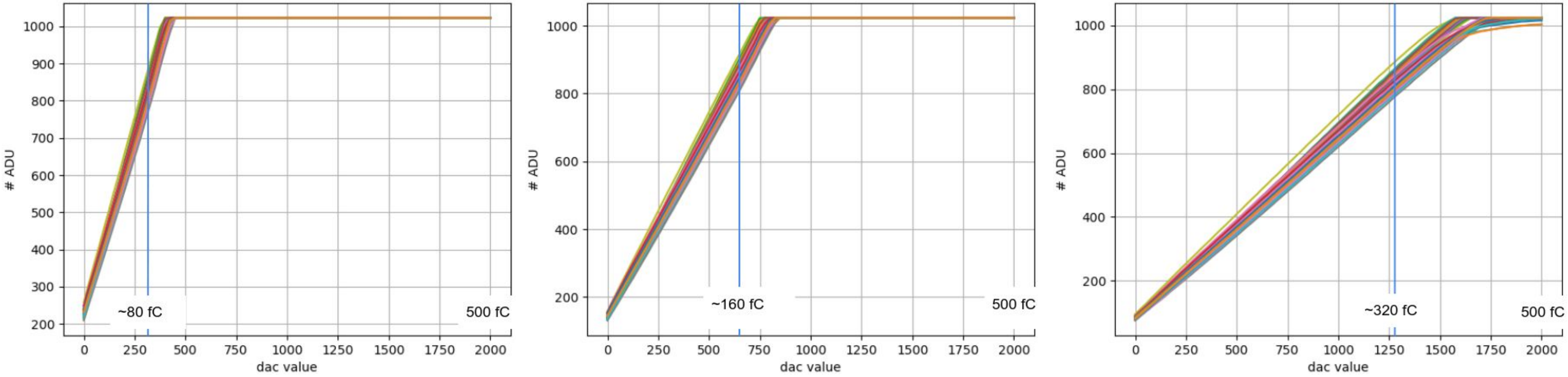
Pedestal trimming and setting: 72 channels responding with low dispersion, low output



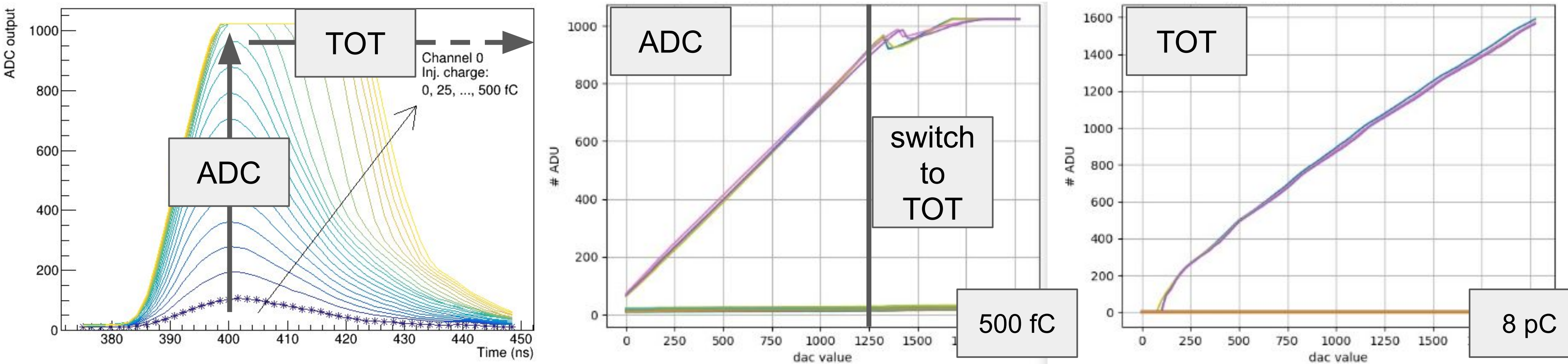
Trigger offset setting: optimal readout (maximum signal) below 400 ns



Preamplifier gain setting: Analog-to-Digital Converter range tuned from 80 to 320 fC

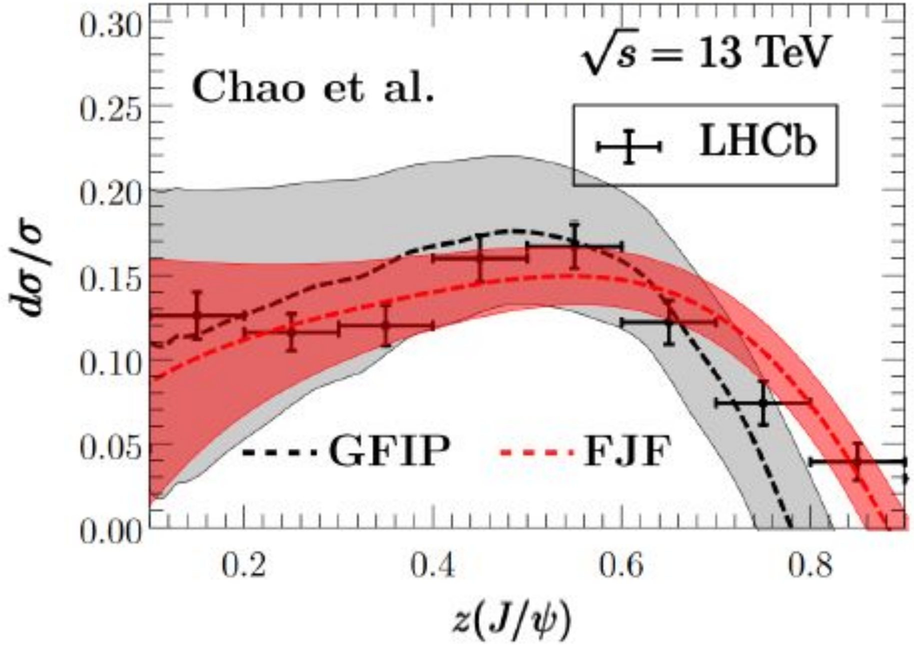


Exploiting the full dynamic range: from fC to pC detection → Analog-to-Digital to Time-Over-Threshold counting



J/ψ in jets

Phys. Rev. Lett. 119, 032002



- Models including parton showers describe data.
- J/ψ produced in parton showers sensitive to parton energy loss.

Data stream

Run 3:

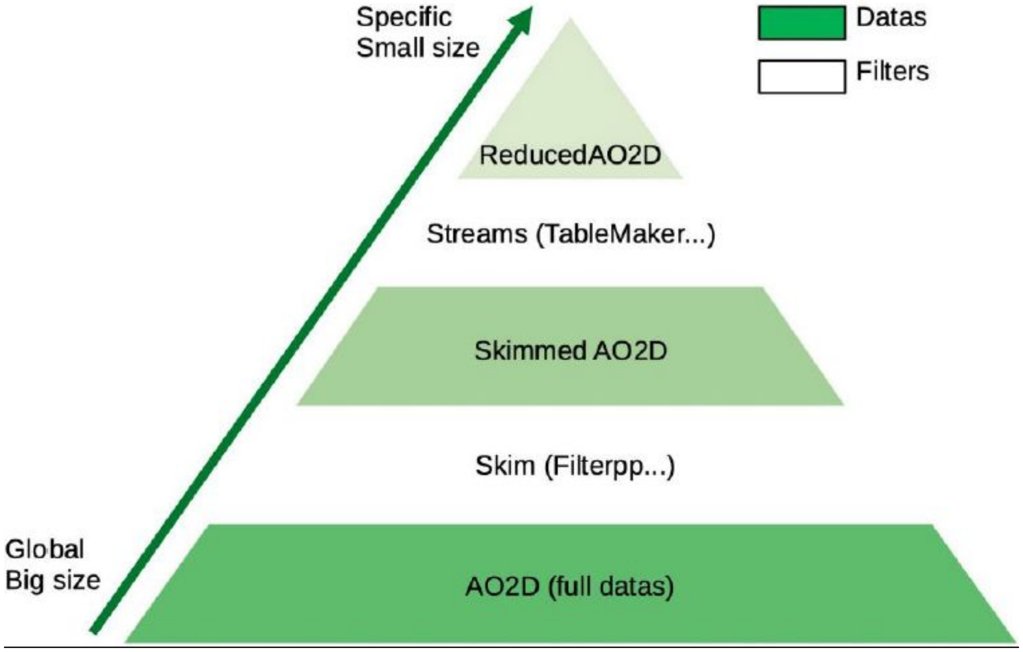
→ continuous readout
→ increase of luminosity

→ not possible to keep all data collected

→ it needs a filtering/pre selection of interesting data to be used in the analysis

→ part of the data is being deleted

→ SW do Leopoldo



Machine Learning Models (Gabriel)

- Neural Network
  - One model per particle (Ξ^-, Ξ^+, Ω^-, Ω^+)
  - Architecture:
    Layers = [11, 256, 64, 16, 4, 1]
    Activation = *sigmoid*
    Cost function = *binary cross entropy*
    Optimizer = ADAM ($\varepsilon=10^{-8}$, $lr=10^{-4}$)

TensorFlow

- BDT
  - One model per particle (Ξ^-, Ξ^+, Ω^-, Ω^+)
  - Architecture:
    Estimators = 100
    Depth = 2
    Cost function = *binary logistic*

dmlc XGBoost

Quarkonium production in pp collisions

Quarkonium production involves perturbative (production of heavy quark pair) and non-perturbative QCD (evolution of the pair into the physical quarkonium state). Models of non-perb:

- Colour Singlet Model (CSM): 1975
  - Assume physical colour singlet state, quantum number are conserved
  - Only pairs with right quantum number can be formed
  - No free parameter
- Colour Evaporation Model (CEM): 1977
  - Doesn’t distinguish states with respect to their colour and spin
  - One free parameter per quarkonium state
- NonRelativistic QCD (NRQCD): 1986
  - Effective field theory based on factorization of soft and hard scales
  - NRQCD matrix elements
  - Several parameters
- Improved Color Evaporation Model: 1997
  - In contrast to the traditional color evaporation model, it is imposed a constraint that the invariant mass of the intermediate heavy quark-antiquark pair needs to be larger than the mass of produced quarkonium. It also introduces a momentum shift between the heavy quark-antiquark pair and the quarkonium.