Introduction to ALICE

Junlee Kim[1]

July 04, 2024
Summer Student Program

1. CERN

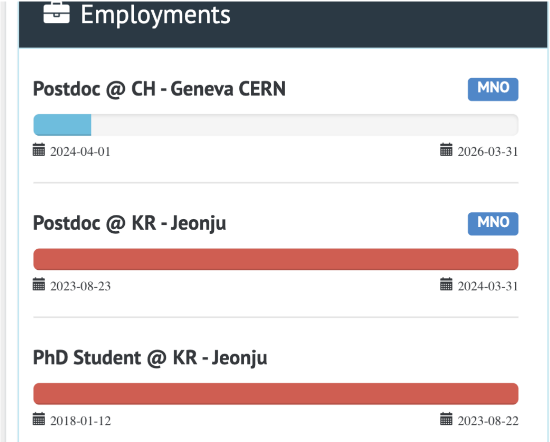
From Beomkyu

김준이 박사님,

안녕하세요. 오늘 예정대로 오후 2시 4/3-001에서 박사님의 강연이 있습니다.
[CERN-Korean summer student program (1-13 July 2024): Timetable · Indico]

50분정도로 ALICE 소개와 CERN Fellow가 될 때의 과정을 재미있게 얘기주시면 됩니다. :-)
그리고 금요일 저녁에 루지아에서 학생들과 저녁식사가 있는데 참석가능한지 물어봅니다!

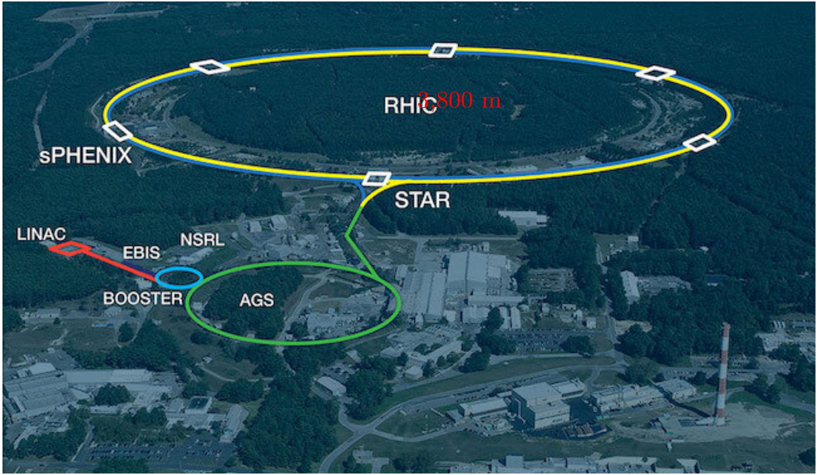
김범규 드림



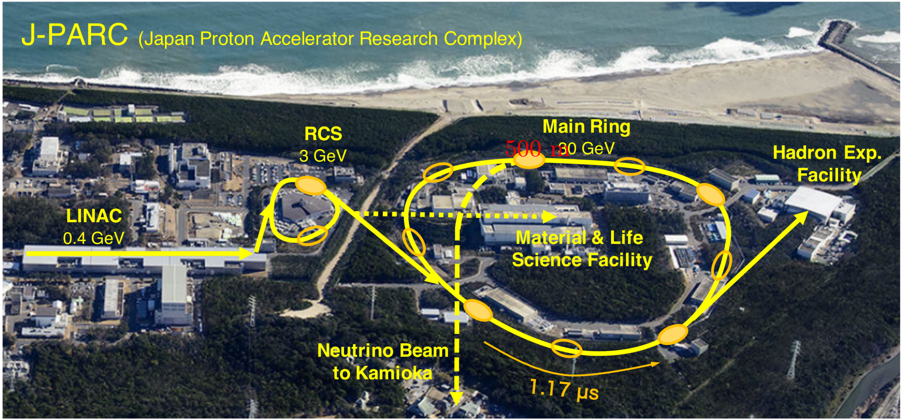
- Personality: Muon `https://scoollab.web.cern.ch/particle-identities`

Education

- **Doctor of Philosophy**,
  Relativistic heavy ion physics,
  Jeonbuk National University, AUG 2023
  Thesis title: Understanding the nature of $f_0(980)$ with ALICE at the LHC
- **Master of Science**,
  Particle physics,
  Korea University, FEB 2018
  Thesis title: Performance of new sampling calorimeter modules in the KOTO experiment
- **Bachelor of Physics in Education**,
  Division of science education, major of physics
  Jeonbuk National University, FEB 2015



- Up to 200 GeV/A, sPHENIX, EIC



- Neutrino facility, World-best kaon beam intensity

- World-best beam energy

Site and Civil Engineering	Mar Capeans
Engineering	Katy Foraz
Theoretical Physics	Gian Francesco Giudice
Accelerator Systems	Brennan Goddard
Information Technology	Enrica Porcari
Technology	José Miguel Jiménez
Beams	Rhodri Jones
Experimental Physics	Manfred Krammer
Industry, Procurement and Knowledge Transfer	Christopher Hartley
Human Resources	James Purvis
Finance and Administrative Processes	Florian Sonnemann

Who are our Member States?

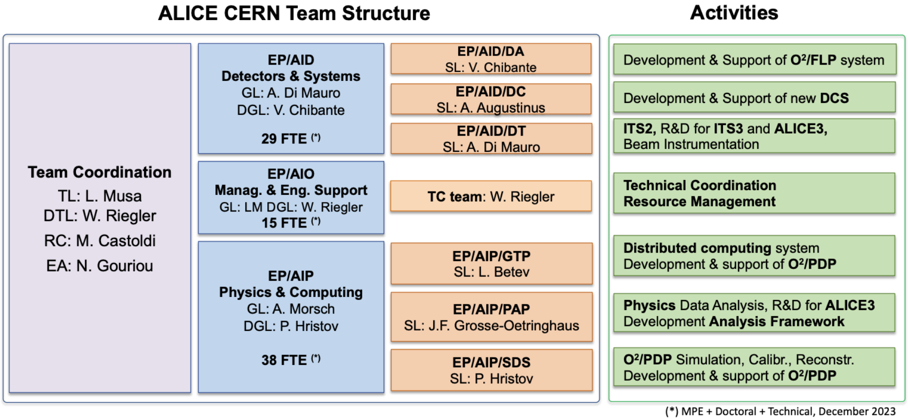
Today CERN has 23 Member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom.

Cyprus, Estonia and Slovenia are Associate Member States in the pre-stage to Membership. Brazil, Croatia, India, Latvia, Lithuania, Pakistan, Türkiye and Ukraine are Associate Member States.

Contribution to CERN

			Net National Income at factor cost			Exchange rates			Net National Income at factor cost	2024 Full Theoretical Contribution	2024 Due Contribution
			in millions in national currency			national currencies in Swiss francs			in MCHF		
	Country	Currency	2019	2020	2021	2019	2020	2021	Average 2019 to 2021	in %	in %
Member States	Austria	EUR	273 900	275 748	290 372	1.1125	1.0705	1.0810	304 592	2.24036%	2.24036%
	Belgium	EUR	347 271	334 387	362 958	1.1125	1.0705	1.0810	378 878	2.78676%	2.78676%
	Bulgaria	BGN	86 550	87 245	101 118	0.5688	0.5473	0.5528	50 958	0.37481%	0.37481%
	Czech Republic	CZK	3 728 029	3 717 429	4 052 149	0.0433	0.0405	0.0422	160 988	1.18411%	1.18411%
	Denmark	DKK	1 657 607	1 700 345	1 840 587	0.1490	0.1436	0.1454	252 907	1.86020%	1.86020%
	Finland	EUR	164 688	167 010	175 888	1.1125	1.0705	1.0810	184 041	1.35368%	1.35368%
	France	EUR	1 700 339	1 576 135	1 758 069	1.1125	1.0705	1.0810	1 826 413	13.43380%	13.43380%
	Germany	EUR	2 608 213	2 571 571	2 743 414	1.1125	1.0705	1.0810	2 873 318	21.13409%	21.13409%
	Greece	EUR	124 984	116 816	131 818	1.1125	1.0705	1.0810	135 528	0.99685%	0.99685%
	Hungary	HUF	30 891 733	30 756 271	34 901 337	0.0034	0.0030	0.0030	101 570	0.74708%	0.74708%
	Israel	ILS	1 041 417	1 065 334	1 157 001	0.2788	0.2727	0.2830	302 737	2.22672%	2.22672%
	Italy	EUR	1 265 902	1 169 427	1 266 166	1.1125	1.0705	1.0810	1 342 943	9.87774%	9.87774%
	Netherlands	EUR	575 497	567 325	615 045	1.1125	1.0705	1.0810	637 462	4.68872%	4.68872%
	Norway	NOK	2 683 239	2 549 803	3 170 969	0.1130	0.1000	0.1064	298 407	2.19487%	2.19487%
	Poland	PLN	1 629 712	1 730 659	1 842 112	0.2588	0.2410	0.2368	424 987	3.12590%	3.12590%
	Portugal	EUR	139 792	132 354	142 400	1.1125	1.0705	1.0810	150 376	1.10606%	1.10606%
	Romania	RON	764 741	772 032	863 722	0.2344	0.2213	0.2197	179 940	1.32351%	1.32351%
	Serbia	RSD	3 897 661	3 981 968	4 559 893	0.0094	0.0091	0.0092	38 327	0.28191%	0.28191%
	Slovakia	EUR	65 818	65 866	69 399	1.1125	1.0705	1.0810	72 916	0.53632%	0.53632%
	Spain	EUR	927 451	820 468	879 188	1.1125	1.0705	1.0810	953 481	7.01313%	7.01313%
	Sweden	SEK	3 319 774	3 395 321	3 679 294	0.1051	0.1022	0.1066	362 597	2.66701%	2.66701%
	Switzerland	CHF	507 864	493 717	528 692	1.0000	1.0000	1.0000	510 091	3.75187%	3.75187%
	United Kingdom	GBP	1 642 190	1 594 419	1 713 215	1.2683	1.2039	1.2575	2 052 198	15.09452%	15.09452%
Total Member States									**13 595 655**	**100.0000%**	**100.0000%**
Associate Member States in the pre-stage to Membership	Cyprus	EUR	16 661	15 845	17 471	1.1125	1.0705	1.0810	18 128	0.13333%	0.09133%
	Estonia	EUR	18 997	19 192	21 637	1.1125	1.0705	1.0810	21 689	0.15953%	0.11965%
	Slovenia	EUR	32 467	33 285	36 189	1.1125	1.0705	1.0810	36 956	0.27182%	0.19028%
Total Associate Member States in the pre-stage to Membership									**76 773**	**0.5647%**	**0.4013%**
Associate Member States	Croatia	EUR	35 611	34 663	39 128	1.1125	1.0705	1.0810	39 673	0.29181%	0.02918%
	India	INR	144 314 136	143 299 736	172 137 728	0.0139	0.0124	0.0123	1 970 363	14.49259%	1.44926%
	Latvia	EUR	19 629	19 818	22 249	1.1125	1.0705	1.0810	22 368	0.16452%	0.01645%
	Lithuania	EUR	35 647	37 173	41 452	1.1125	1.0705	1.0810	41 420	0.30465%	0.03047%
	Pakistan	PKR	31 485 797	34 405 119	40 585 931	0.0073	0.0062	0.0057	224 602	1.65201%	0.16520%
	Türkiye	TRY	3 099 619	3 653 410	5 272 805	0.1751	0.1349	0.1056	530 805	3.90423%	0.39042%
	Ukraine	UAH	2 859 128	3 055 491	3 964 974	0.0385	0.0348	0.0335	116 336	0.85568%	0.08557%
Total Associate Member States									**2 945 566**	**21.6655%**	**2.1666%**

- 1,000 MCHF to be associated member states



- Doctoral Student Program projects: `https://careers.cern/doct-projects`
- One Ph.D. student from non-member states in ALICE (Maria Paula)

Dear Junlee,
Thank you for your interest in the postdoctoral position in the Heavy-Ion group at Yale and for your patience as we conducted interviews. We appreciate you taking the time and effort to apply and interview.
After careful consideration, we decided to move forward with other candidates. We received many strong applications for this position, including yourself, which made the decision very difficult. We were very impressed with your qualifications and research and believe you have a bright future in academia and research.
Thank you once again for your interest in our group. We wish you the best of luck in your future endeavors and Postdoc search.
Best regards,
Laura

Laura Havener, Ph.D
Assistant Professor
Yale University
she/her/hers


To exit full screen, press esc

아침
햇살

Pen/Highlighter
Hand Eraser

- Light Flavor
  - pp: multiplicity dependent production of $f_0(980)$
    ⇒ paper proposal: accepted
  - p–Pb: "Observation of abnormal suppression of $f_0(980)$ production in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV"
    ⇒ paper submitted to PLB (arXiv:2311.11786)
  - Pb–Pb: preparation for Run3, code development etc
    ⇒ v_2 for $f_0(980)$ was measured
    ⇒ more statistics is required to access high p_T region
    ⇒ Event plane and jet-axis dependent $f_0(980)$ production in Pb–Pb for v_2 in Run3: ongoing

- Flow
  - A few requests from ARC and PWG: done
  - paper review ongoing: done
    "Multiplicity and event-scale dependent flow and jet fragmentation in pp collisions at $\sqrt{s}$ = 13 TeV and in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV"
    ⇒ paper submitted to JHEP (arXiv:2308.16591)
- Jet
  - Jet shape from two-particle correlations
    ⇒ paper proposal: accepted
- Service work: done
  - Luminosity measurement with PNU using LHC22q data
- Luminosity: Running tasks for LHC23 data in HL
- Development on the event plane determination in Run3
- SHINCHON project: ongoing

Dear Kim,

The selection committee for Research Fellowship : Experimental Physics took place recently. We would like to inform you that your application is still under consideration and we will get back you as soon as possible regarding the outcome.

We thank you for your patience.

Best regards,

CERN Talent Acquisition Team

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We thank you for your patience.

Best regards,

CERN Talent Acquisition Team

Dear Kim ,

We are pleased to confirm your selection on the position of Research Fellowship : Experimental Physics at CERN and you will soon receive an email from our Registration services (edh.system@cern.ch) tonight for you to provide necessary information in preparation for the administration of your contract.

Please make sure you upload a copy of your CV in the EDH document.

Your appointment in the **EP Department** will start on **1st March 2023.**

Once you have confirmed me the start date and sent me the necessary documents and I will send you your contract (please note that you are expected to choose the experiment you would to join within 3 weeks after the start date of your contract).

Should you require a visa (**non-EU citizens**) - Please note that the procedure can take up to 3 months, depending on the consulate. We recommend you to discuss this aspect with your future supervisor when defining your contract start date. You should contact our VISA service (visa.hr@cern.ch) 3 months before your start date.

You can find some interesting information about housing in France and in Geneva by clicking on the underlined keywords.

Specific information concerning your contract can be found at this **link**.

Your contract will start on the first calendar day of a month. Should your contract starting date fall on a Saturday or Sunday, or public holiday, your first working day will be the first working day thereafter.

Should you need further information, please do not hesitate to contact us. We look forward to welcoming you!

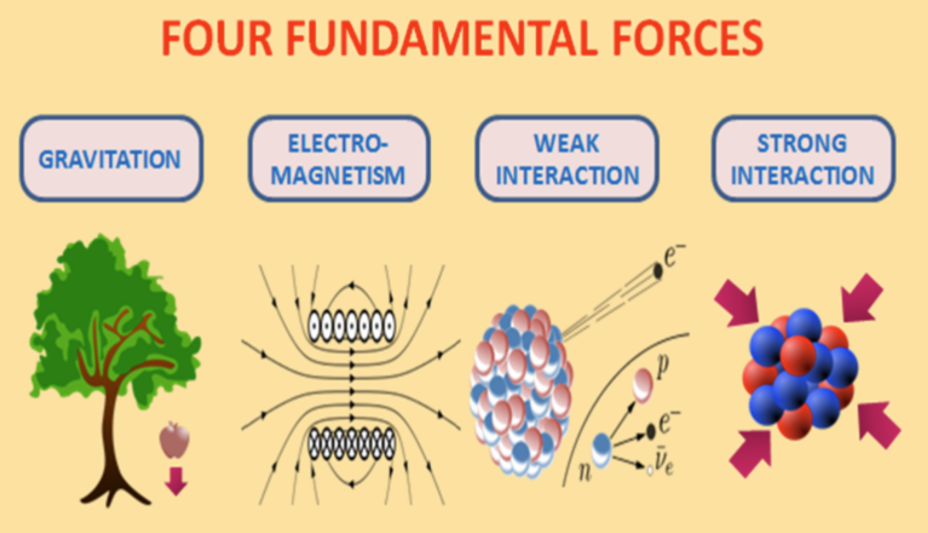
Best regards,

Virginie

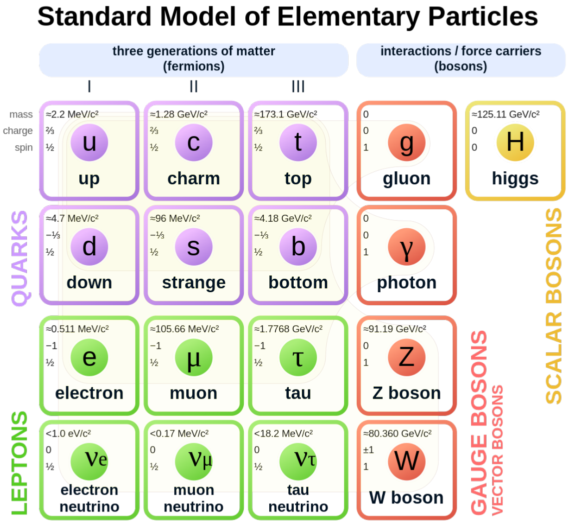
CERN Talent Acquisition Team

- + Exciting physics topic

Fundamental force



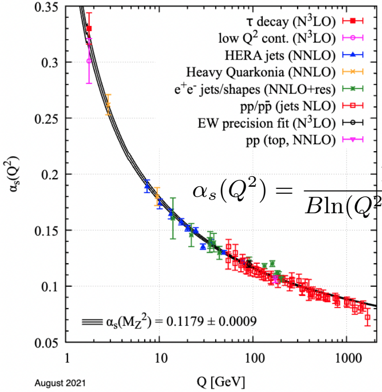
*no gravity yet



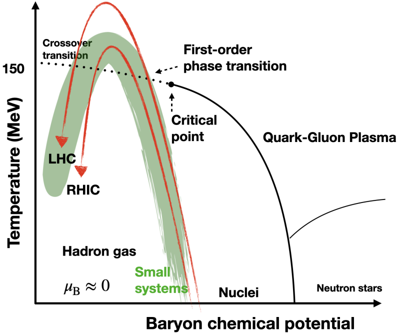
- Three generations of quarks and leptons
- Gauge bosons mediating interactions
  - Photon: electromagnetic interaction
  - W and Z bosons: weak interaction
  - Gluon: strong interaction
- Higgs boson → W and Z boson mass

Photon: neutral electric charge
Gluon: color charges

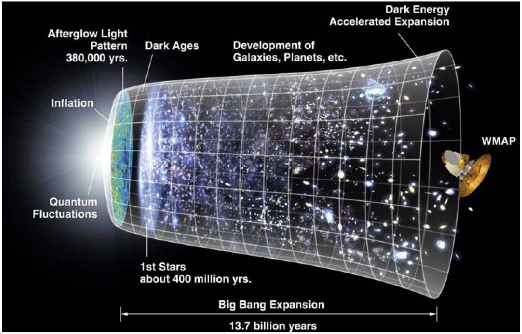
PTEP 2022 (2022)

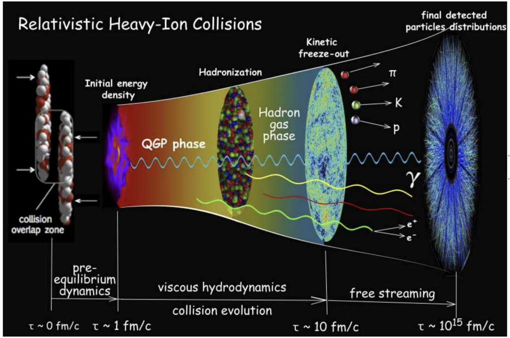


$$\alpha_s(Q^2) = \frac{1}{B\ln(Q^2/\Lambda^2_{\rm QCD})}$$



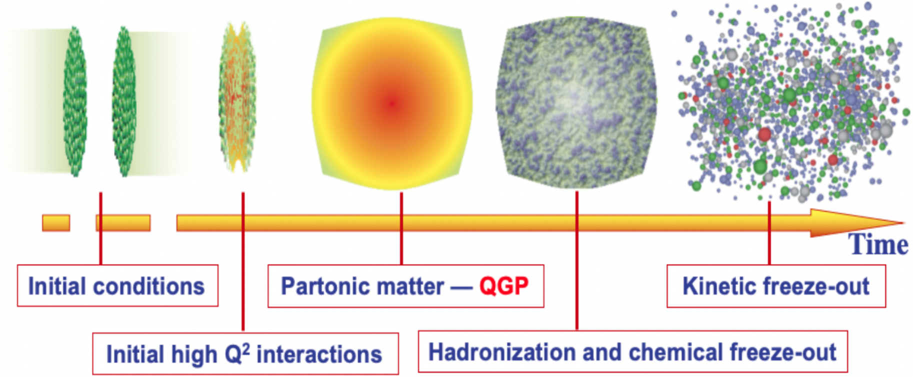
- Running coupling constant exhibiting "quark confinement" ($Q \approx \Lambda_{\rm QCD}$) and "asymptotic freedom" ($Q \gg \Lambda_{\rm QCD}$) originates from **self-interactions of gluons.**
- The environment of high temperature and density, in which ordinary matters deconfine, is expected to form Quark-Gluon Plasma. → Experimental reproduction with relativistic heavy ion collisions



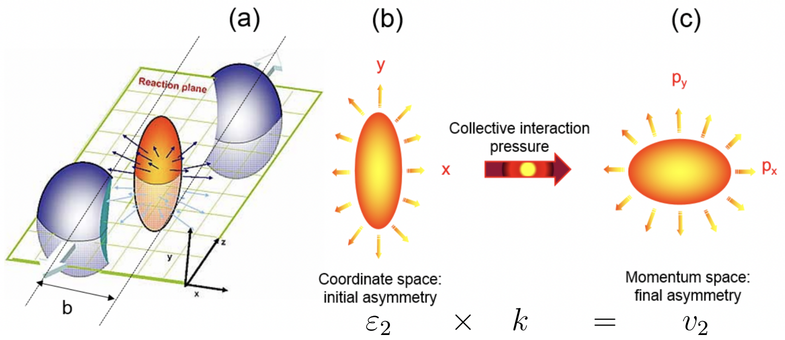


- The evolution history of “Little Bangs” has much similarity with the Big Bang that created our universe.

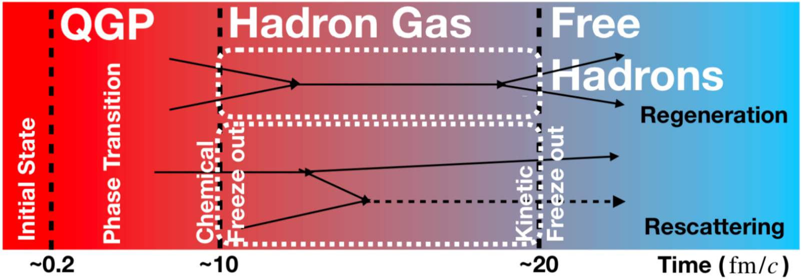
Relativistic heavy ion collisions



- Hard probes from initial hard scatterings with high Q^2
- Geometry of initial collision and its evolution signifying QGP as near-perfect fluid
- Freeze-outs: final-state particle distributions



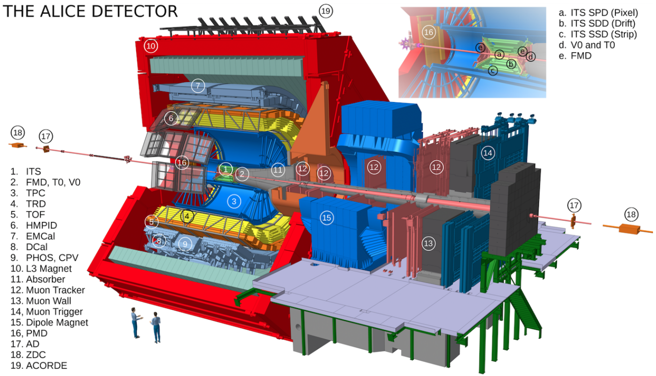
- Initial collision geometry is determined by the impact parameter of heavy ions (ε_2).
- The evolution of QGP due to the pressure gradient (k)
- Final-state anisotropic particle distribution (v_2)



- Kinetic freeze-out: All elastic interactions between hadron cease.
- Hadron gas: Stage between chemical and kinetic freeze-outs, where the density of hadrons is high enough to (pseudo-)elastically interact with each other, modifying their momenta.
  - Regeneration: Combining the hadrons into a resonance at the early stage of the hadron gas
  - Rescattering: Modifying the momenta of the decay products of the resonance, resulting in failure of the reconstruction of the invariant mass of the resonance (dominantly observed)

ALCE detector

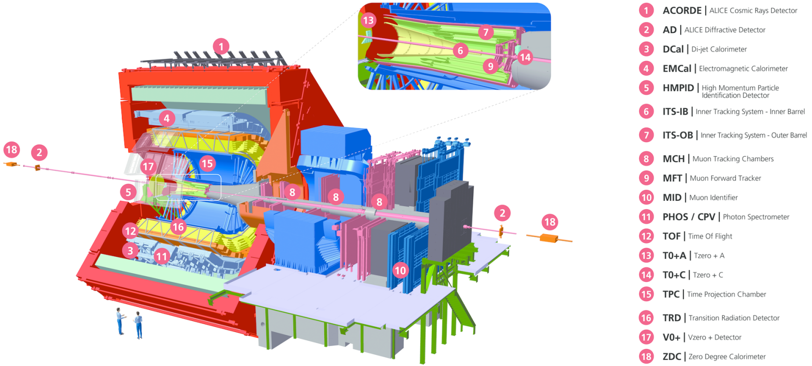
Detector	Tasks
V0 (2)	Triggering Centrality Event plane
ZDC (18)	Centrality
ITS (1)	Tracking Vertexing
TPC (3)	Tracking PID
TOF (5)	PID



- Multilayered configuration for the high acceptance by capturing produced particles in each event
- High momentum resolution to reconstruct 2,000 particles in the same event

Upgrade during Long shutdown 2

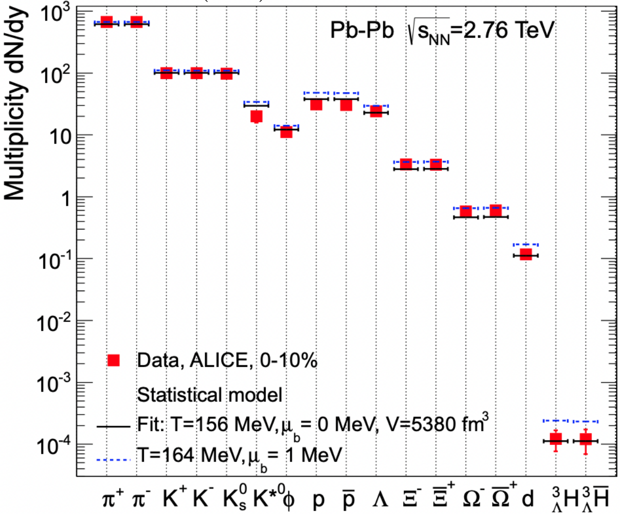
Detector	Run 3
TPC	GEM
ITS	7 layers Resolution
FIT	Trigger
MFT	Forward



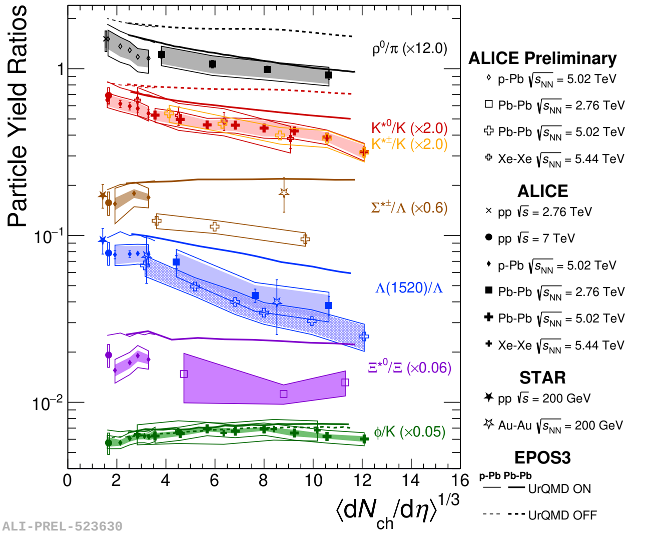
- Continuous data taking with “Timestamp” → ×30 in Pb–Pb and ×800 in pp

- Chemical freeze-out: all inelastic interactions stop, no deconfined partons.
- Relative particle composition predicted by statistical thermal model with the assumptions that
  - Thermal and chemical equilibrium
  - Conservation of charges such as electric charge, strangeness, and so on.
- Fits to the experimental data of dN/dy for different particles result in baryon chemical potential ($\mu_{\rm b}$), freeze-out temperature (T), and the volume (V) of QGP.
- Overestimation of K^{*0} due to:
  - Additional modifications of yields after chemical freeze-out

JPCS 509 (2014) 012019



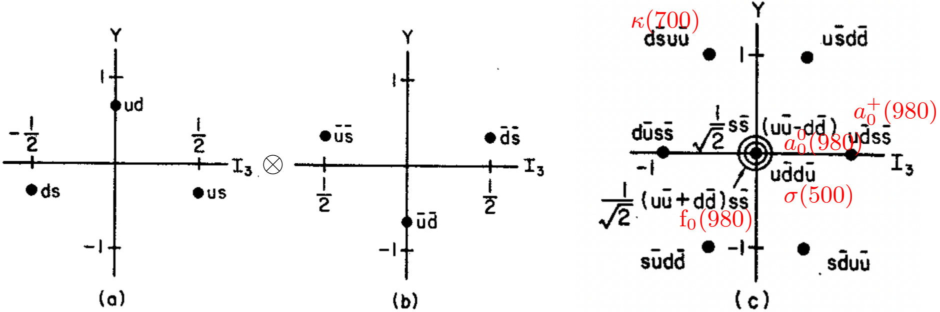
- Particle yield ratios of resonances (short-lived) to the ground particle (long-lived) having the same quark composition
- Decreasing trend of ρ^0/π, $\mathrm{K}^{*0}/\mathrm{K}$, and $\Lambda(1520)/\Lambda$ from small to large systems
  - $\tau_\rho = 1.3$ fm/c
    $\tau_{\mathrm{K}^*} = 4.2$ fm/c
    $\tau_{\Lambda^*} = 12.6$ fm/c
- No suppression for Ξ^*/Ξ and ϕ/K
  - $\tau_{\Xi^*} = 22$ fm/c
    $\tau_\phi = 46.2$ fm/c
- Resonances with short lifetime are much suppressed in the hadron gas.
  - Qualitative agreement with UrQMD afterbunner



$u \rightarrow d\overline{s}$

$\overline{u} \rightarrow ds$

PRD 15 (1977) 267

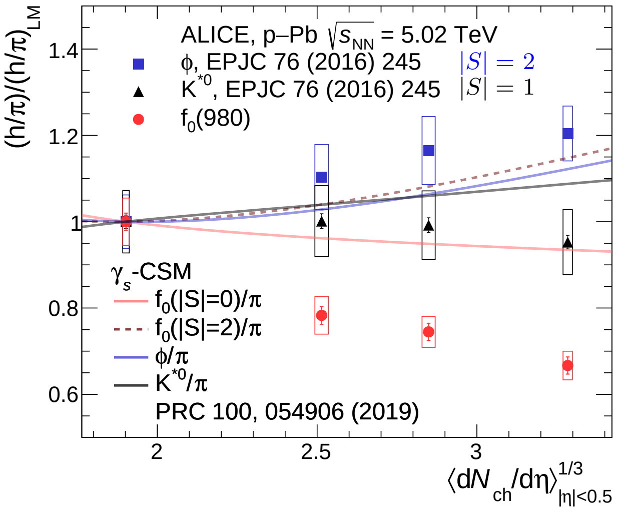


- Quantum state of 0^{++}, which is chiral partner of 0^{-+}
  - Chiral partner of π?
- $m_{a_0} < m_\kappa < m_{f_0}$ expected with $q\bar{q}$ config.
- $m_\sigma < m_\kappa < m_{f_0}, m_{a_0}$ expected with tetraquark config.
  - Consistent with experiments
  - $f_0(980)$ mass solely well described in PHYSICS REPORTS 127, No. 1(1985) 1-97

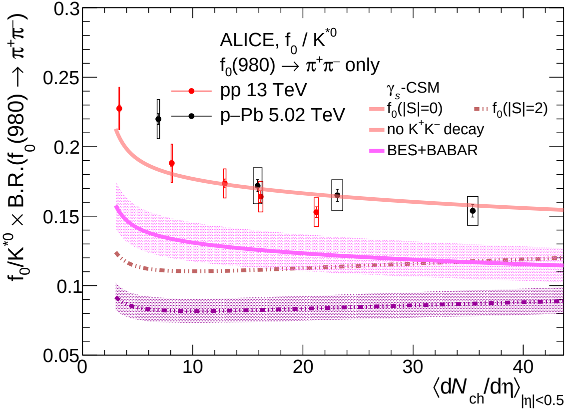
States	I	S	Mass (MeV/c^2)
a_0 ($\leftrightarrow \pi$)	1	0	990
κ ($\leftrightarrow$ K)	1/2	±1	630–730
f_0	0	0	990
σ	0	0	400–550

PLB 853 (2024) 138665

- Decreasing particle yield ratio of $f_0(980)$ to the charged pion with increasing multiplicity.
  - Dominant rescattering effects
- CSM overestimates yield ratio of the K^{*0} to charged pion due to the no consideration of interactions between the hadron gas and the decay products of K^{*0}.
- CSM calculations overestimate the ratio of $f_0(980)$ to the charged pion yields because of no rescattering effects.

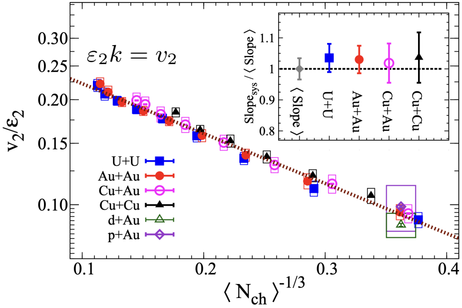


- Decreasing particle yield ratio of $\mathrm{f}_0(980)$ to $\mathrm{K}^*(892)^0$ with increasing
  - Both particles are expected to experience rescatterings
- One strange component for $\mathrm{K}^*(892)^0$
  - Strangeness enhancement for $\mathrm{K}^*(892)^0$ in small systems
- Ratio well described with assumed branching ratio across different multiplicity classes

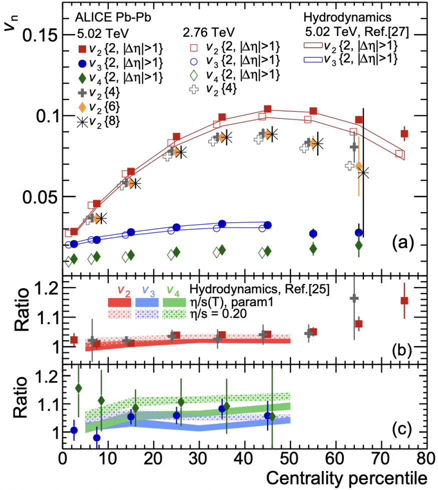


https://alice-publications.web.cern.ch/node/10931

PRL 122 172301 (2019)

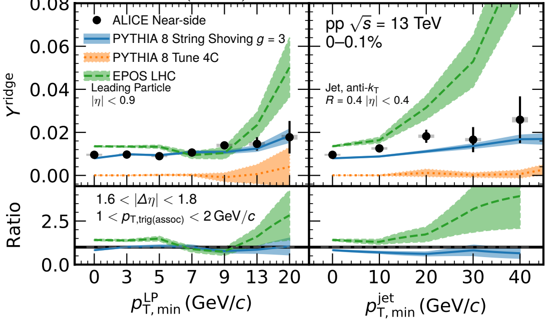


PRL 116 132302 (2016)

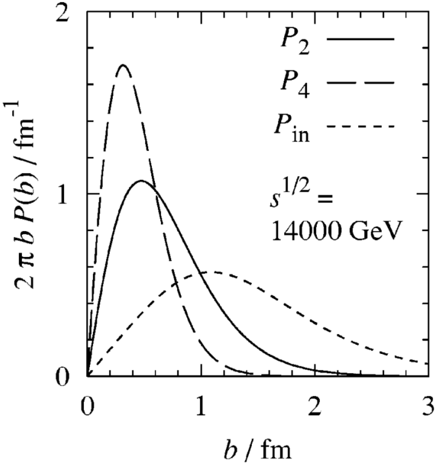


- Expansion power increases with increasing multiplicity, which is proportional to the volume of QGP.
- Relativistic hydrodynamic calculations support the fluidity of QGP.

JHEP 05 (2021) 290



PRD 69 (2004)114010

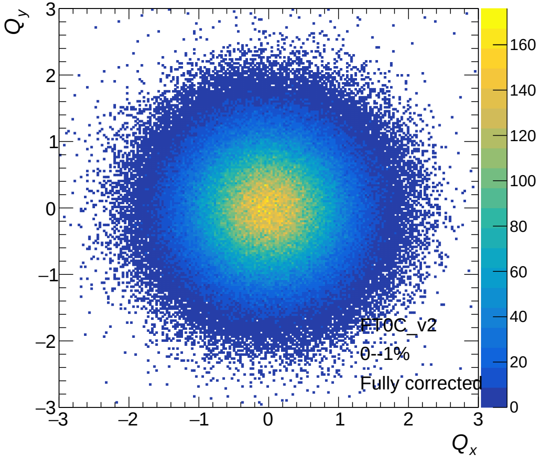


- Constraints on the impact parameter in pp collisions with hard probes to engineer the impact parameter
- No significance so far owing to poor statistical uncertainties

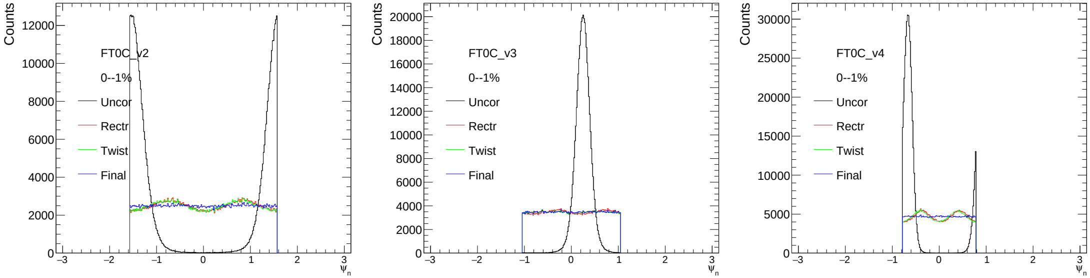
Event plane determination

- Flow coefficients can be extracted using the reaction plane of ψ_n
  - $v_n = \langle \cos[n(\varphi - \psi_n)] \rangle$
  - Not possible to access ψ_n in experiment.
- Alternatively, the event plane (Ψ_n) is reconstructed for n-th modulations using the Q-vector
  - $Q_{n,x} = \sum_i \omega_i \cos(n\varphi_i)$ and $Q_{n,y} = \sum_i \omega_i \sin(n\varphi_i)$
    - ω_i: weight factor of each component, detector amplitude or p_{T} ($v_n \propto p_{\mathrm{T}}$)
    - Gain equalization for FIT
  - $\Psi_n = (1/n) \arctan(Q_{n,y}/Q_{n,x})$
  - $v_n^{\mathrm{obs}} = \langle \cos[n(\varphi - \Psi_n)] \rangle$
- The resolution of the event plane can be calculated with 3-sub event method
  - $\mathcal{R}_n = \langle \cos(n(\Psi_n^A - \psi_n)) \rangle \approx \sqrt{\frac{\langle \cos(n(\Psi_n^A - \Psi_n^B)) \rangle \langle \cos(n(\Psi_n^A - \Psi_n^C)) \rangle}{\langle \cos(n(\Psi_n^B - \Psi_n^C)) \rangle}}$
  - Individual booking for $\langle \cos(n(\Psi_n^A - \Psi_n^B)) \rangle$, $\langle \cos(n(\Psi_n^A - \Psi_n^C)) \rangle$, and $\langle \cos(n(\Psi_n^B - \Psi_n^C)) \rangle$.
  - $v_n^{\mathrm{cor}} = v_n^{\mathrm{obs}} / \mathcal{R}_n$

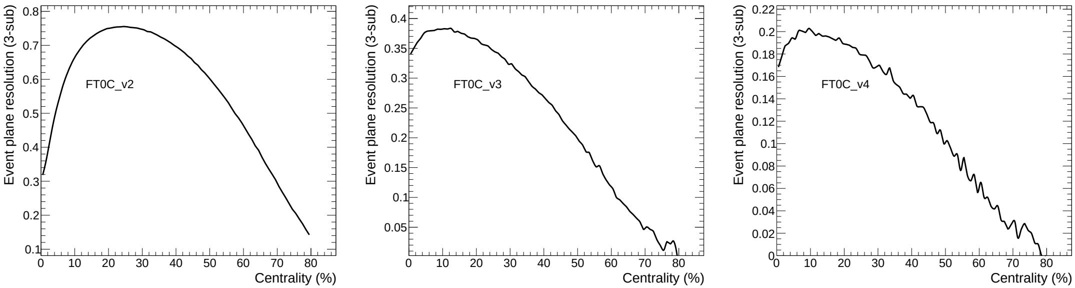
- LHC23_zzh_pass3
- The gain for each channel has been equalized.
- Scatter plot of $Q_{n,x}$ and $Q_{n,y}$ would be symmetric and centered around the origin.
  - Flatness of the event plane distribution
- In reality, $(Q_{n,x}, Q_{n,y})$ distribution is not centered and elongated.
  - **Recentering** corrects the center position
  - **Twist** corrects the possible rotation
  - **Rescaling** corrects the possible deformation
- ω_i, weight factor: detector amplitude



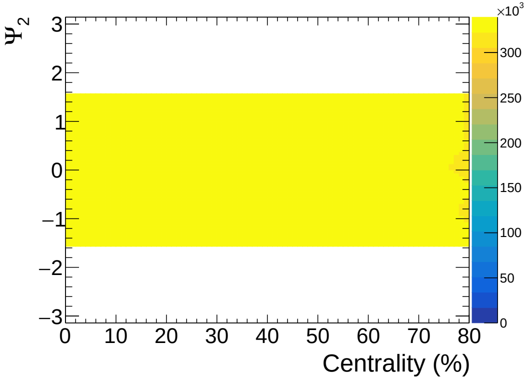
Event plane distribution

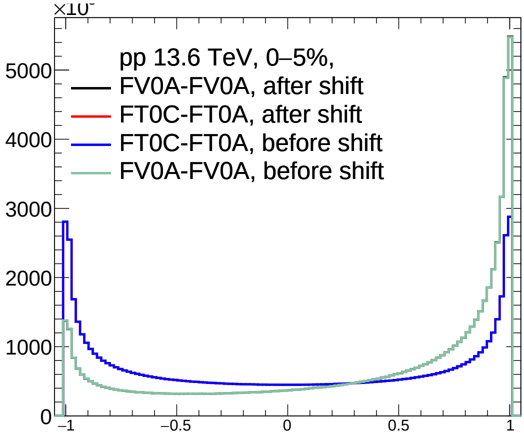


Event plane resolution



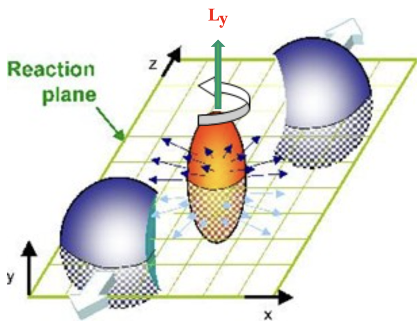
Event plane in pp?

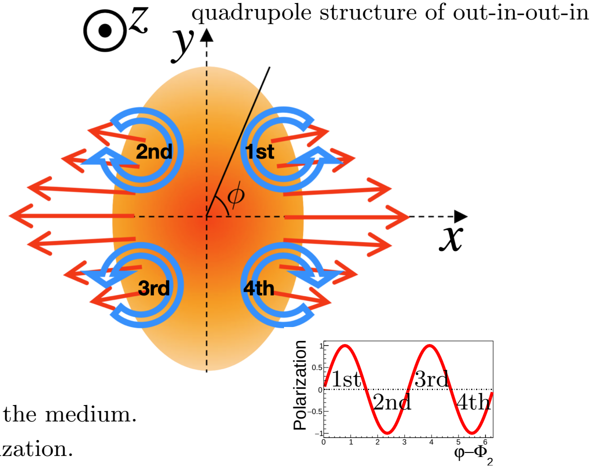




- Additional shift correction applied (Phys.Rev.C56:3254-3264,1997)
- Small event plane resolution when correlating forward and backward detectors.
- FT0A–FV0A results in resolution of 30%

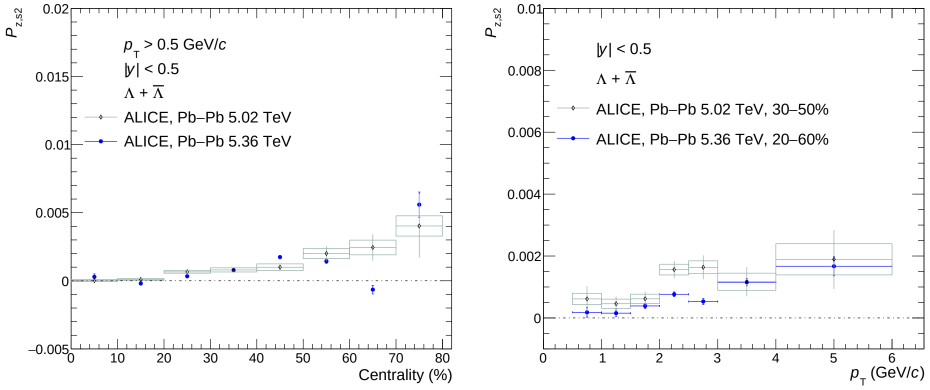
Large Orbital Angular Momentum





- Non-isotropic initial geometry causes vorticity of the medium.
- The vorticity can be accessed with particle polarization.
- The longitudinal polarization is modulating in the azimuthal angle relative to the reaction plane.
  → **Local Polarization**

Polarization measurement in Run 3



- The polarization increases with decreasing centrality → dependence on ϵ_2
- No significance p_T dependence of the polarization
- Comparable with each other, uncertainty to be more precise with improved Λ efficiency

Summary

Congratulation on your onboarding@CERN

- Join all programs as many as possible!

Quark-Gluon Plasma: interesting research topic

- Properties of near-perfect fluidity
- Modification of particle distributions

There are still a lot of missing points

- Welcoming you to join this game