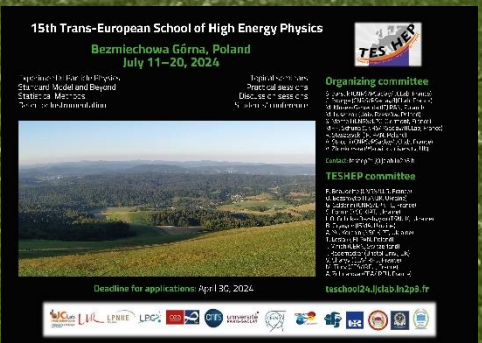
Concluding remarks

on behalf of the Organising/Program Commitee

19th July 2024



Nice and inspiring to have a school in a such wonderful place


Ideal place to search for new … Strange … particles…and to find them !

Ukraine

Ukraine is close by !

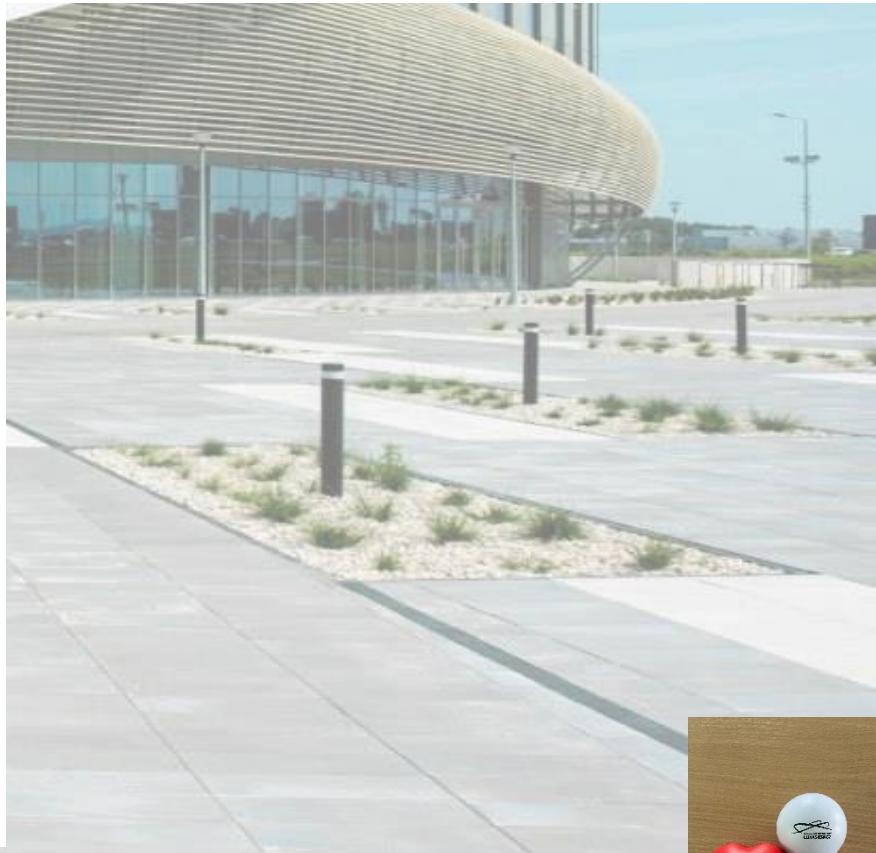
Event 100 years of Georges Charpak

Before the school an event was organised for the
100 years of Georges Charpak

17:00 – powitanie, krótka prezentacja o Podkarpackim Centrum Nauki Łukasiewicz
17:15 – wykład „A dizzying journey: from the infinitely large of the infinitely small...which is still going on!", prof. Achille Stocchi
18:00 – wykład „A Quest Inside Proton", dr Rafał Staszewski
18:15 – Science Dating: nieformalne rozmowy z naukowcami

To wyjątkowa okazja, aby zgłębić tajemnice wszechświata i zainspirować się do dalszego odkrywania nauki!

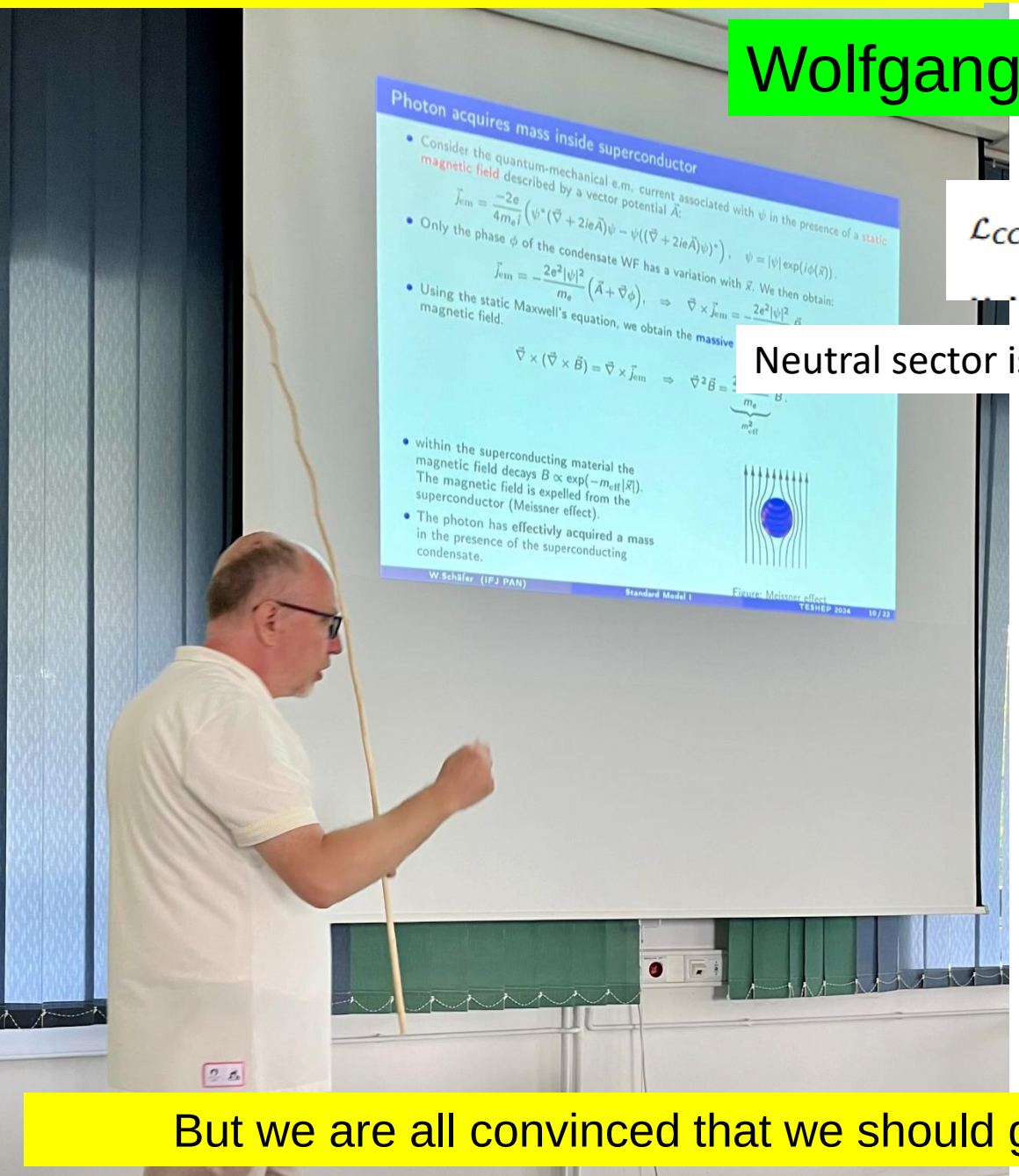
Wydarzenie towarzyszy konferencji naukowej: **Trans-European School of High Energy Physics 2024**
Językiem wydarzenia będzie język angielski.



Podkarpackie Centrum Nauki Łukasiewicz (Subcarpatian Science Centre Łukasiewicz)
Rzeszów-Jasionka

Standard Model in 4hours

The basics… (Gauge) Symmetries are of prime importance



Wolfgang

QED Lagrangian

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \bar{\psi}iD^{\mu}\gamma_{\mu}\psi - m\bar{\psi}\psi$$

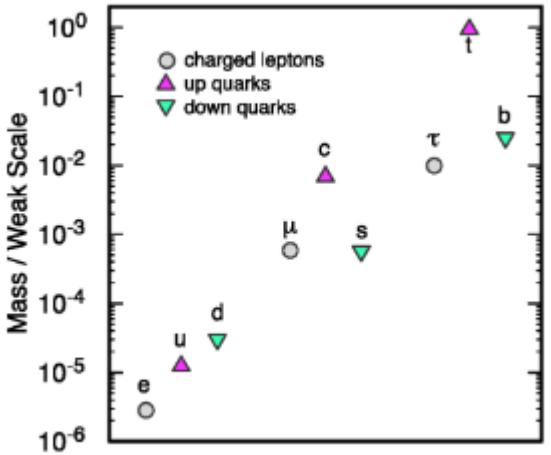
EW gauge theory of $SU(2)_L \otimes U(1)_Y$

$$\mathcal{L}_{CC} = -\frac{g}{2\sqrt{2}}\left(W_{\mu}^{\dagger}[\bar{u}\gamma^{\mu}(1-\gamma_5)d + \bar{\nu}_e\gamma^{\mu}(1-\gamma_5)e] + W_{\mu}[\bar{d}\gamma^{\mu}(1-\gamma_5)u + \bar{e}\gamma^{\mu}(1-\gamma_5)\nu_e]\right).$$

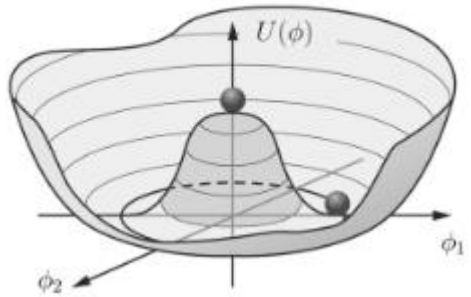
Neutral sector is particuluarly new !

$$\mathcal{L}_{NC}^{Z} = -\frac{e}{2\sin\theta_W\cos\theta_W}Z_{\mu}\sum_f \bar{f}\gamma^{\mu}(v_f - a_f\gamma_5)f$$

where $v_f = T_3^f - 2Q_f\sin^2\theta_W$ and $a_f = T_3^f$.



Higgs mechanism



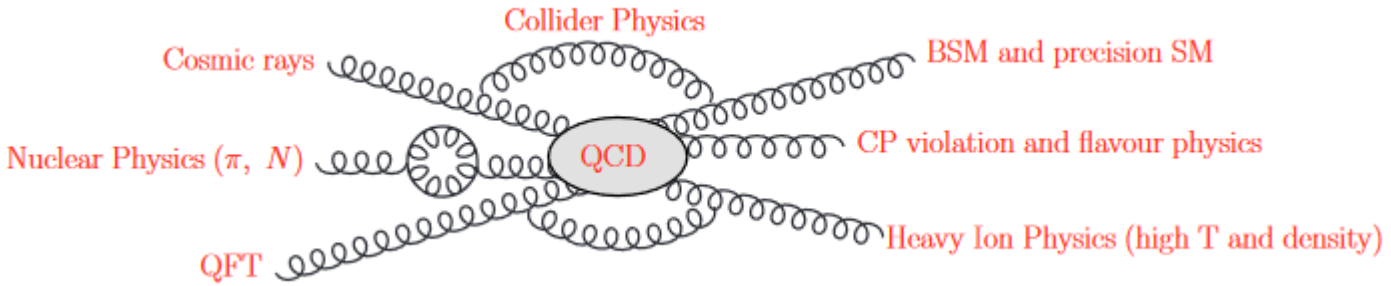
Not forgetting QCD !

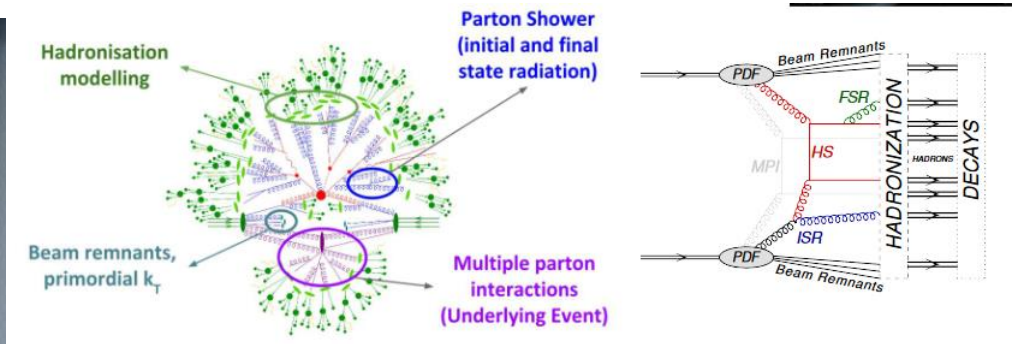
$$\mathcal{L}_{QCD} = \sum_f \bar{q}_f^{\alpha}(i\gamma^{\mu}\partial_{\mu} - m_f)q_f^{\alpha} + gA_{\mu}^{a}\sum_f \bar{q}_f^{\beta}\gamma^{\mu}(t^a)_{\beta\alpha}q_f^{\alpha}$$
$$-\frac{1}{4}(\partial^{\mu}A^{a\nu} - \partial^{\mu}A^{a\mu})(\partial_{\mu}A_{\nu}^{a} - \partial_{\nu}A_{\mu}^{a})$$
$$-\frac{1}{2}gf_{abc}(\partial^{\mu}A^{a\nu} - \partial^{\nu}A^{a\mu})A_{\mu}^{b}A_{\nu}^{c} + \frac{1}{4}g^2f_{abc}f_{ade}A^{a\mu}A^{b\nu}A_{\mu}^{c}A_{\nu}^{d}.$$

But we are all convinced that we should go beyond the SM !

Introduction to QCD

Rafal

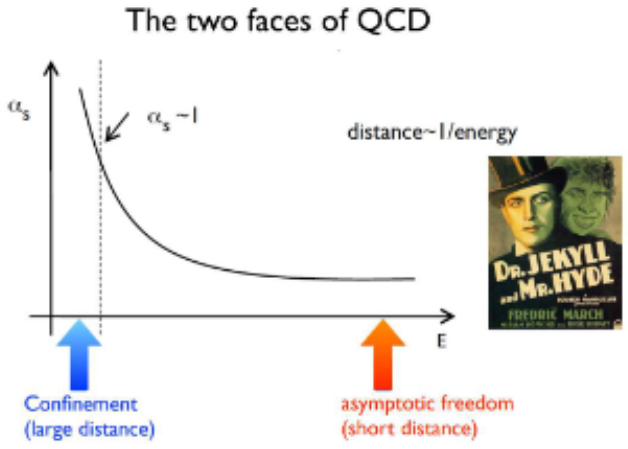




- understand all the physics behind at different energy scales: from ~ 1 GeV up to ~ 1 TeV

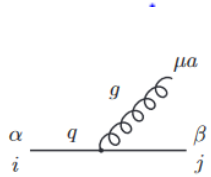
The global symmetries of Quantum Chromo Dynamics and their consequences

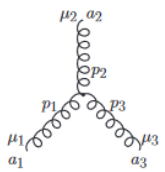
We learned a lot on QCD Lagrangian

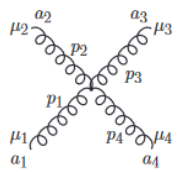


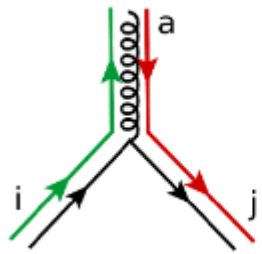
Main properties of QCD: **NON-ABELIAN** and RENORMALIZABLE gauge theory

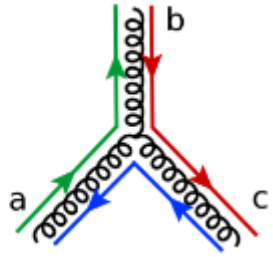
$$\mathcal{L}(x) = -\frac{1}{4}F^a_{\mu\nu}F^{a\mu\nu} + \sum_{f=1}^{N_f}\overline{\psi}^i_f\left[i\gamma^\mu(D_\mu)_{ij} - m_f\delta_{ij}\right]\psi$$







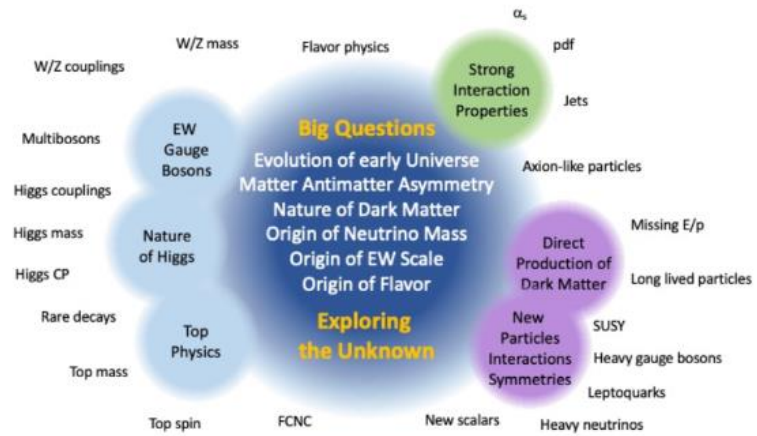


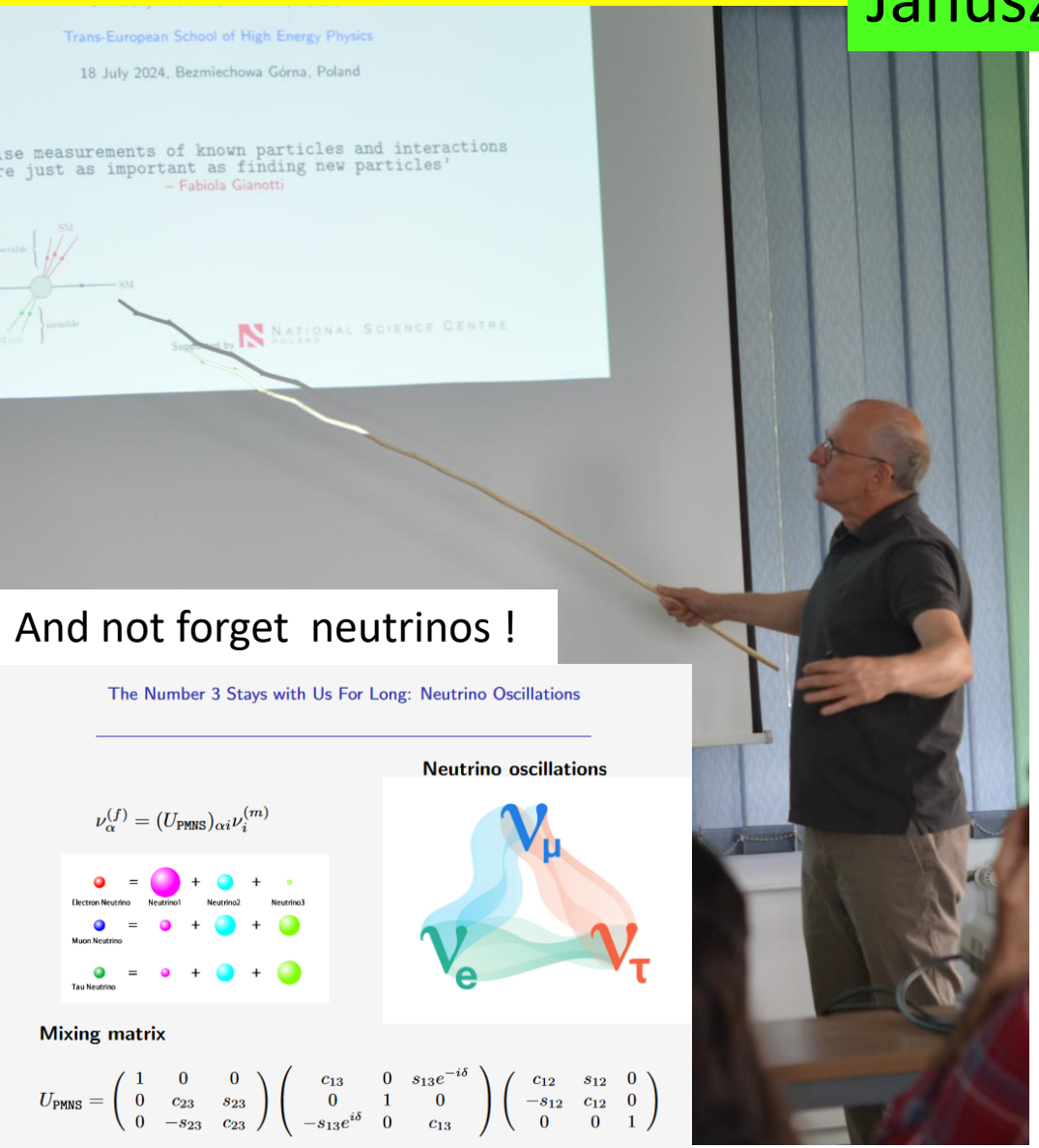


Beyond Standard Model

Janusz

So far all it is working too well !!





And not forget neutrinos !

The Number 3 Stays with Us For Long: Neutrino Oscillations

$$\nu_\alpha^{(f)} = (U_{\text{PMNS}})_{\alpha i}\nu_i^{(m)}$$

Electron Neutrino = Neutrino1 + Neutrino2 + Neutrino3

Muon Neutrino = Neutrino1 + Neutrino2 + Neutrino3

Tau Neutrino = Neutrino1 + Neutrino2 + Neutrino3

Neutrino oscillations

Mixing matrix

$$U_{\text{PMNS}} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Discovery strategies in PP

Two ways for discoveries (in both cases precision is crucial):

1. within the known theory (anomalies[1])
2. new processes and (rare) phenomena;

The magnetic moment of charged leptons (e, μ, τ): $\vec{\mu} = g\frac{e}{2m}\vec{S}$

Dirac: $g = 2$

quantum effects

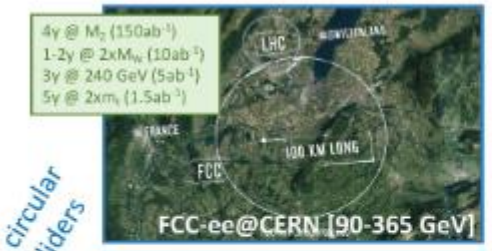
Julian Schwinger [1948]

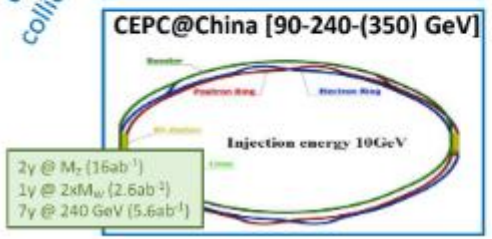
$g = 2\left(1 + \frac{\alpha}{2\pi}\right)$

$\alpha \approx \frac{1}{137}$

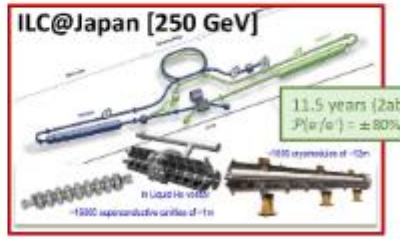
WE NEED PRECISION

e^+e^- Higgs Factories





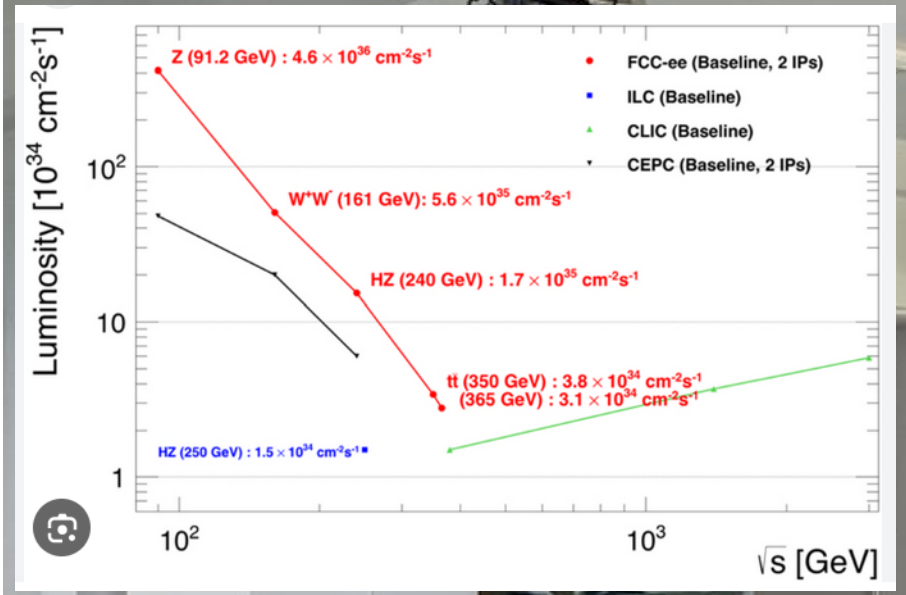
circular colliders



linear colliders

The future : FCC

Tadek

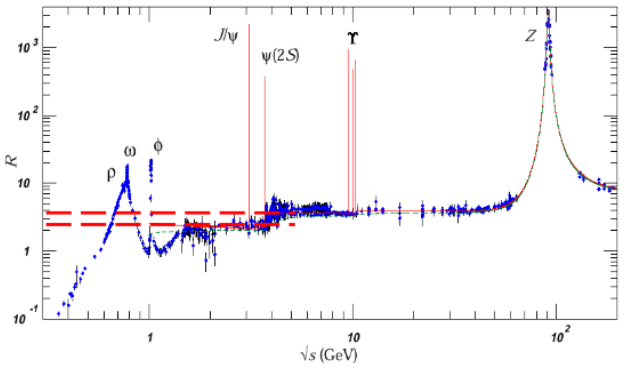


FCC – ee as a first step
To go to FCC-hh after ?

Charm discovery

Sergey and Guillaume

From discovery…



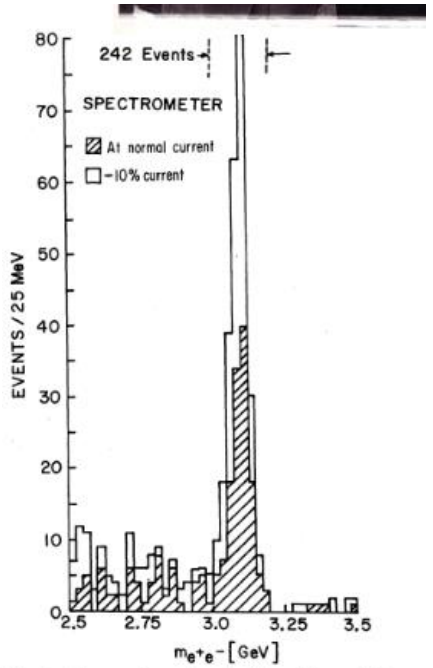
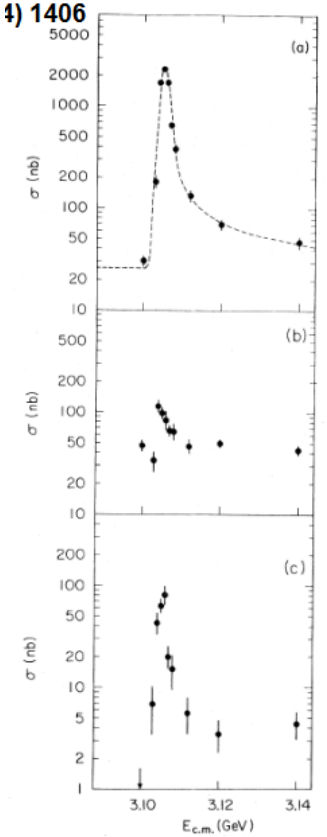
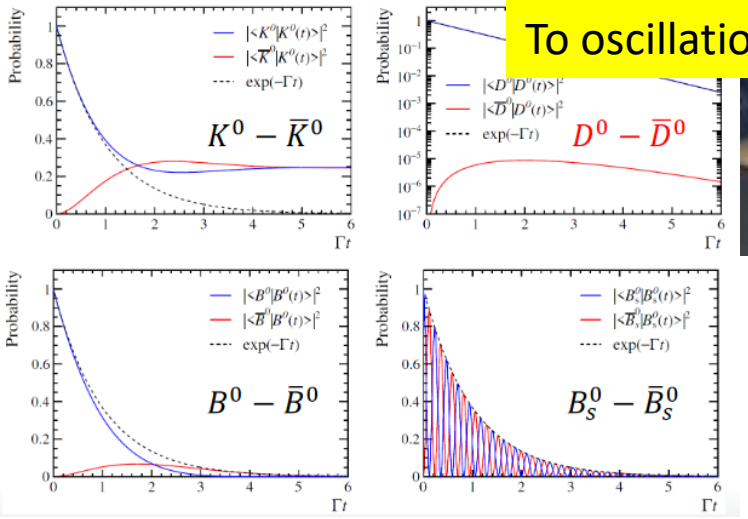
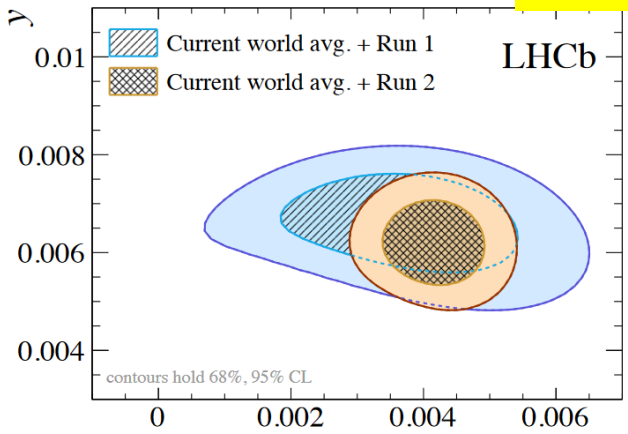


FIG. 2. Mass spectrum showing the existence of J. Results from two spectrometer settings are plotted showing that the peak is independent of spectrometer currents. The run at reduced current was taken two

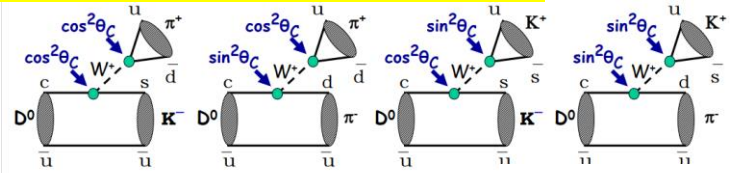


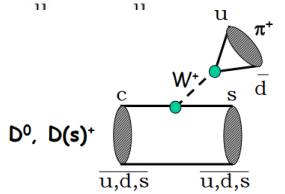
To oscillations…. and CP !

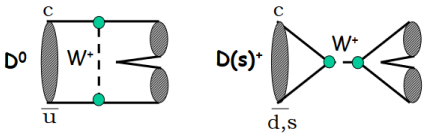




…To detailed studies of decays







CP Violation in charm discovered at LHCb !

Flavour Physics…

And CP Violation

1963 ΔS=1 vs ΔS=0 Cabibbo theory

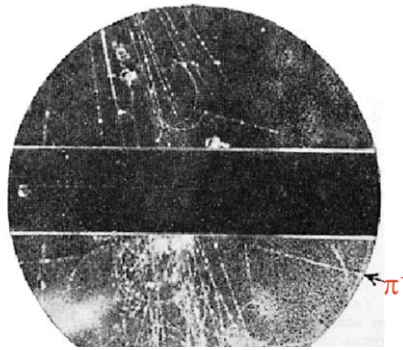
The quarks *d* e *s* involved in weak processes are « rotated » by an angle

Couplings : u d $G_F \cos\theta_c$ u s $G_F \sin\theta_c$

θ_c : the Cabibbo angle

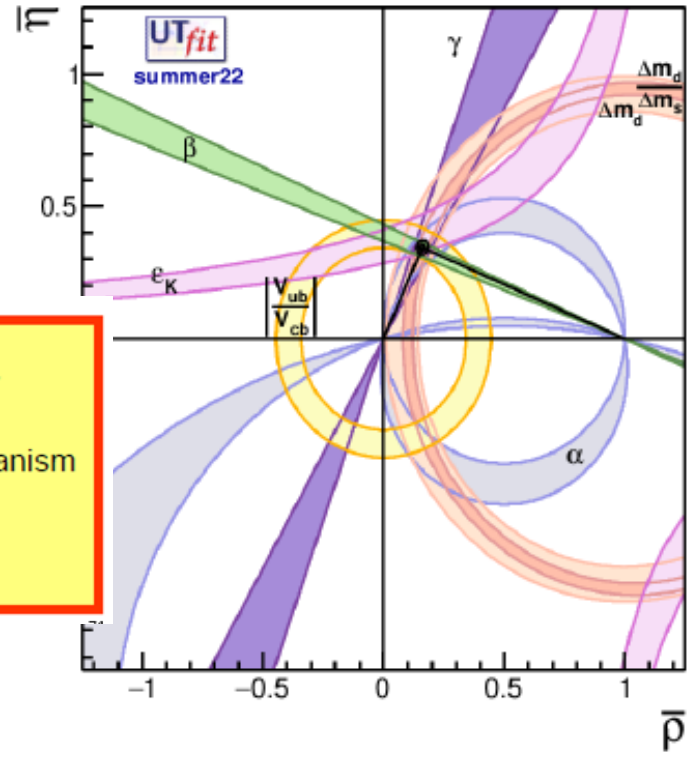
$$\begin{pmatrix} u \\ d_c \end{pmatrix} = \begin{pmatrix} u \\ d\cos\theta_c + s\sin\theta_c \end{pmatrix}$$

$K^0 \to \pi^+\pi^-$



$$(\bar{u},\bar{c})\gamma^\mu(1-\gamma_5)V\begin{pmatrix} d \\ s \end{pmatrix}$$

$$V = \begin{pmatrix} \cos\theta_c & \sin\theta_c \\ -\sin\theta_c & \cos\theta_c \end{pmatrix}$$



The CKM Matrix

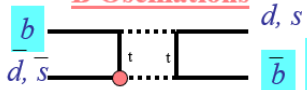
Wolfenstein parametrization
4 parameters : λ ,A, ρ, η

	d	s	b
u	$1-\lambda^2/2$	λ	$A\lambda^3(\rho-i\eta)$
c	$-\lambda$	$1-\lambda^2/2$	$A\lambda^2$
t	$A\lambda^3(1-\rho-i\eta)$	$-A\lambda^2$	1

b → c,u : V_{ub}, V_{cb} — B decays

V_{tb}

B Oscillations



V_{td}, V_{ts}

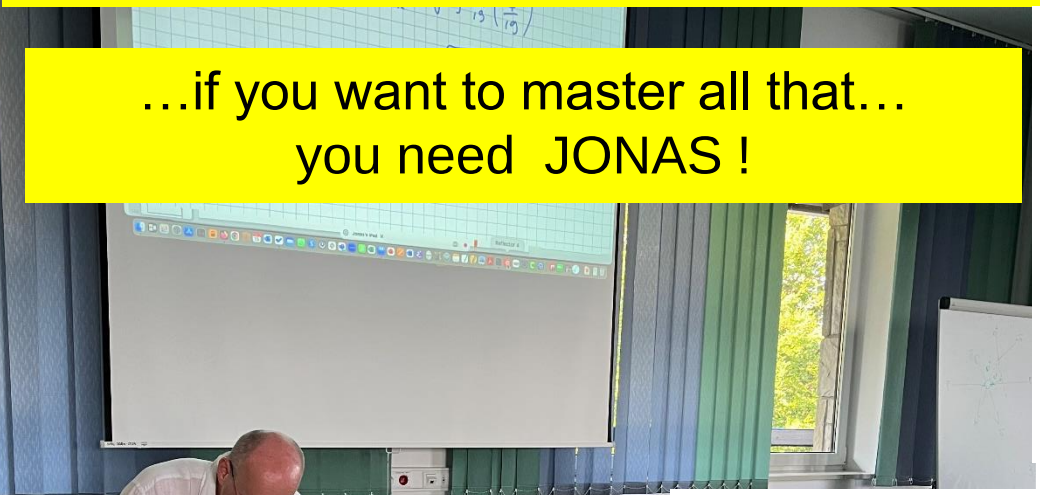
The *b-Physics* plays a very important role in the determination of those parameters 63

1. ~1970 charm quark from FCNC and GIM-mechanism $K^0 \to \mu\mu$
2. ~1973 3rd generation from CP violation in kaon (ε_K) KM-mechanism
3. ~1990 heavy top from B oscillations Δm_B

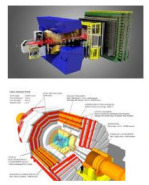
Discovery : absence of New Particles up to the ~2×Electroweak Scale !

…if you want discovery… you have to be sure…
…if you want precision…you have to deal with small errors…and systematics..

…if you want to master all that…
you need JONAS !



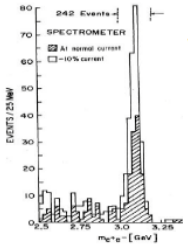
What we get



What we want

$\mathscr{L} =$

Roadmap



What do I see?

Describing Data

What do I expect?

Probability and probability distributions, Probability density functions

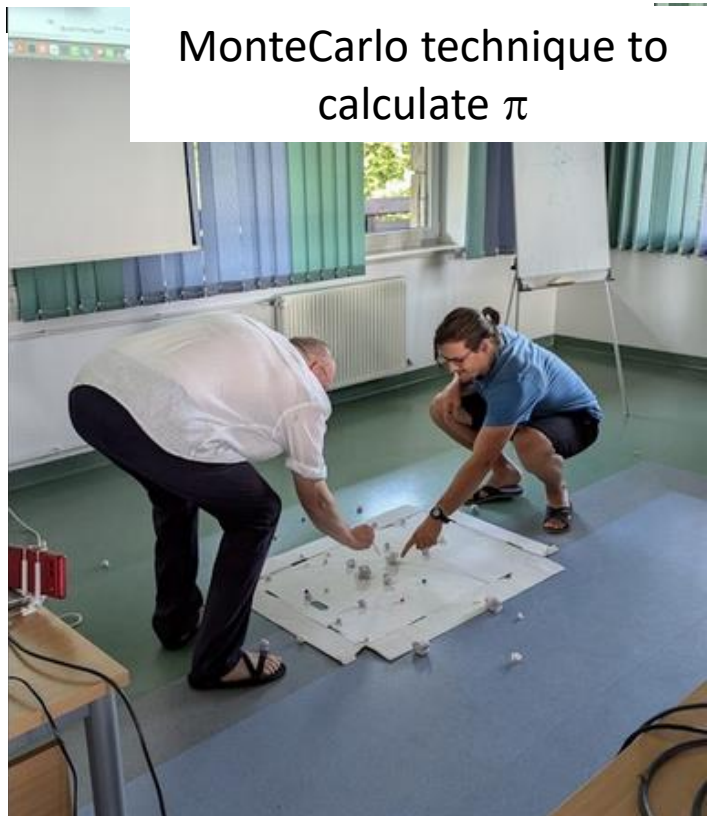
Central Limit Theorem

Is what I see compatible with what I expect?

Discoveries
Confidence Levels
Hypothesis testing
Fitting

Monte Carlo simulation

MonteCarlo technique to calculate π

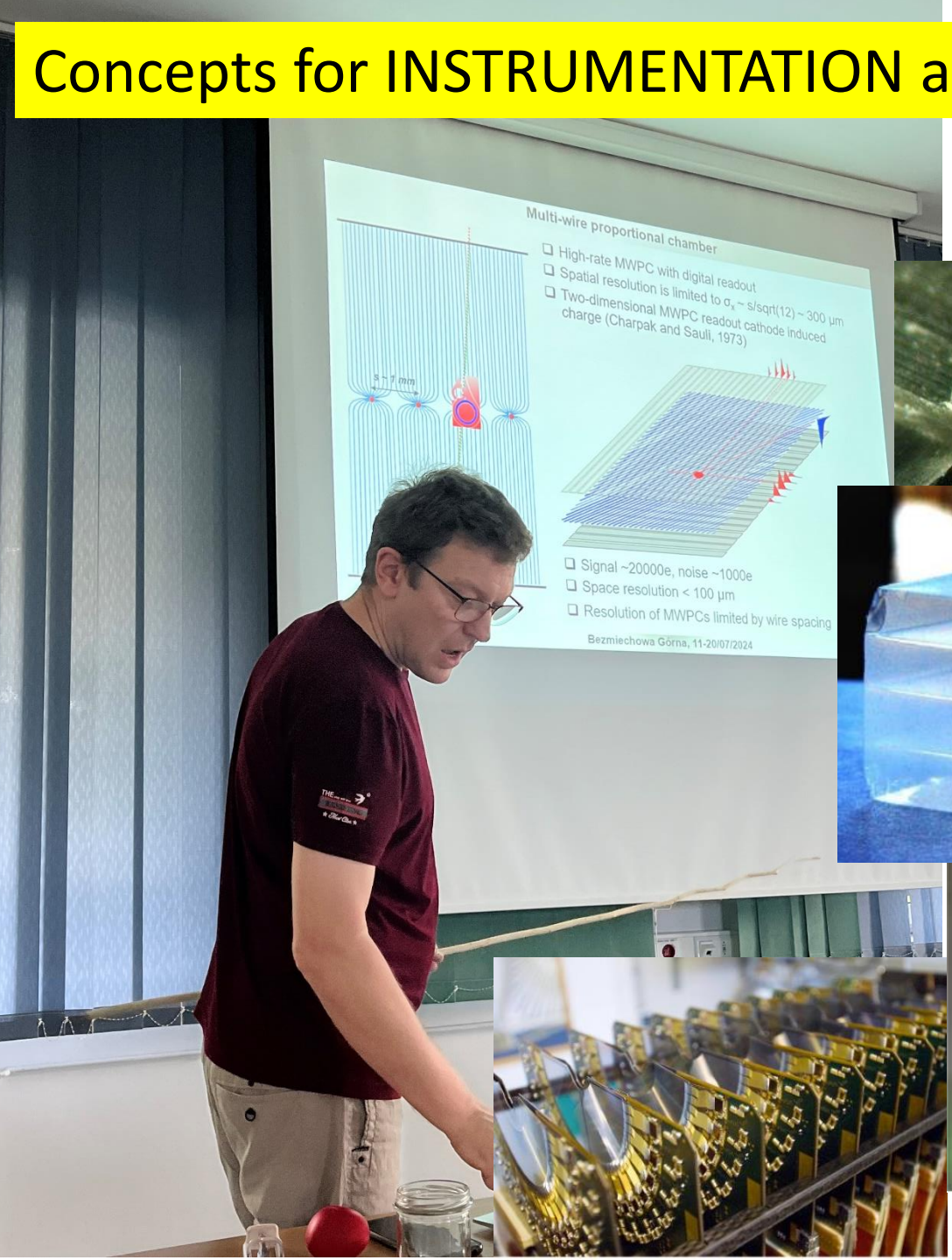


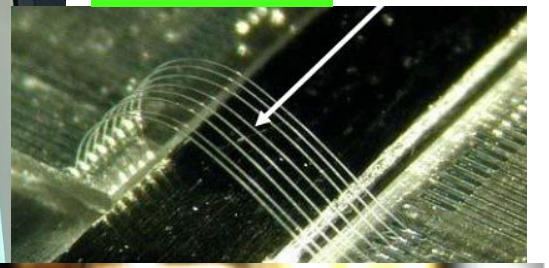
Concepts for INSTRUMENTATION and building detector

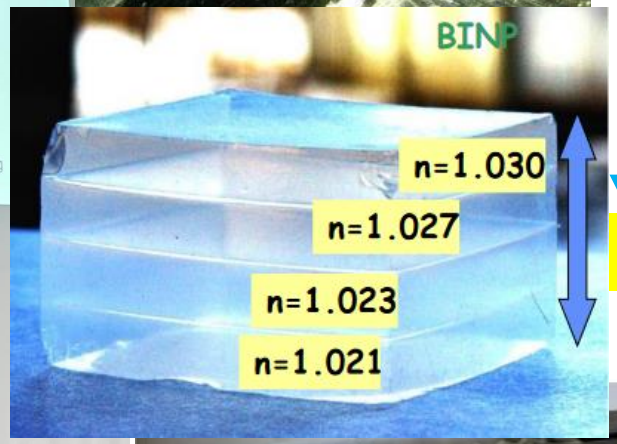
Sergey

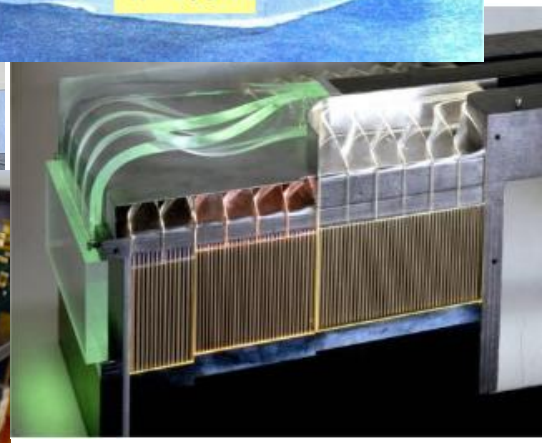
From concepts

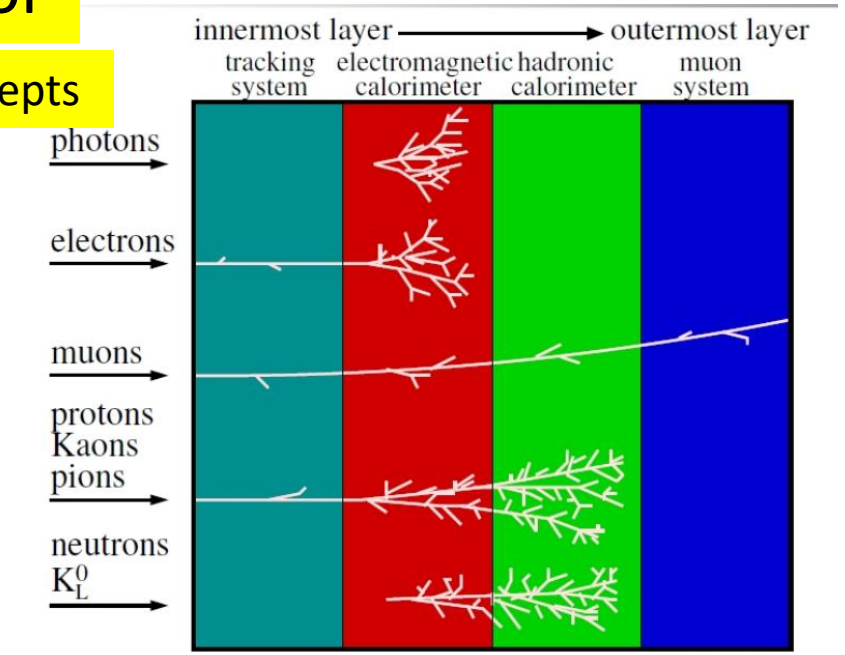
To complex detector

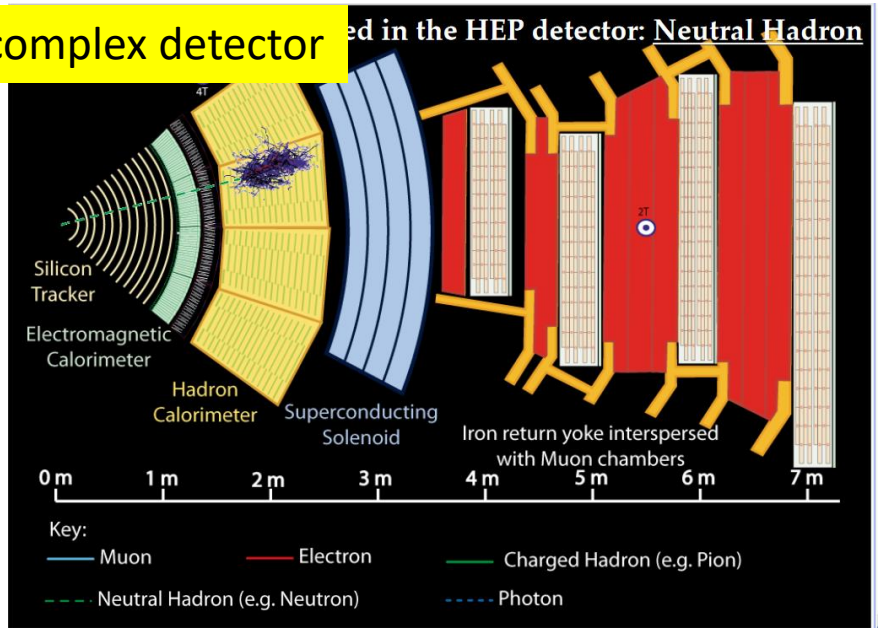












Accelerator Physics

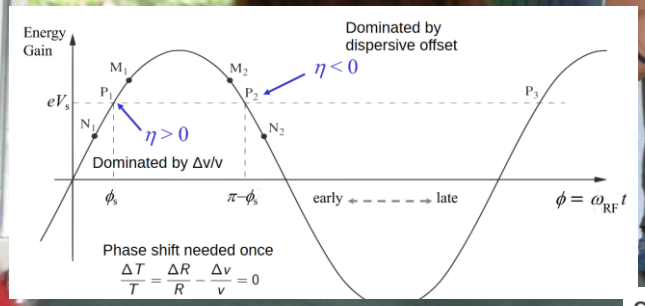
Pascal

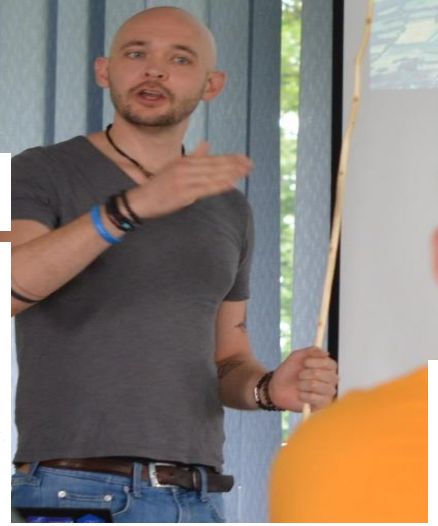
- Linac 4
- Transfert lines
- Dump
- Collimations

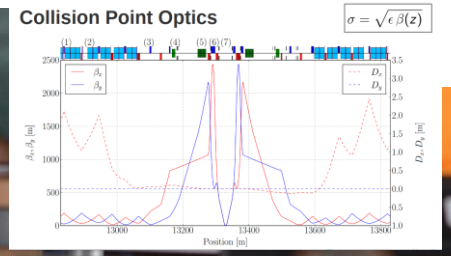
Accelerators are essential instruments for our research

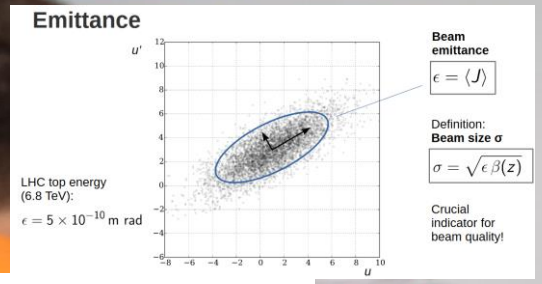
LHC is the machine of all the challanges !

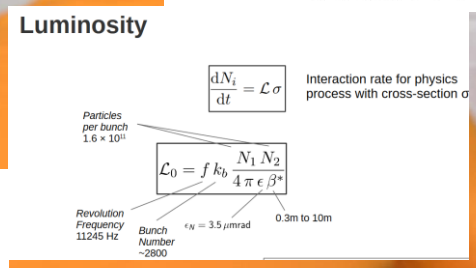
Synchrotron oscillations:





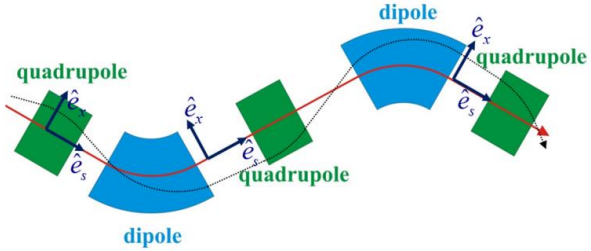






Matrix Formalism

Can combine matrices → calculate *M* for combination of elements



$$\vec{x} = \underbrace{\mathbf{M}_d \cdot \mathbf{M}_Q \cdot \mathbf{M}_d \cdot \mathbf{M}_D \cdot \mathbf{M}_d \cdot \mathbf{M}_Q \cdot \mathbf{M}_d \cdot \mathbf{M}_D \cdot \mathbf{M}_d \cdot \mathbf{M}_Q \cdot \mathbf{M}_d}_{= \text{Transfer Matrix } \mathbf{M}} \cdot \vec{x}_0$$

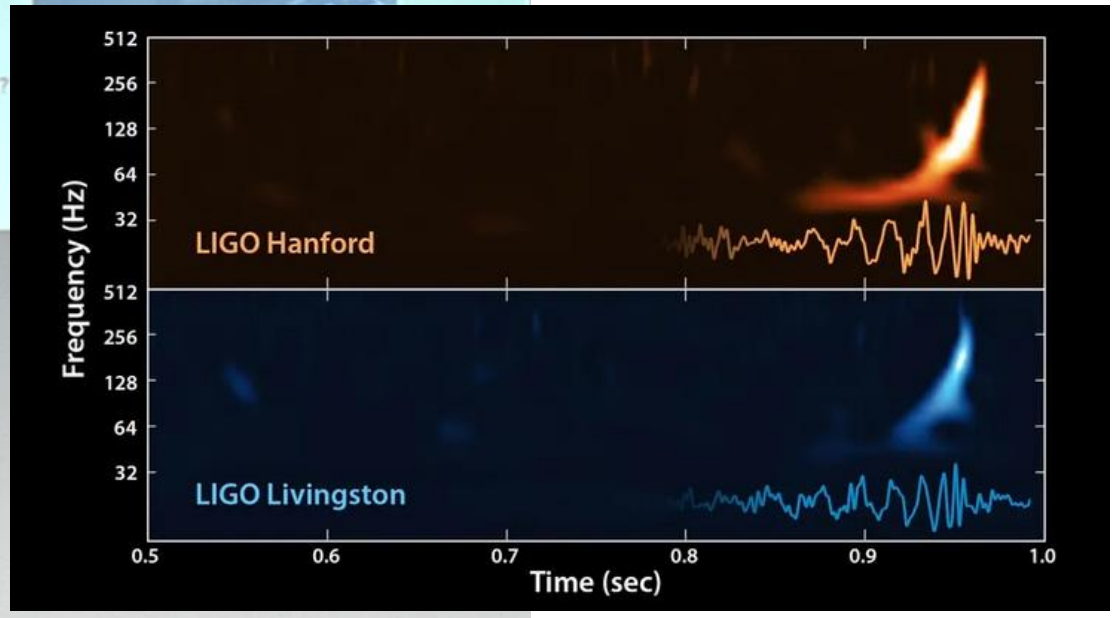
$$\begin{pmatrix} y_1 \\ y_1' \end{pmatrix} = \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} y_0 \\ y_0' \end{pmatrix}$$

$$\begin{pmatrix} y_1 \\ y_1' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ \pm\frac{1}{f} & 1 \end{pmatrix} \cdot \begin{pmatrix} y_0 \\ y_0' \end{pmatrix}$$

Cosmic rays and CREDO

Robert

Gravitational waves

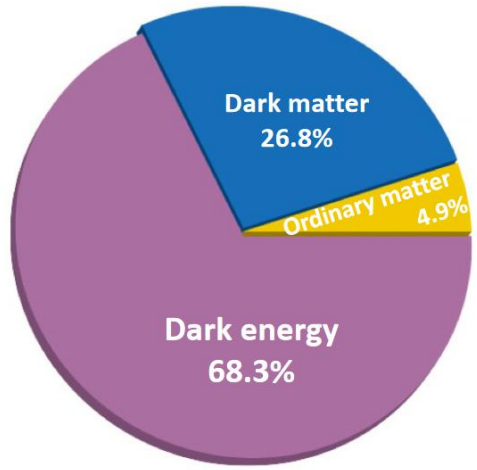


Challenging Future physics

Vincenzo

andard Model: how stubborn is it?

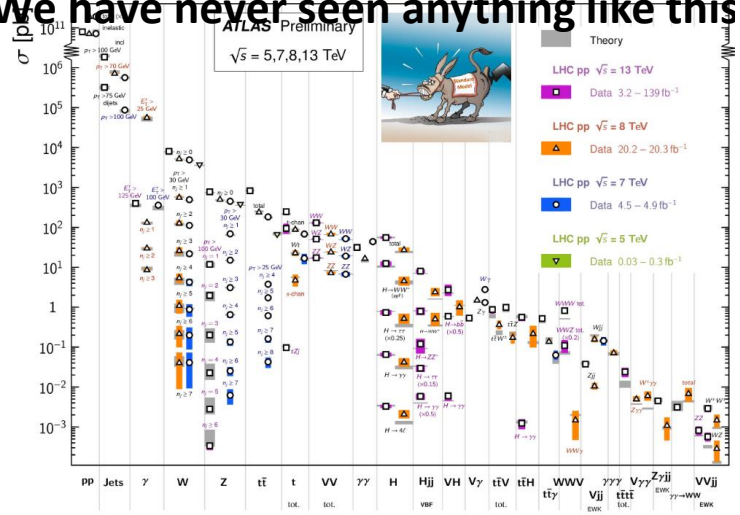
- Why three generations of leptons and quarks?
- Why such a huge difference in the masses of fundamental particles?
- What's the origin of the structure of flavour couplings?
- Why is the universe made of "matter" and not "antimatter"?
- What stabilises the Higgs mass?
- What's the nature of dark matter?
- And what about gravity?

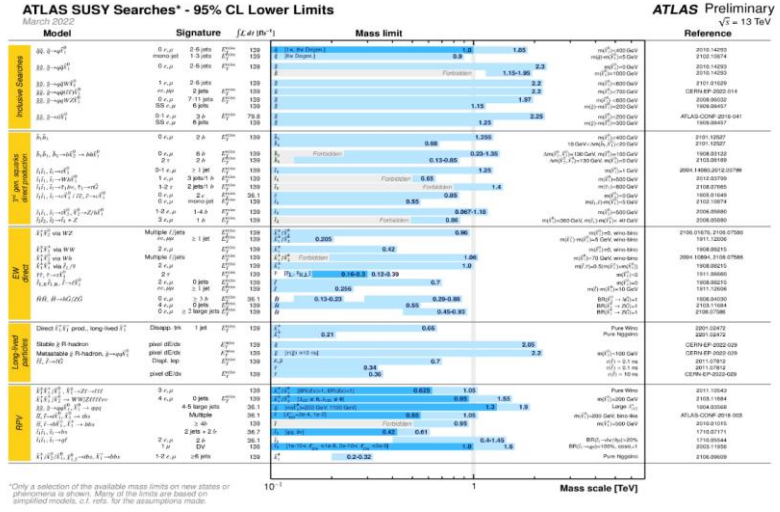


The Standard Model is certainly incredibly stubborn, but it can't be the ultimate theory…

New Physics is out there, but "where is everybody"?

We have never seen anything like this

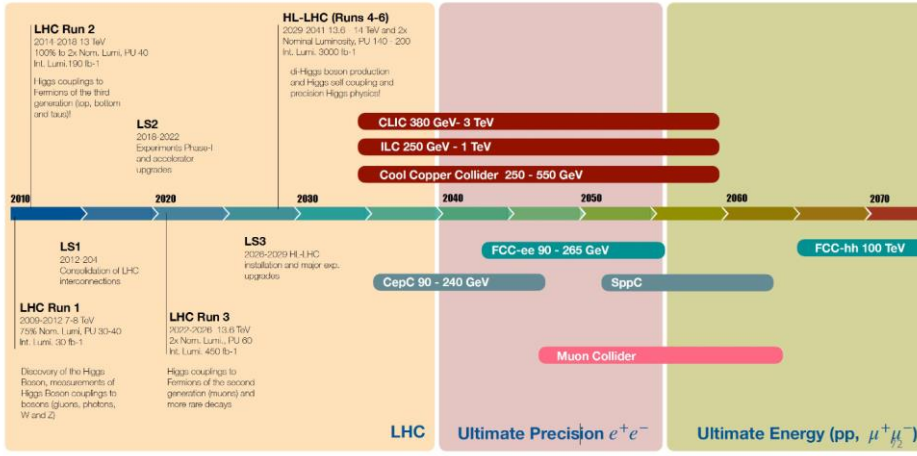




Can we explain the asymmetry by Standard Model physics?

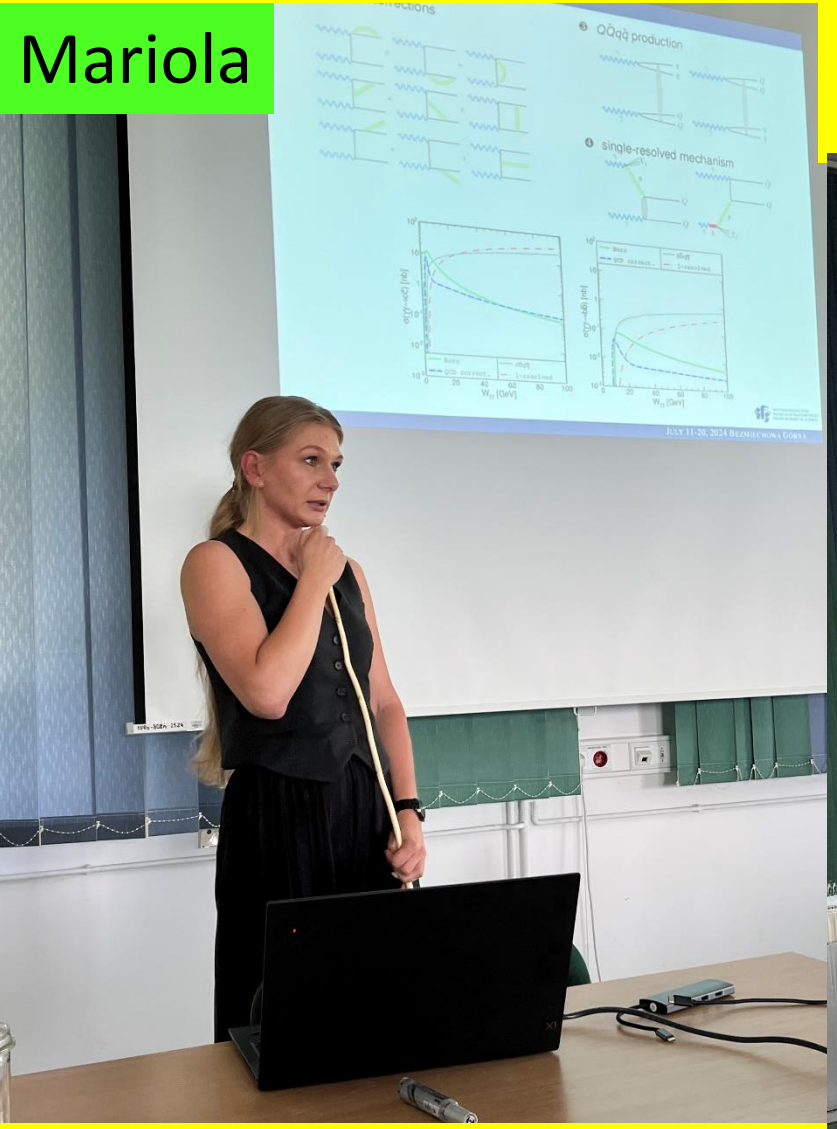
- Quantitatively: no
- The previous equation gives $\eta \approx 10^{-19}$, which is off by 10 orders of magnitude with respect to the experimental observation
- *CP* violation in the Standard Model is too small

Roadmap to this century's particle accelerators



Seminars from professors !

Mariola



photon-photon fusion in heavy-ion collisions

Event-by-event correlations in heavy ions

Marta

Photon induced processes in pp collisions

From theory → experiments → data analyses : the Hands-On !

And you have to be smart and well educated to perform analysis…

And you need Rafal and Valeriia

and Guillaume !

We had a seminar of the CERN History and his mission.

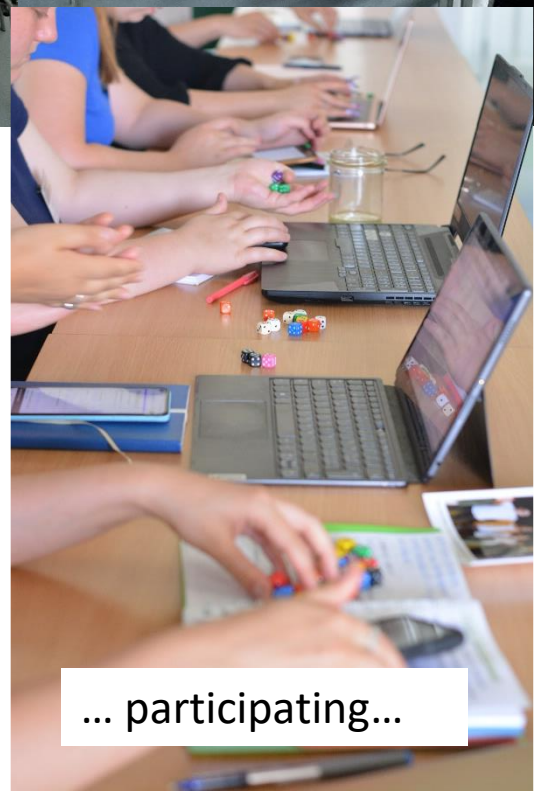
Christoph

Thanks to CERN for supporting the School since the beginning !

LectureTime @ TESHEP2024

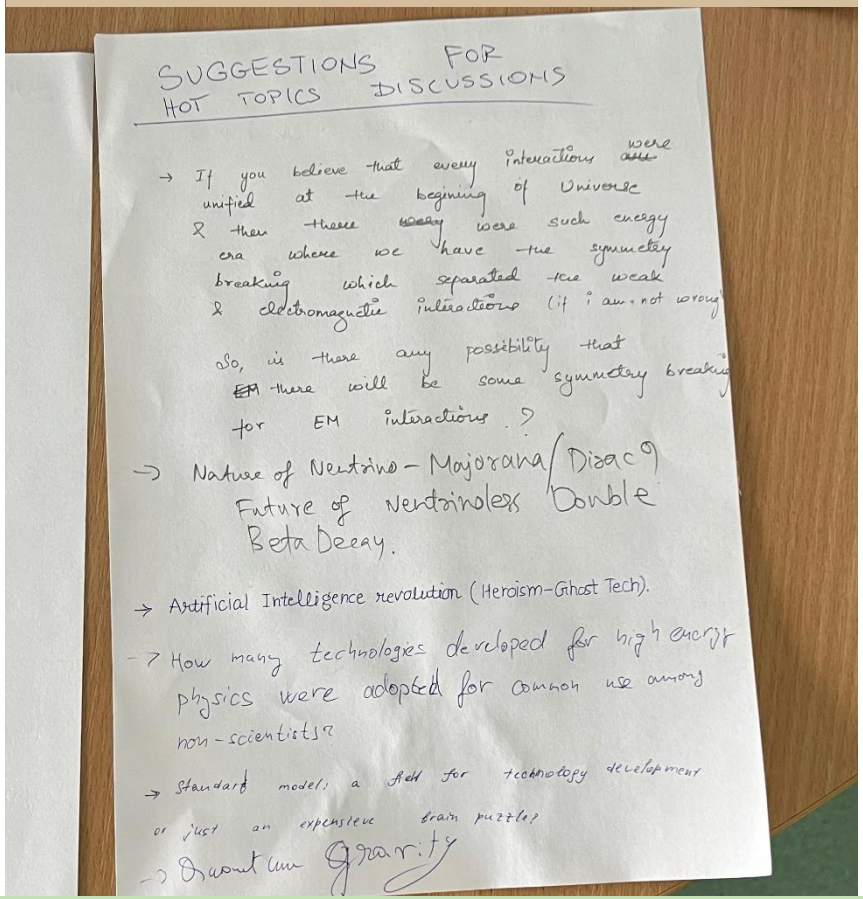
Class were almost everytime full !

Very concentrated !



… participating…

And we also had two interesting « Hot Topic discussion »



SUGGESTIONS FOR HOT TOPICS DISCUSSIONS

→ If you believe that every interactions were unified at the beginning of Universe & then there were such energy era where we have the symmetry breaking which separated the weak & electromagnetic interactions (if i am not wrong)

So, is there any possibility that there will be some symmetry breaking for EM interactions ?

→ Nature of Neutrino – Majorana / Dirac ? Future of Neutrinoless Double Beta Decay.

→ Artificial Intelligence revolution (Heroism-Ghost Tech).

→ How many technologies developed for high energy physics were adopted for common use among non-scientists?

→ Standard model: a hell for technology development or just an expensive brain puzzle?

→ Quantum Gravity

Which are the open questions in particle physics / at large ?
From observations … and/or From other reasons

Which are the priority in the next decades : Experiment / Theory

Is particle physics (high energy) useful ?
Has particle physics an important impact on other domains ?

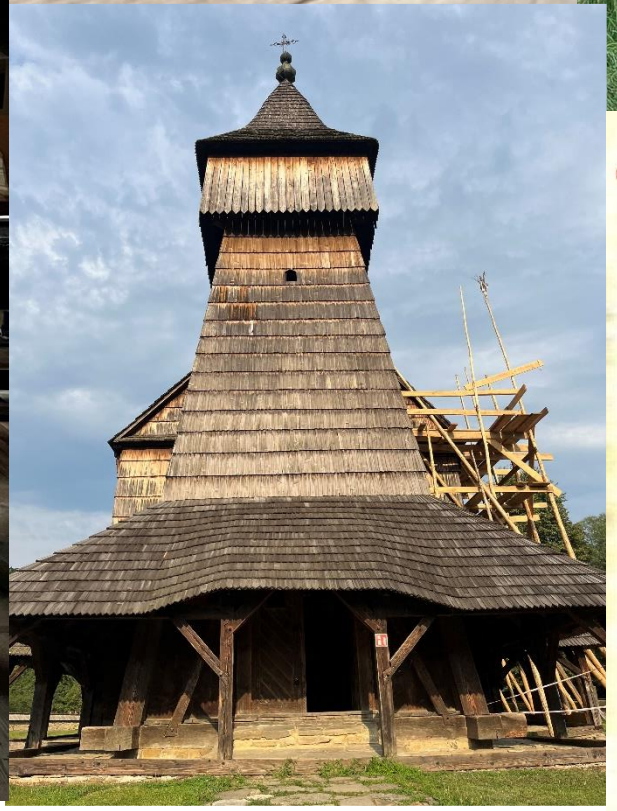
The preparation of the presentations was very intense

RELAX AND FUN TIME !

Excursion at Sanok

we discovered a very nice region

Back to school



RELAX AND FUN TIME !

Excursion at Sanok

we discovered a very nice region

Back to school

NICE MOMENTS@Bezmiechowa Górna

Nice night singing session

MAGIC MOMENTS@Bezmiechowa Górna

The main actor of the week …

Cytrynowka : The polish limoncello ! …

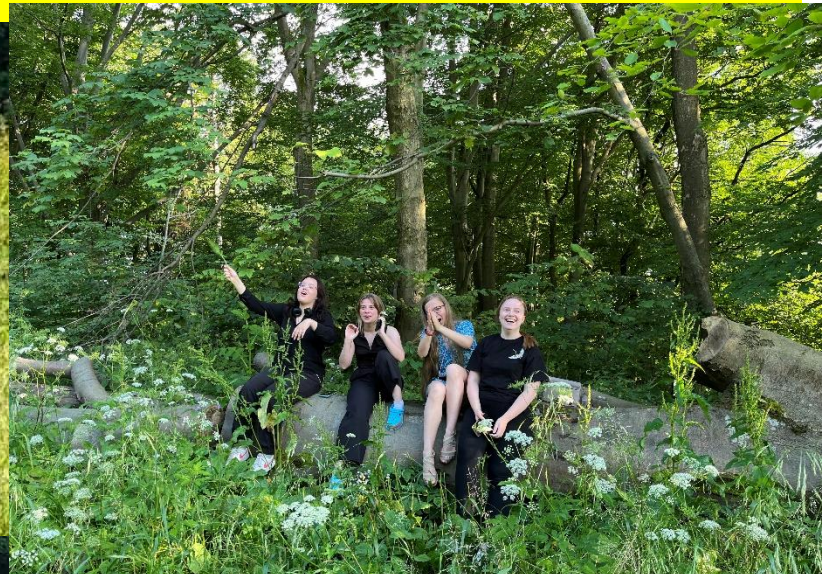








Football as usual as always !!



Spectators were passionated in the stadium !

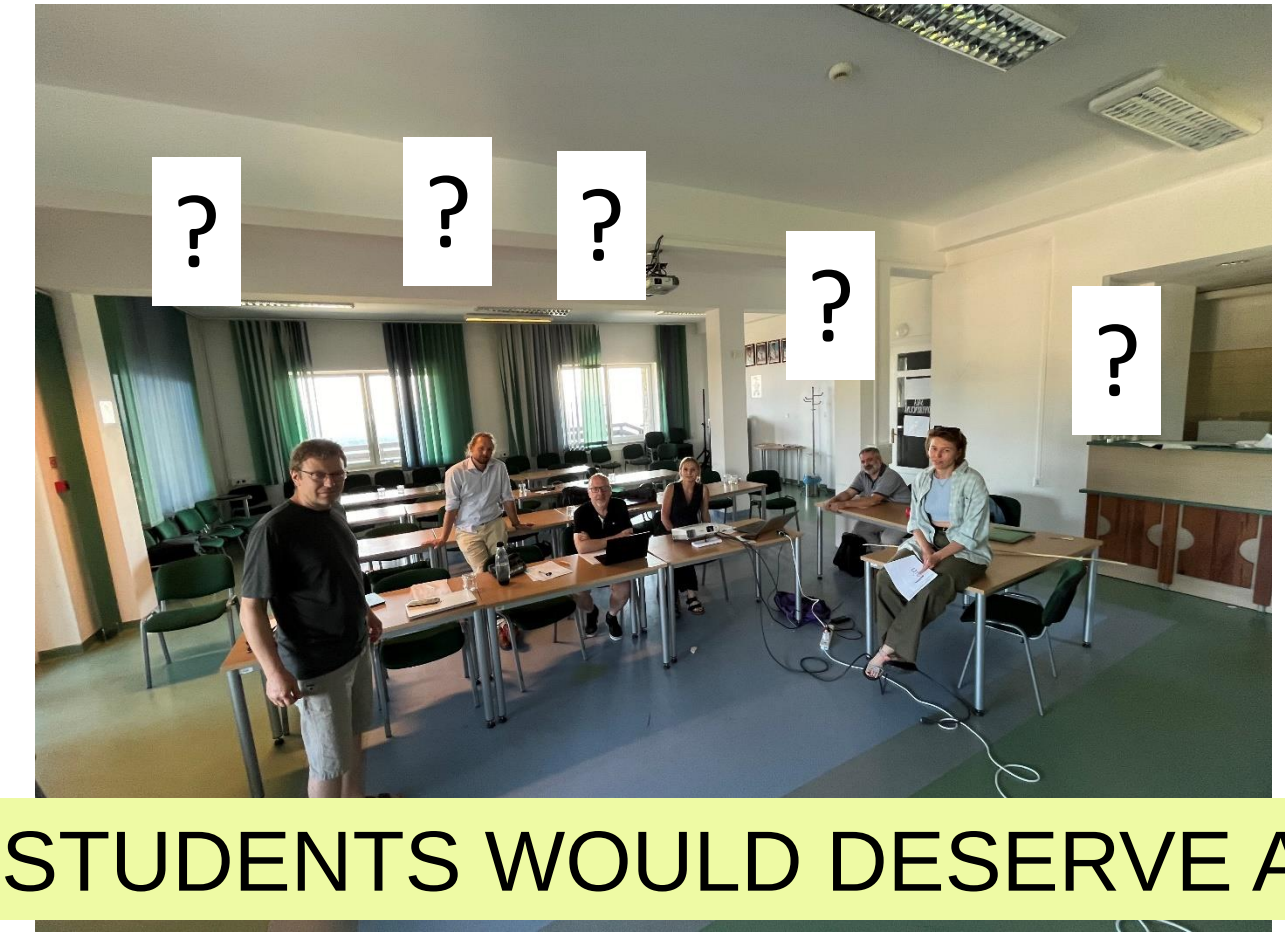
Contacts were… friendly !!

Ball control not always perfect…

At the end everybody was happy, tradition was kept… professors win !

Student’s presentation were good and professionally prepared…

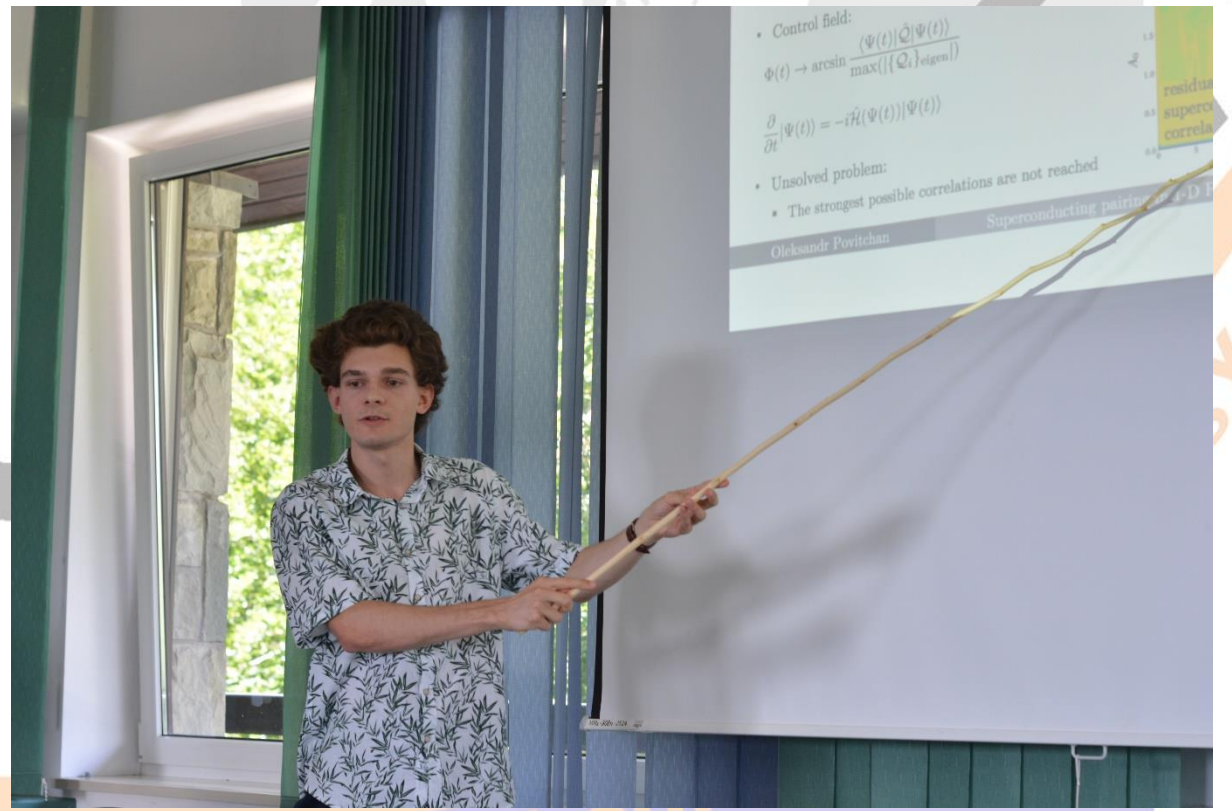
We had a Conference 22 fast communications..



ALL STUDENTS WOULD DESERVE A PRIZE

Prize for the best presentation

Oleksandr Povitchan



But we want also to mention for their presentation :
Vitali Dididze, Renata Osypova, Zak Williams, Baraa Yahya and Shenghui Zeng

Prize for the best questions

Zak Williams

Really one of the best school in terms of questions asked and quality of the questions!

But we want also to mention for their questions and participation :
Saleh Bashiri, Vitali Dididze, Frantisek Hruby, Oleksandr Povitchan, Jan Straka, Shreya Sharma, Adam Watroba, Baraa Yahya, Shenghui Zeng

Prize for the best lecture

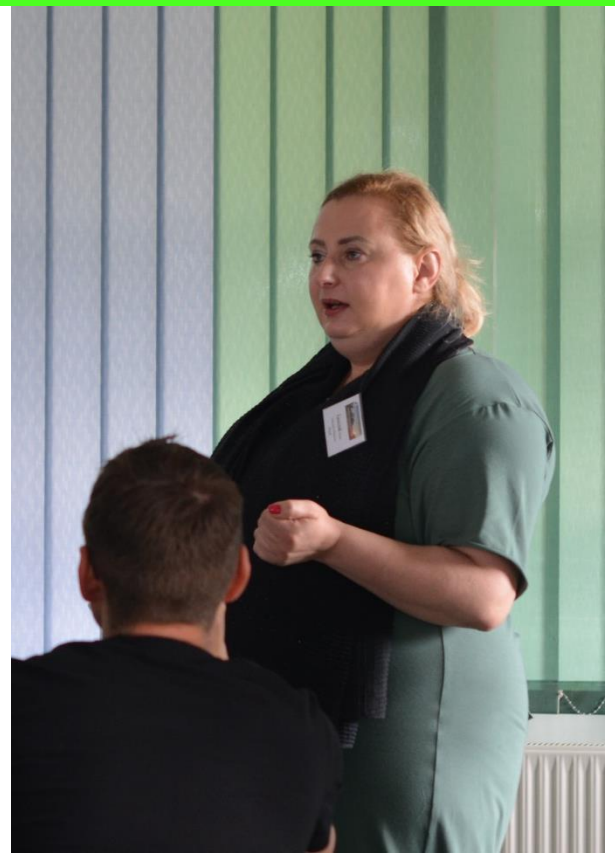
To the local organisers

- for making this school possible
- for the UNPECCABLE organisation in a such beautiful and convenient place

Thanks to

Tadek – Director of IFJ

Marta – Dean University of Rzeszow



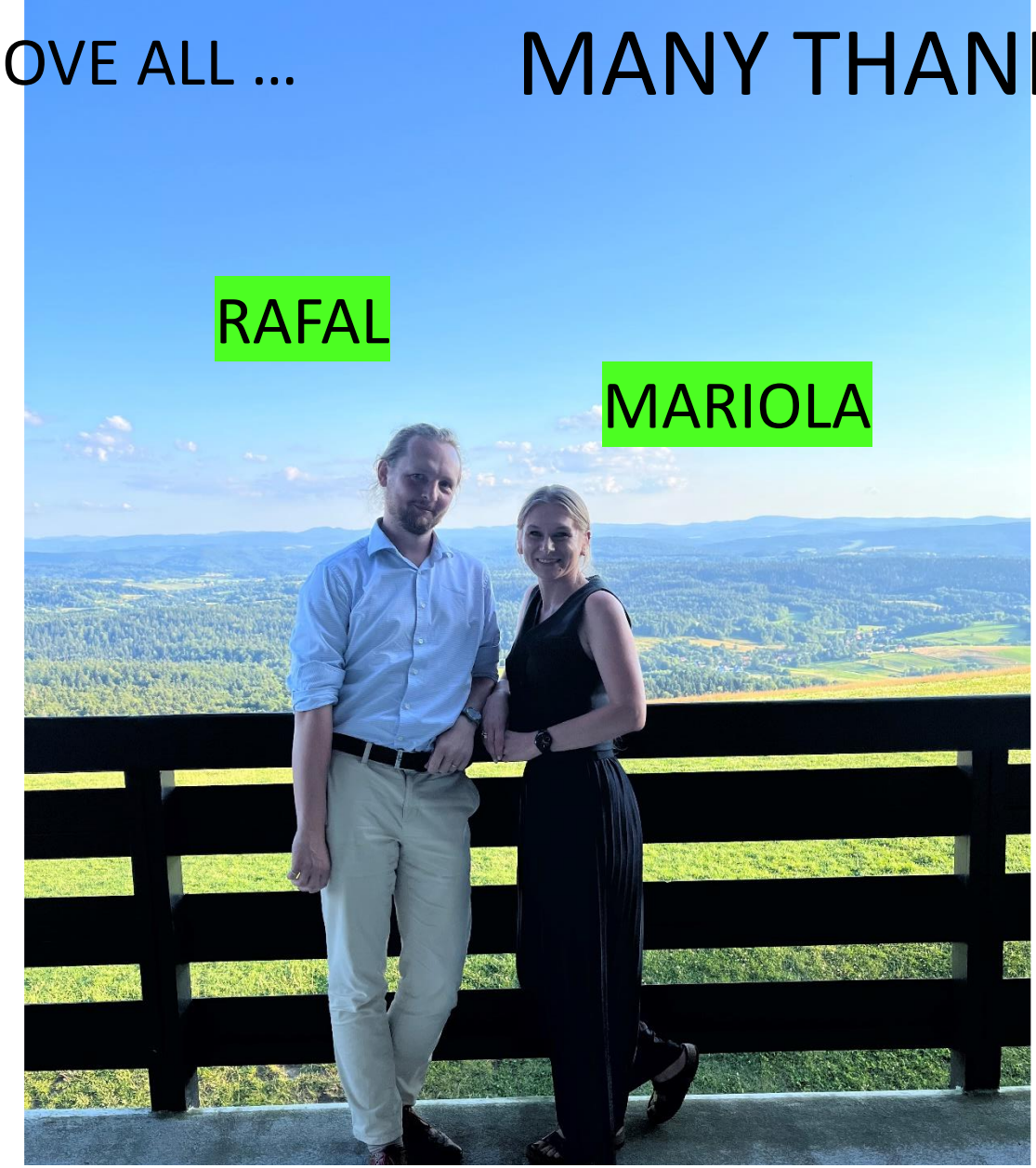
Czeslan –Dean Politechnik of Rzeszow

But this it has been possible also thank to practical organization and in particular to

Catherine Bourge

BUT MAINLY AND ABOVE ALL …

MANY THANKS TO



The school was only possible thank to your work, enthusiasm
The organisation was more than perfect

We would like to have your feedback
A questionnaire will be sent to you !
Please take time to fill it up

Thanks for coming, have a safe journey back home