Non LHC Experiments at CERN with Slovak Participation

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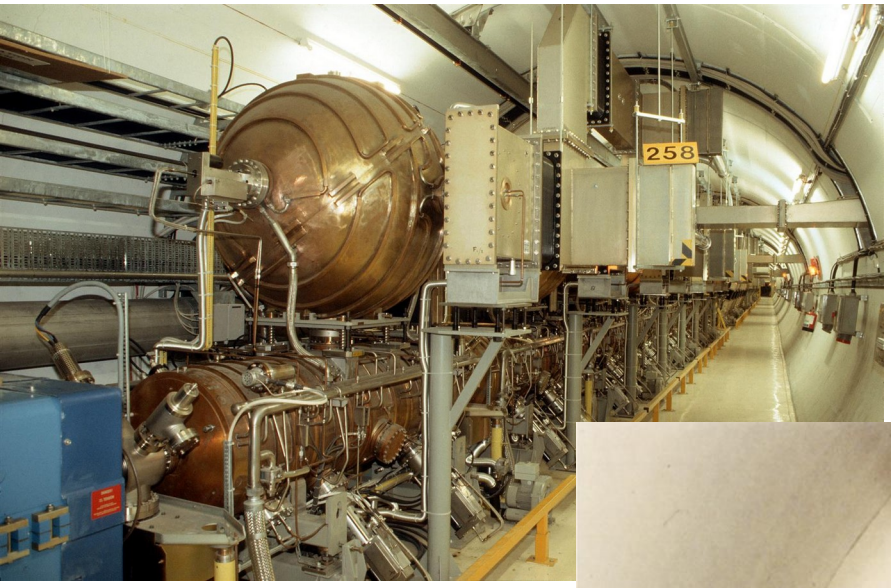
Ústav experimentálnej fyziky SAV, v.v.i.
Košice

Introduction

- 30 years ago the LHC has not yet been built...
- **The CERN flagship: Large Electron Positron collider**
  - the largest electron-positron collider evet built
  - precise tests of the Standard Model and precise measurement of its many parameters
- **Heavy Ion Programme at the Super Proton Sychrotron**
  - systematic studies of many aspects of the collisions of heavy atomic nuclei accelerated to very high energies
  - at that time the SPS provided the largest energies for nuclear projectiles (O, S, Pb) in laboratory

Large Electron Positron collider

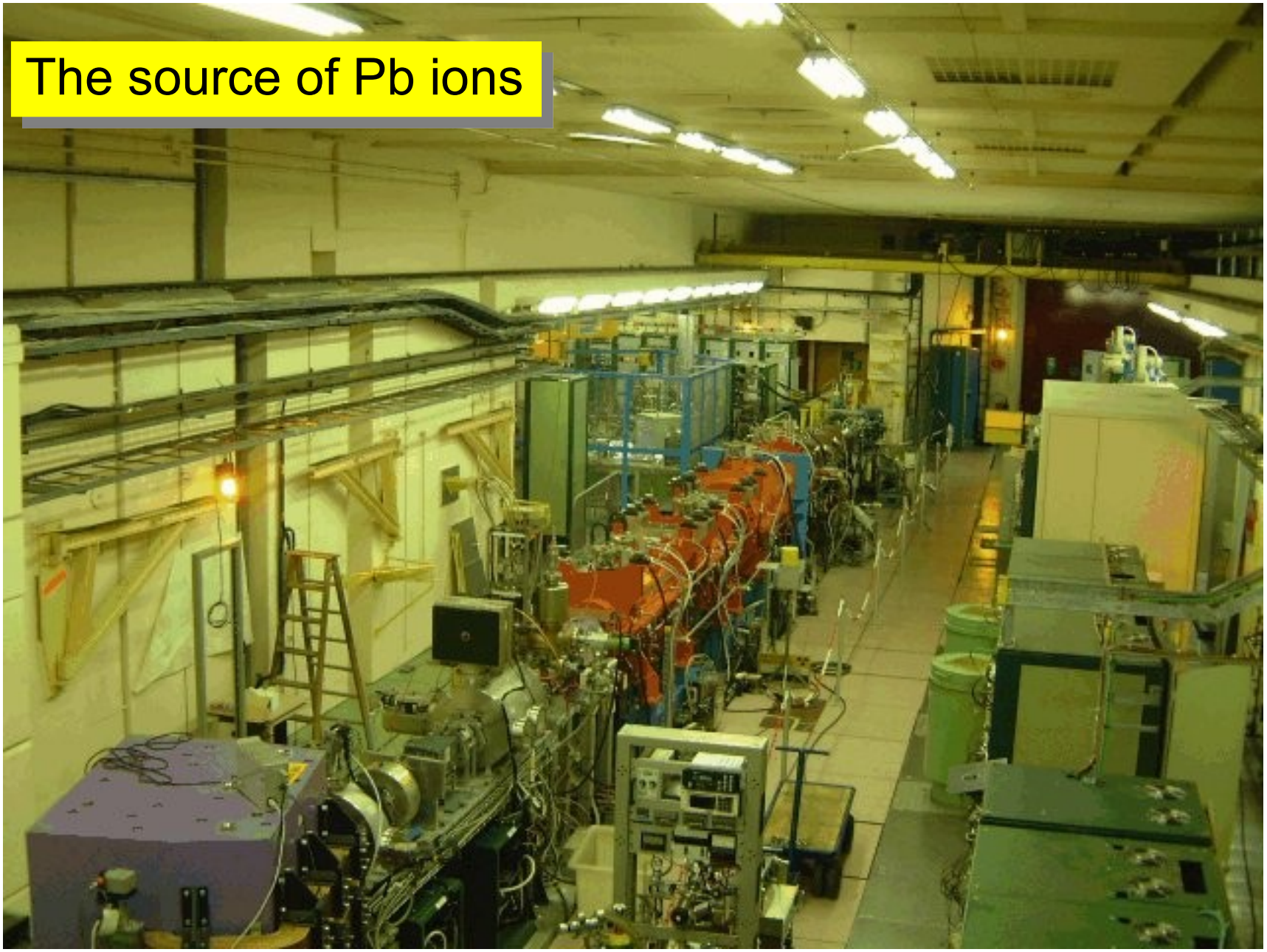


- 27 km circumference
- The largest electron-positron collider ever built
- Initial energy: 91 GeV
- Max energy: 209 GeV

LEP RF Copper Cavity

- electron and positron acceleration
- copper spheres at the top stored the microwave energy between bunches
  - energy saving

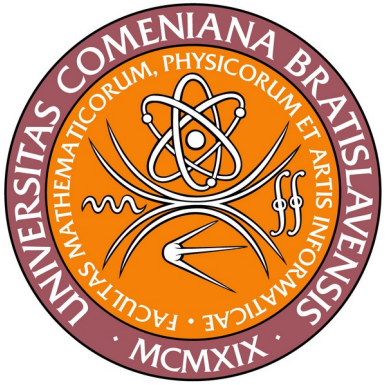
Heavy Ion Acceleration @ CERN



LINAC3 – linear accelerator for Pb ions, 4.2 MeV/u

Super Proton Synchrotron SPS

O: (8p, 8n) **S: (16p, 16n)** **Pb: (82p, 126n)**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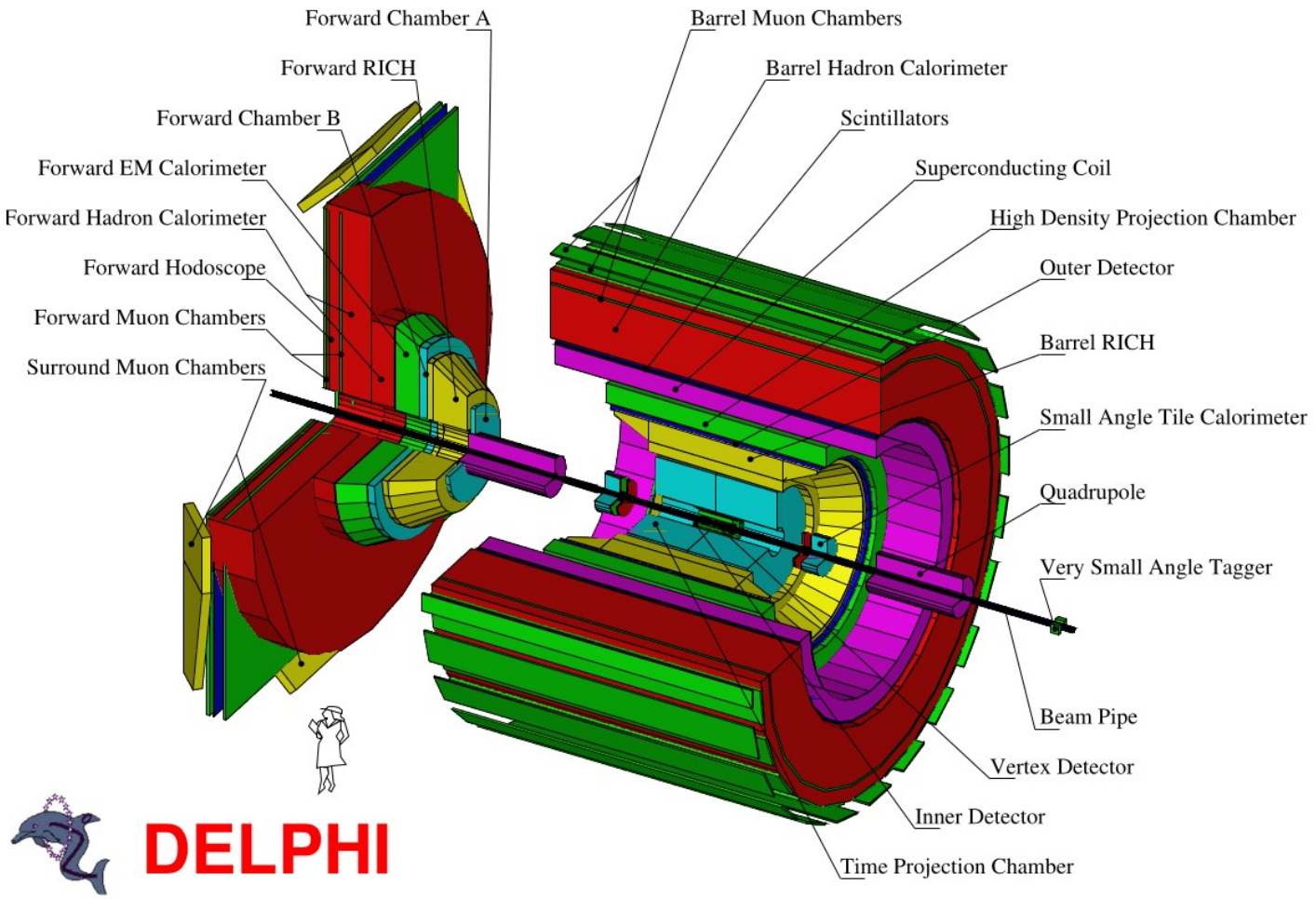
DELPHI @ LEP

Dramatis personæ

- **1990** – East-West Cooperation Project (Austria)
  - collaboration between MMF UK Bratislava + HEPHY Wien
  - P. Povinec, P. Kubinec, I. Mikulec, P. Chochula
    - J. Braciník, P. Rosinský (students)
- **1993**
  - B. Sitár, R. Janík
- **1995 -** Bratislava accepted as a regular member of the DELPHI Collaboration

DELPHI experiment

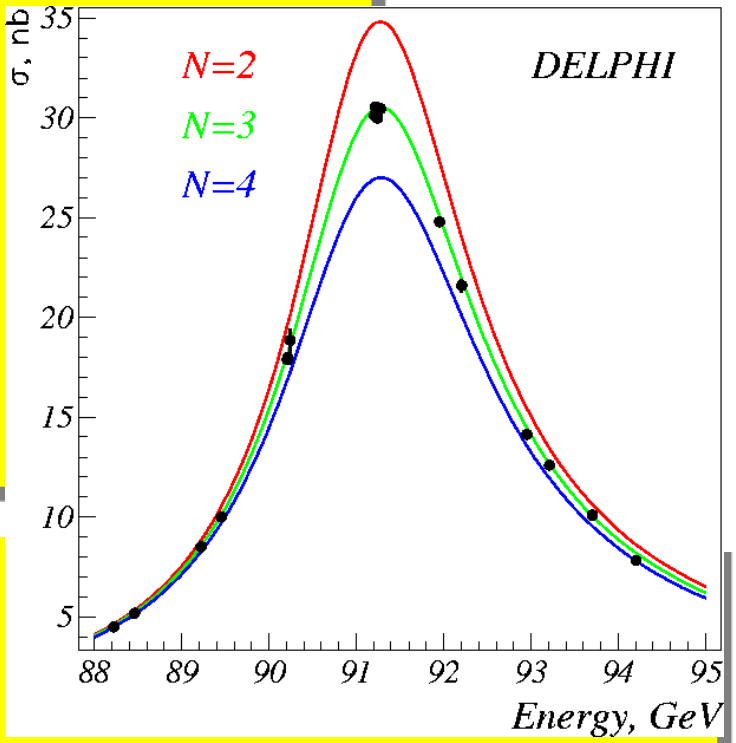


- 550 physicists
- 56 institutions
- 22 countries

- 1.23 T magnet, 10m diameter
  - at that time the largest supraconducting magnet
- First use of the silicon pixel detectors in a collider experiment

DELPHI physics

- **Study of various aspects of the Standard Model**
  - measurement of the electroweak interaction parameters
  - decays of Z^0 boson
    - one of the results was fixing the number of neutrino generation to 3
  - measurement of the fragmentation functions and quantum chromodynamics tests



Bratislava contribution

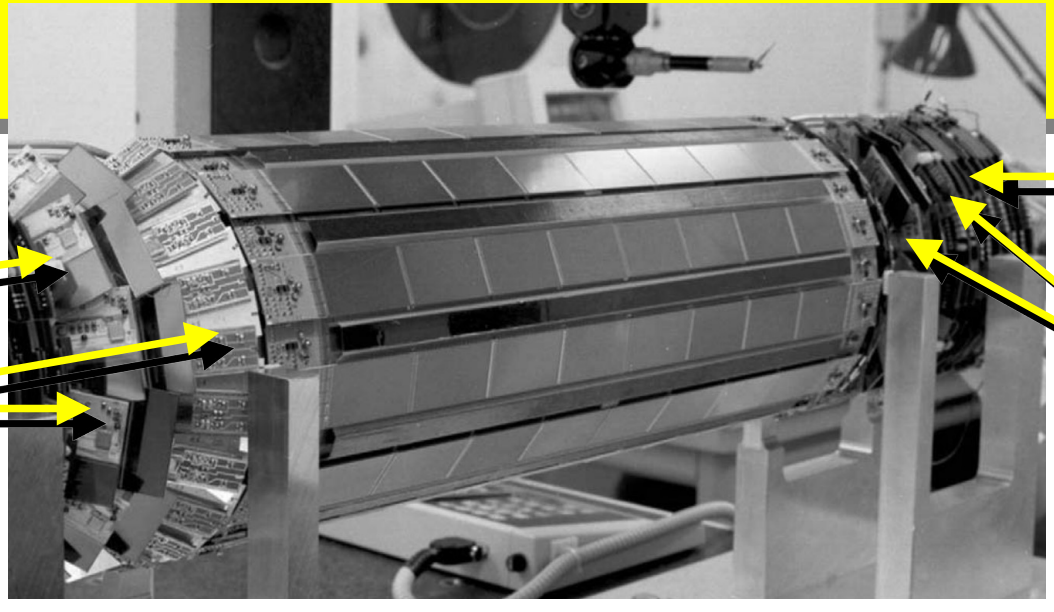
- τ meson polarization
- study of rare events $\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^- / a_1^-$

$$\Lambda_c^+ \rightarrow p K^- \pi^+ , p K_S^0 , \Lambda^0 \pi^0$$

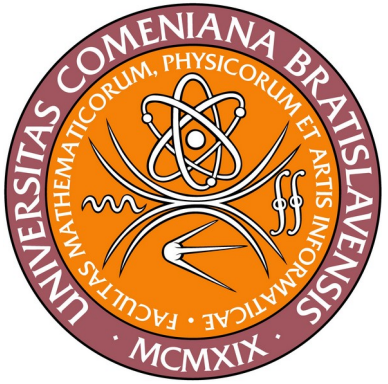
$$a_1^- \rightarrow \rho^0 \pi^- , \pi^+ \pi^-$$

R&D for DELPHI : semiconductor detectors

- **VFT (Very Forward Tracker)**
  - R&D and production of microstrip modules
  - assembly and tests of preamplifiers
  - climatic tests of silicon detectors in a specialized climatic chamber
    - temperature and humidity effects on semiconductor detectors)
  - Study of the Lazarus effect: Si detector damaged by radiation will function when kept at cryogenic temperature



Heavy Ion Saga



SPS Heavy Ion Programme

- 1986: ^{16}O ions accelerated to **60** a **200** AGeV/c
- 1987: ^{32}S ions accelerated to **200** AGeV/c
- 1994: ^{208}Pb ions accelerated to **156** AGeV/c
- at the end of the 20. century the energy of Pb ions was **lowered** to **40** AGeV/c

NA34/3 : HELIOS-3

Dramatis personæ

- First contacts of physicists from IEP SAS Košice with the NA34 (HELIOS) experiment lead by Christian Fabjan
  - 1984 M. Seman
  - 1987 L. Šándor
  - 1989 J. Antoš
- were extended to an offer for the Košice team (J. Antoš, I. Králik, L. Šándor, J. Urbán) to join the NA34/3 (HELIOS-3) experiment.
  - *affiliation of all slovak authors was Slovak Academy of Sciences, Košice*
- A slovak institution is officially mentioned in the CERN *"Grey Book"* (*Experiments at CERN*) for the year 1991.

NA34/3 (HELIOS-3)

Measurement of Low Mass Muon Pairs in Sulphur-Nucleus Collisions with an Optimized HELIOS Muon Spectrometer

p-W, S-W @ 200 AGeV/c

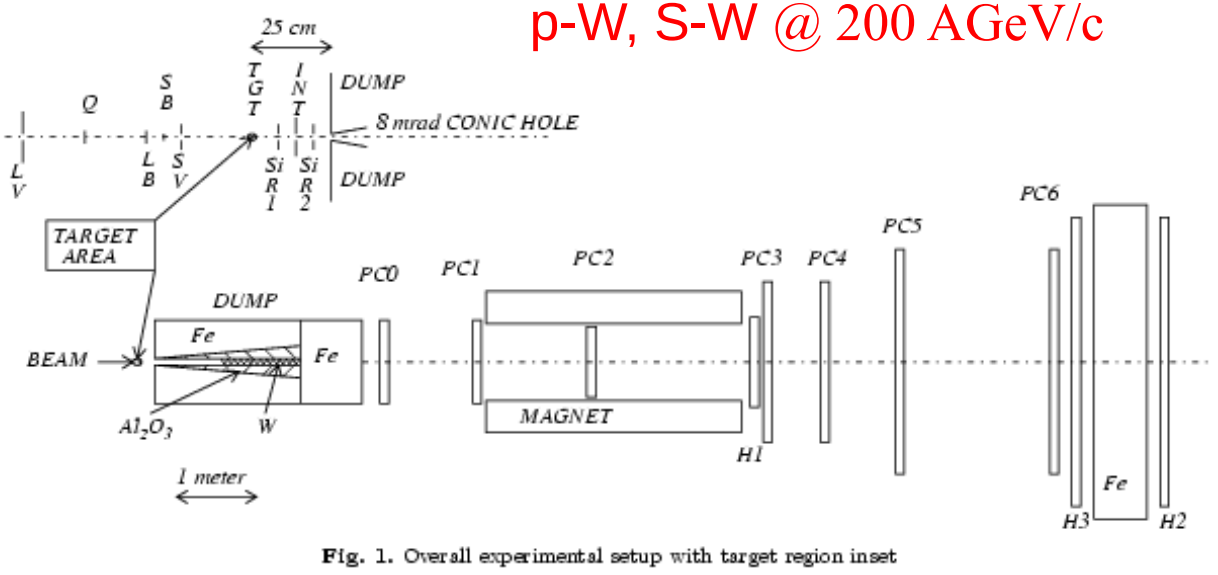


Fig. 1. Overall experimental setup with target region inset

The first experiment mentioned in the CERN "Grey Book" with slovak participation

(without financial and harware contribution)

Optimized for the dimuon measurement in the mass ranges from the threshold up to the mass of J/ψ.

Dilepton emission during all the phases of the expected QGP creation, evolution and freezout → Expected insight into the underlying dynamics.

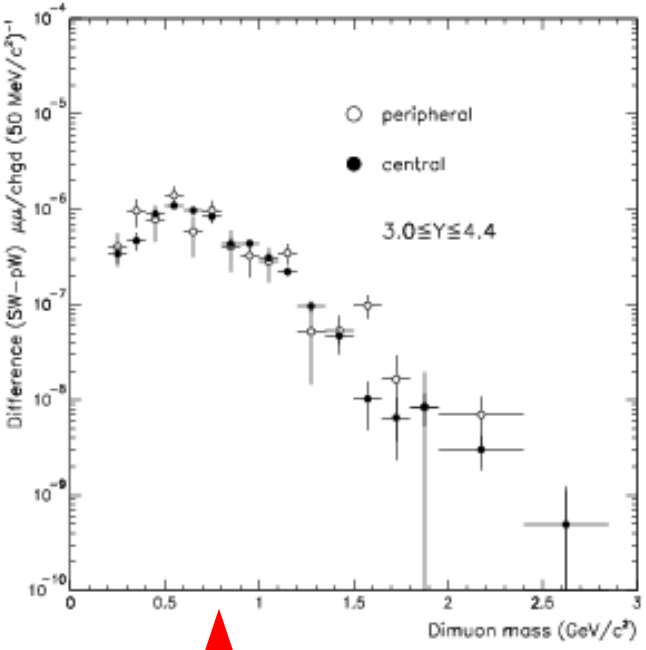
Changes of the vector meson properties in very dense hadronic medium.

UEF: J. Antoš, I. Králik, L. Šándor

UPJŠ: J. Urbán

NA34/3 (HELIOS-3)

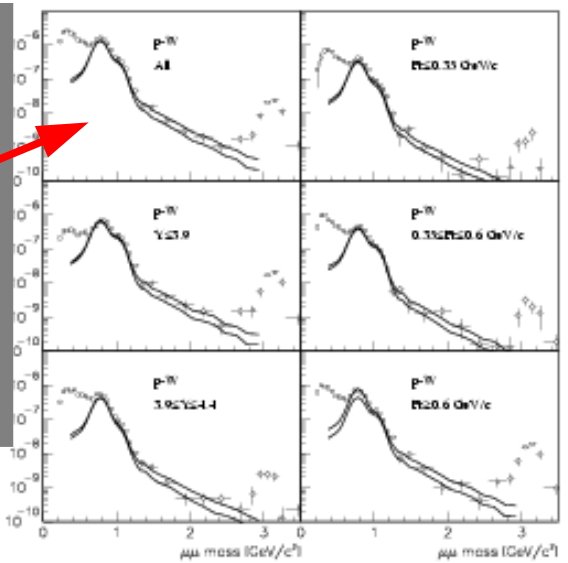
Dimuon mass continuum



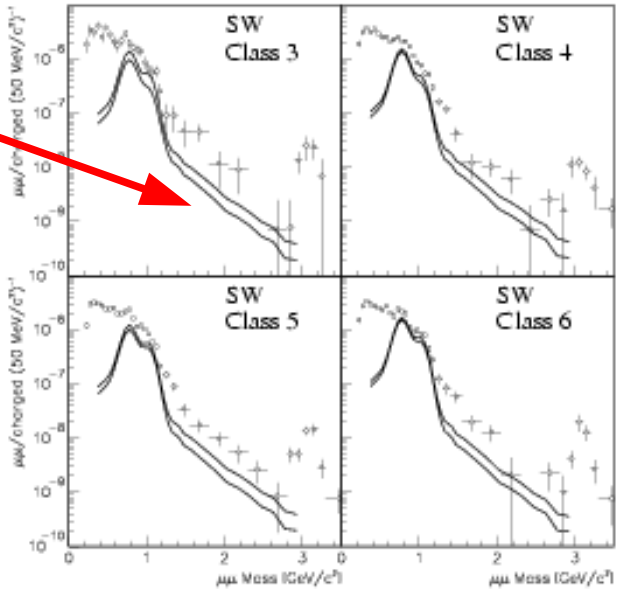
μμ in p-W for M>1GeV/c2

- Drell-Yan
- ρ, ω, φ, (J/ψ) decays
- charm meson decays

Observations and expectations agree

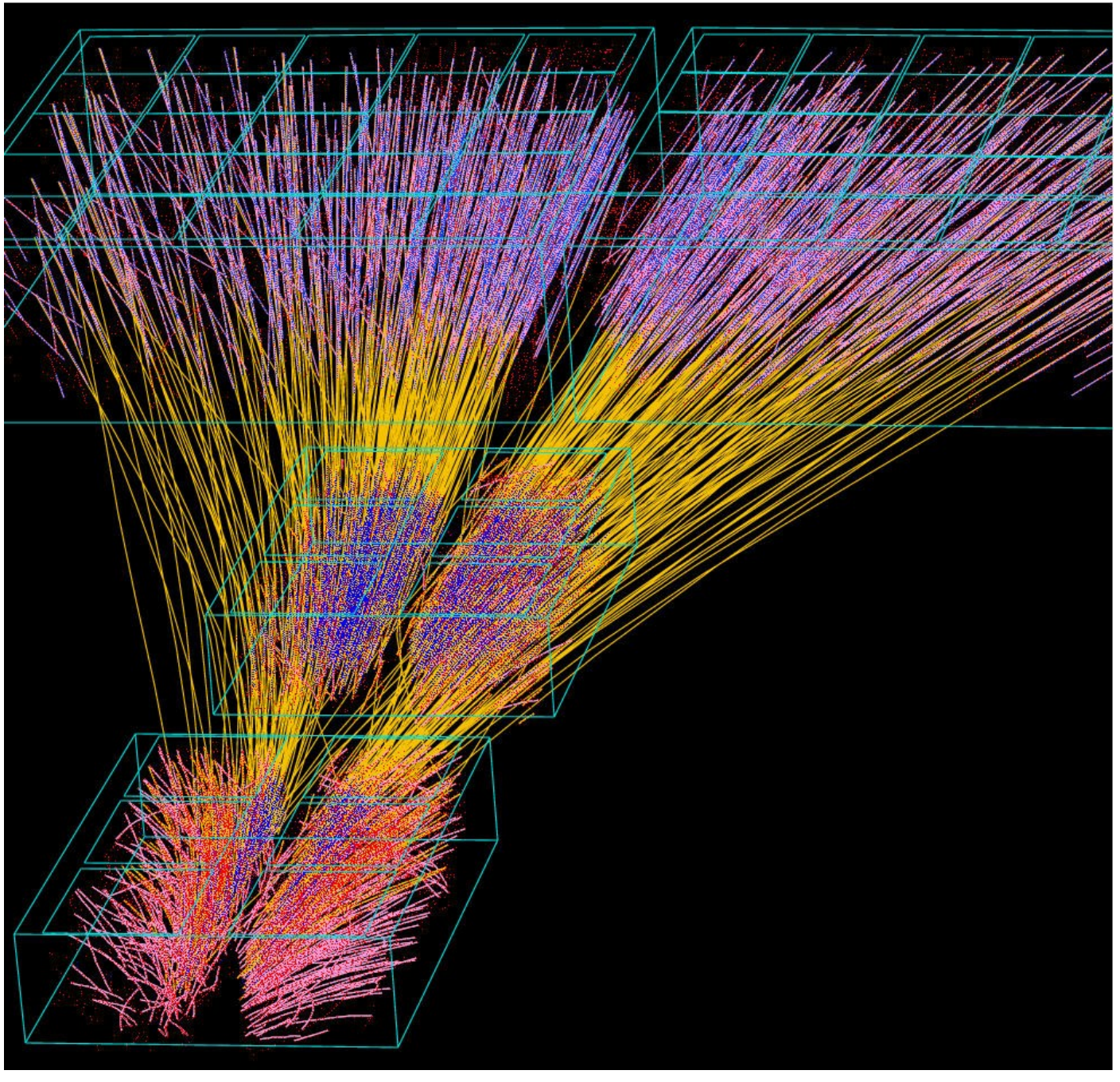


In S-W collisions the observed signal exceeds all expectations



Observed signal above all expectations

Pb-Pb: experimental challenge



1 Pb-Pb collision
at 156 AGeV/c

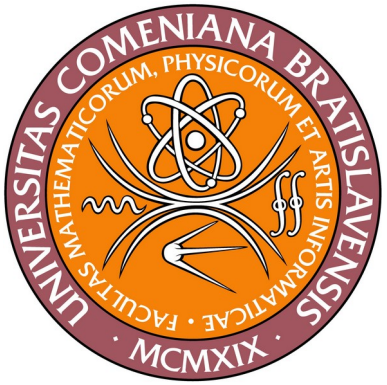
Experiments that could handle O and S beams could not cope with the huge number of particles produced in Pb-Pb collisions

New generation of heavy ion experiments


ÚSTAV EXPERIMENTÁLNEJ FYZIKY SAV, v. v. i.
1969

WA97
NA57


PRÍRODOVEDECKÁ FAKULTA UNIVERZITY P. J. ŠAFÁRIKA V KOŠICIACH
1963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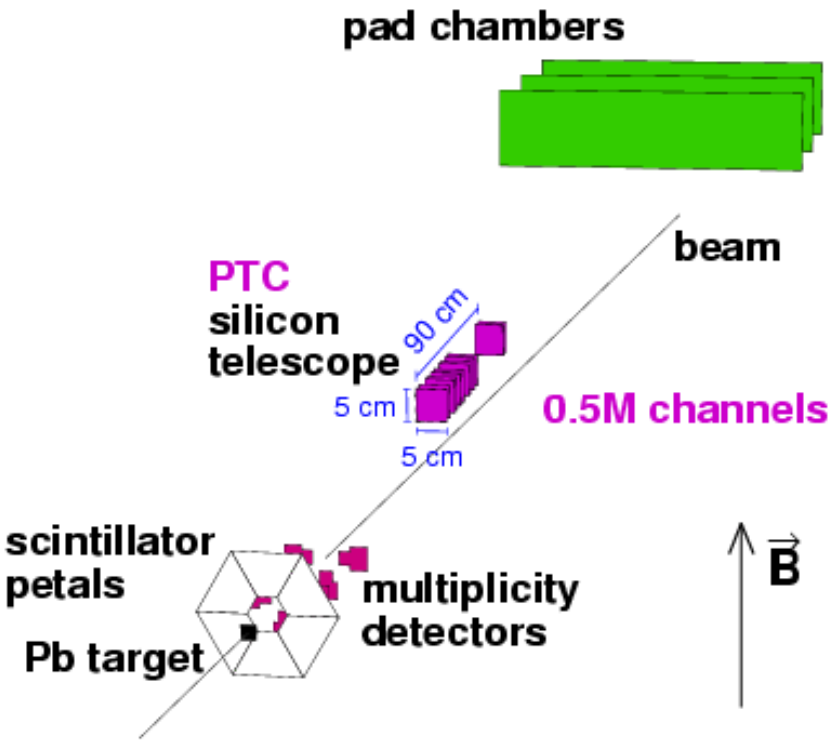
Dramatis personæ

- **List of physicists and engineers participating in WA97 and NA57**
  - J. Bán, ÚEF SAV Košice
  - J. Ftáčnik, FMFI UK Bratislava
  - T. Jusko, ÚEF SAV Košice
  - B. Kocper, ÚEF SAV Košice
  - I. Králik, ÚEF SAV Košice
  - R. Lietava, FMFI UK Bratislava
  - M. Lupták, ÚEF SAV Košice
  - B. Pastirčák, ÚEF SAV Košice
  - **K. Šafařík,** ÚEF SAV Košice, CERN driving force behind slovak participation in WA97/NA57
  - **L. Šándor**, ÚEF SAV Košice team leader
  - J. Urbán, UPJŠ Košice
  - G. Martinská, UPJŠ Košice
  - J. Pišút, FMFI UK Bratislava
  - N. Pišútová, FMFI UK Bratislava
  - J. Fedorišin, ÚEF SAV Košice

WA97

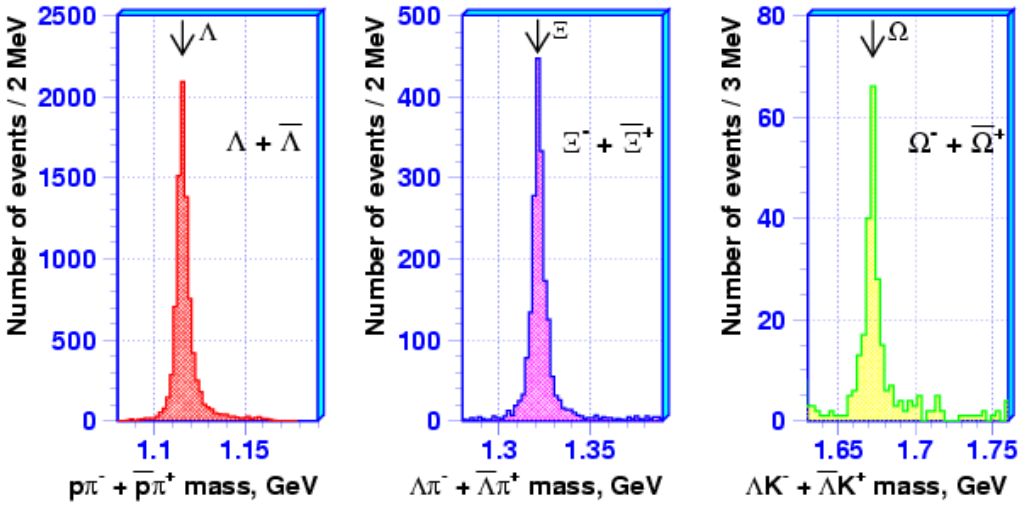
Study of Baryon and Antibaryon Spectra in Lead Lead Interactions at 160 GeV/c per Nucleon



Very compact detector optimized for the detection of the weak decays of Λ, Ξ, Ω a K^0_S at y*=0.
It could handle the particle multiplicity from Pb-Pb collisions at 160 AGeV/c

- Very good mass resolution for reconstructed particles.
- Very clean signal with minimum background.

Pb-Pb and **p-Pb** collisions at **158 AGeV/c**

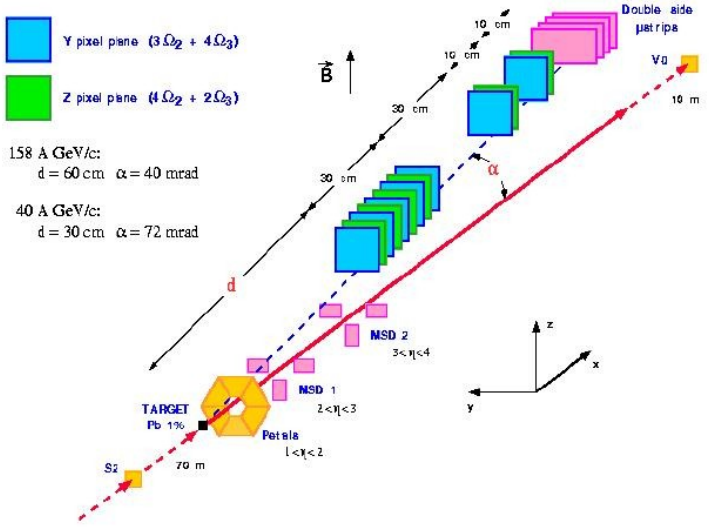


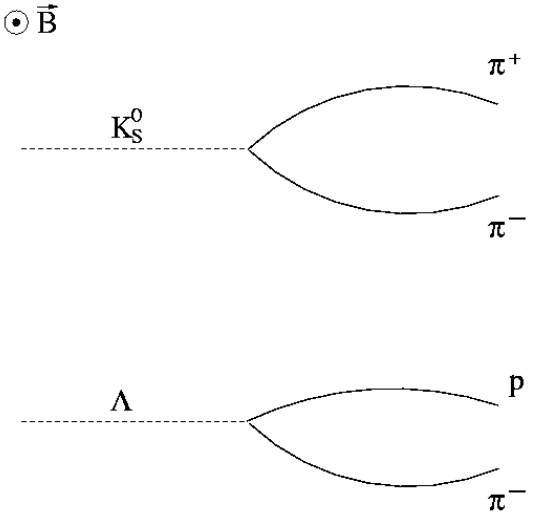
NA57

Study of Strange and Multistrange Particles in Ultrarelativistic Nucleus-Nucleus Collisions

Follow up of the WA97 experiment

- Enlarged range of collision centralities
- Collecting data from **Pb-Pb** and **p-Be** collisions at **158** and **40 AGeV/c**





Effect of the enhanced production of strange baryons

$$
\begin{aligned}
K^0_S &\rightarrow \pi^+ + \pi^- \\
\Lambda &\rightarrow p + \pi^- \\
\Xi^- &\rightarrow \Lambda + \pi^- \\
&\quad \hookrightarrow p + \pi^- \\
\Omega^- &\rightarrow \Lambda + K^- \\
&\quad \hookrightarrow p + \pi^-
\end{aligned}
$$

K0 : ds $\bar{s}\bar{d}$

Λ: uds

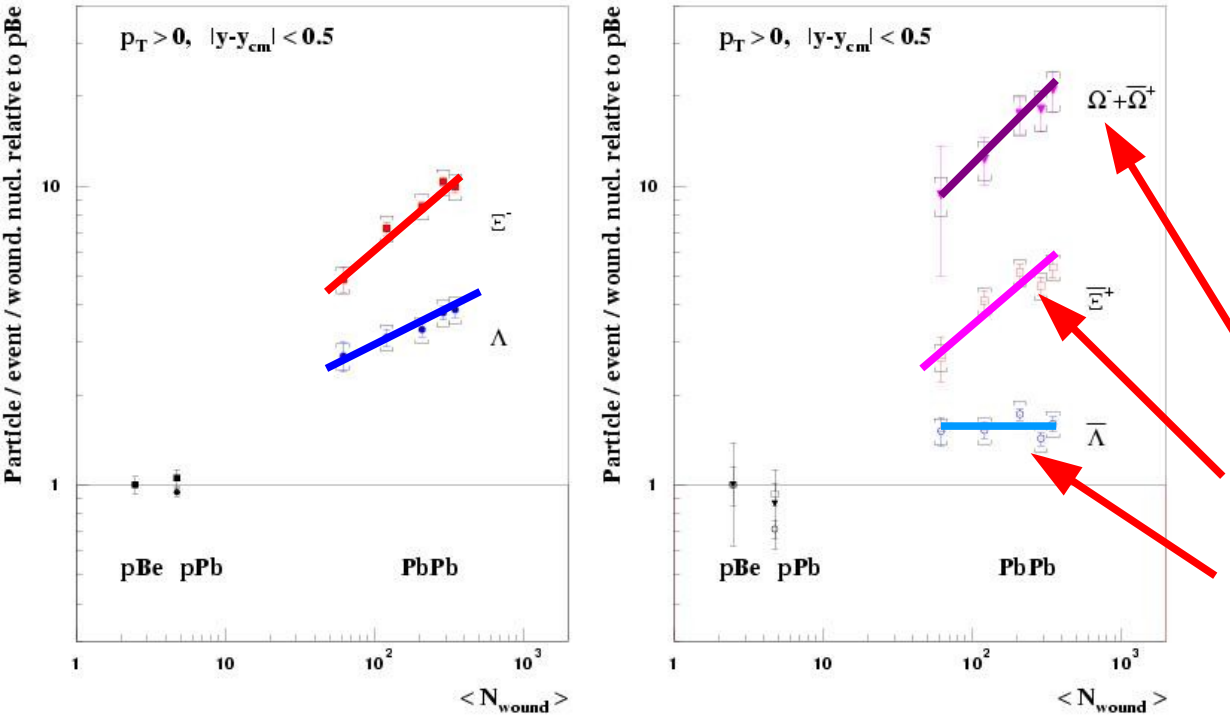
Ξ-: dss

Ω: sss

Baryons with different strange quark content can be identified thanks to their weak decays into final states with only charged particles

WA97 a NA57

Effect of the enanced production of strange particles in Pb-Pb collisions compared to p-Be collisions

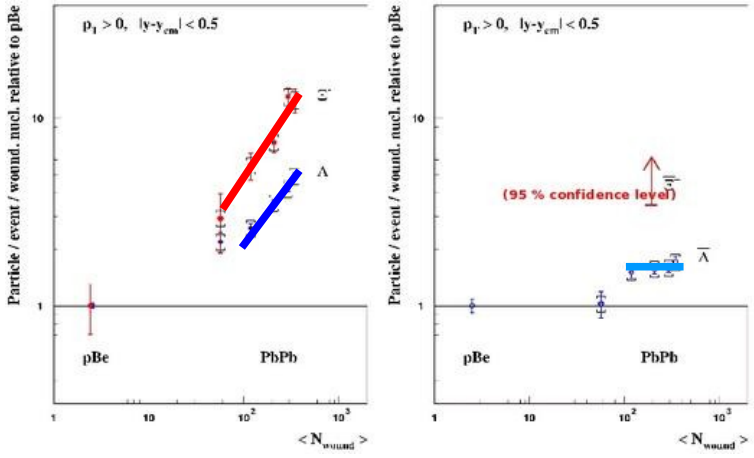


Λ-Ξ-Ω hierarchy

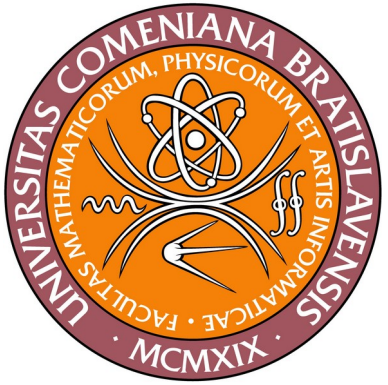
Strong increase of the production of strange baryons and antibaryons.

This enhancement is more pronounced for particles with more valence strange quarks.

An effect of this kind predicted for the Quark-Gluon Plasma by P. Koch, B. Müller and J. Rafelski.



40 AGeV/c – study of the energy dependence and search for possible threshold effects when compared to results at 160 AGeV/c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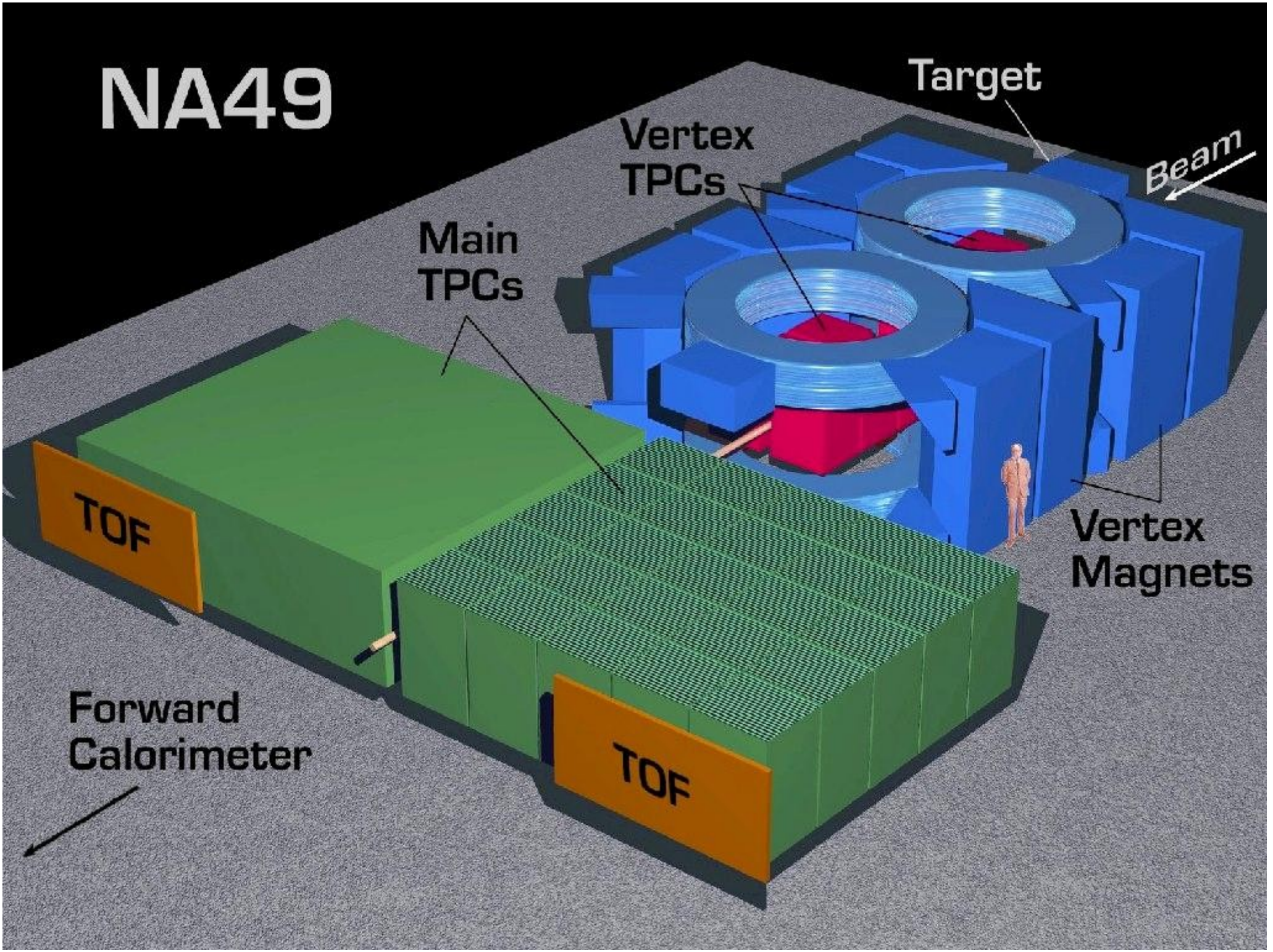
NA49

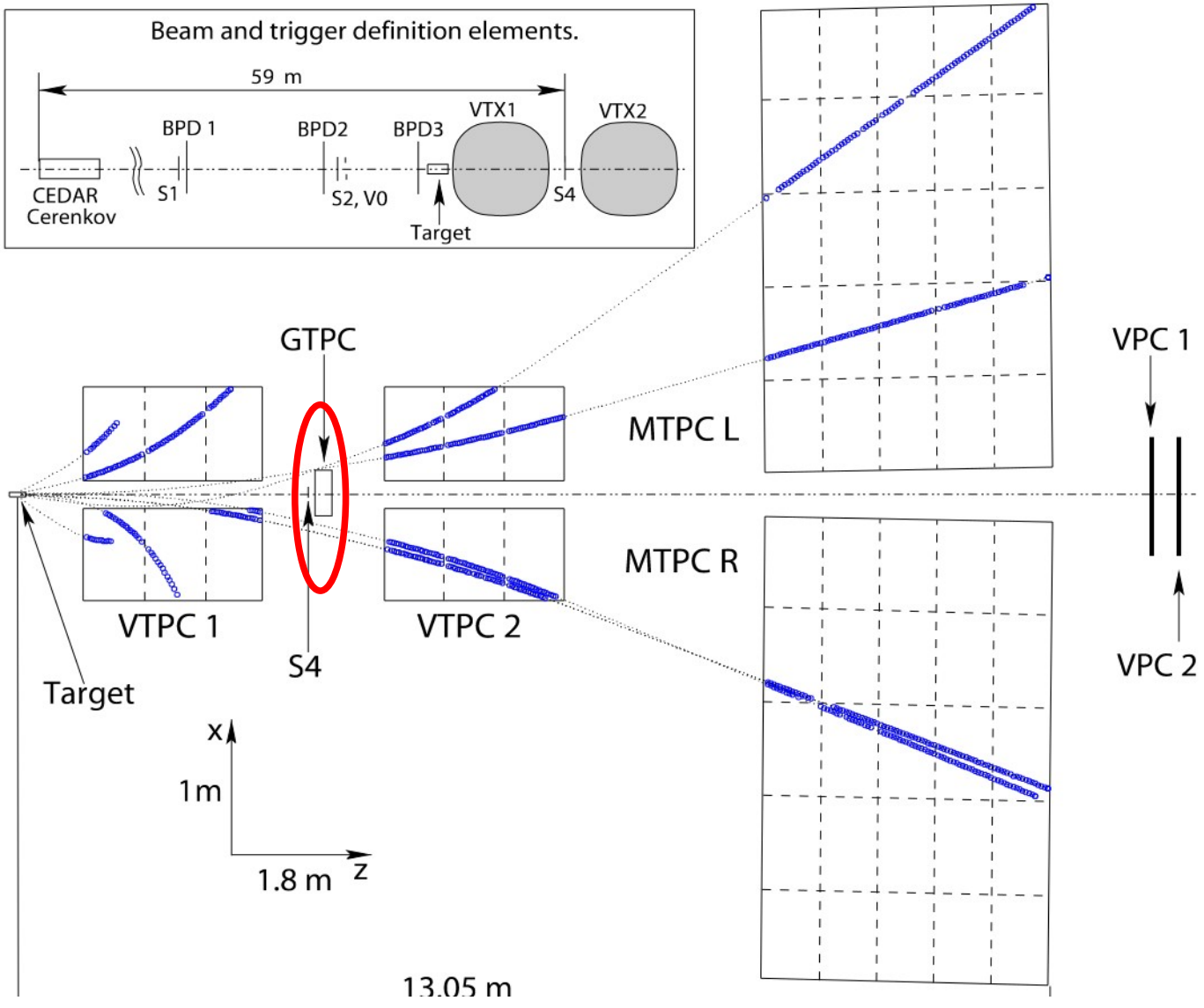
Dramatis personæ

- 1997: Memorandum of Understanding
  - J. Braciník
  - J. Ftáčnik
  - V. Hlinka
  - R. Janík
  - M. Ivanov
  - M. Pikna
  - **B. Sitár** **team leader**
  - P. Strmeň
  - I. Szarka
  - 1998: **V. Černý** **team leader 2001 - 2010**


NA49
Target
Vertex
TPCs
Beam
Main
TPCs
TOF
Vertex
Magnets
Forward
Calorimeter
TOF

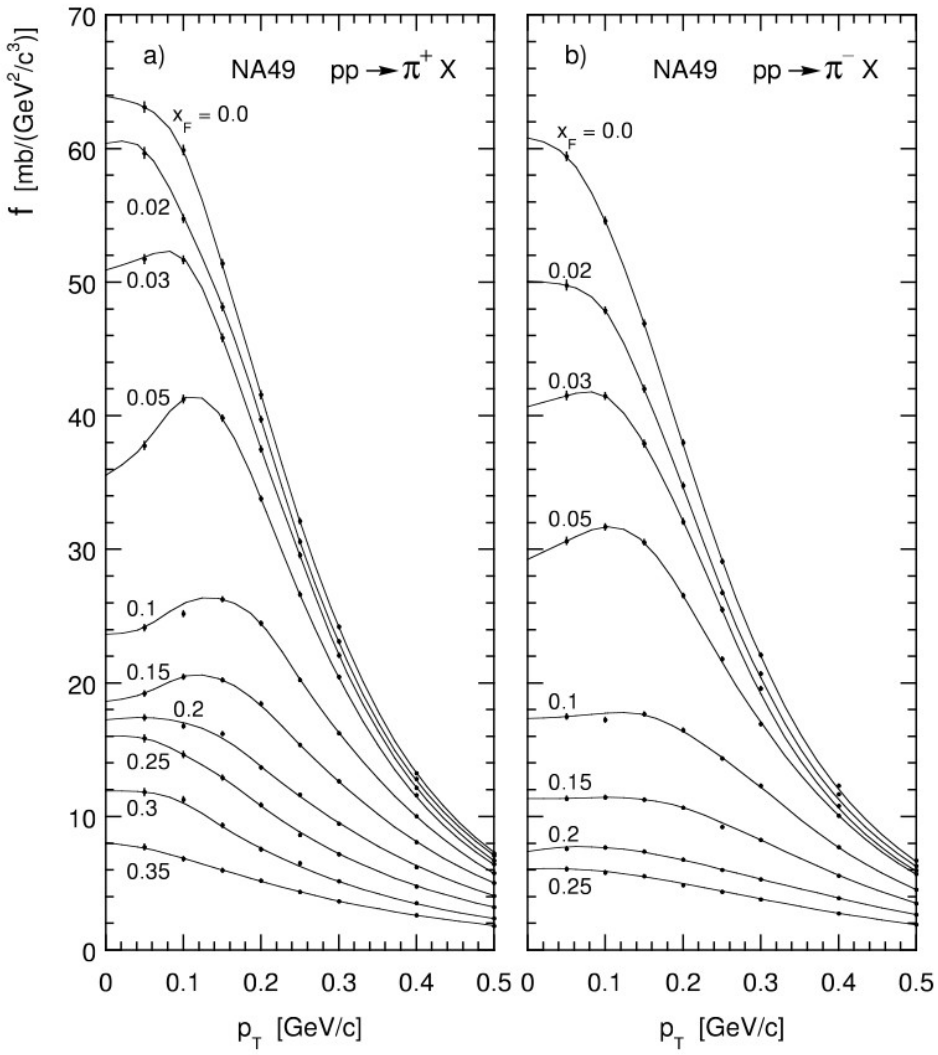
Bratislava contribution

- Construction of a new “Gap TPC” covering a gap in the tracking acceptance not covered by the Vertex TPC’s and the Main TPC.
  - building GTPC
  - software for GTPC
- Software for the TPC
- Physics analysis



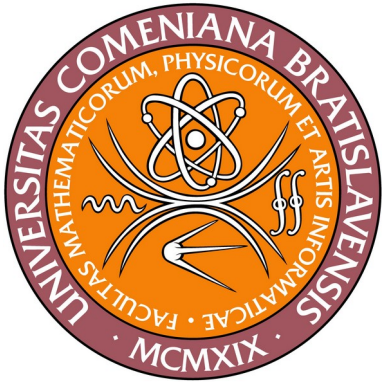
NA49 Physics in Bratislava

- NA49 was a multupurpose experiment for the study of the multiparticle production in pp, p-Nucleus and Nucleus-Nucleus collisions
- Many aspects of the Pb-Pb collisions
- Bratislava:
  - study of the inclusive production of π, p, K, $\bar{p}$ and n
  - study of the resonance production Δ, N^*.
  - etc...



10.2.2000: A new state of matter

L. Maiani, CERN Director: *"..We now have evidence of a new state of matter where quarks and gluons are not confined. There is still an entirely new territory to be explored concerning the physical properties of quark-gluon matter..."*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NA62

Dramatis personæ

- **Comenius University Bratislava joined in 2011**
- **T. Blažek** **FMFI UK Bratislava** **team leader**
- V. Černý FMFI UK Bratislava
- R. Lietava FMFI UK Bratislava
- M. Kovaľ FMFI UK Bratislava
- P. Maták FMFI UK Bratislava
- F. Herman FMFI UK Bratislava
- L. Bičian FMFI UK Bratislava
- Z. Kučerová FMFI UK Bratislava
- A. Zajac FMFI UK Bratislava
- A. Kleimenova FMFI UK Bratislava
- R. Volpe FMFI UK Bratislava
- Uhliarik FMFI UK Bratislava
- Híveš FMFI UK Bratislava
- D. Novotný FMFI UK Bratislava
- Veľaš FMFI UK Bratislava
- Z. Šinská FMFI UK Bratislava
- V. Zaujec FMFI UK Bratislava
- V. Kraľovič FMFI UK Bratislava
- P. Mészáros FMFI UK Bratislava

NA62 Experiment

Data taking

- 2016 Commissioning + Physics run (45 days).
- 2017 Physics run (160 days).
- 2018 Physics run (217 days).
- 2021 Physics run (85 days [10 beam dump]).
- 2022 Physics run (215 days).
- 2023 Physics run ongoing…

Currently ~ 30 institutes, ~ 300 collaborators

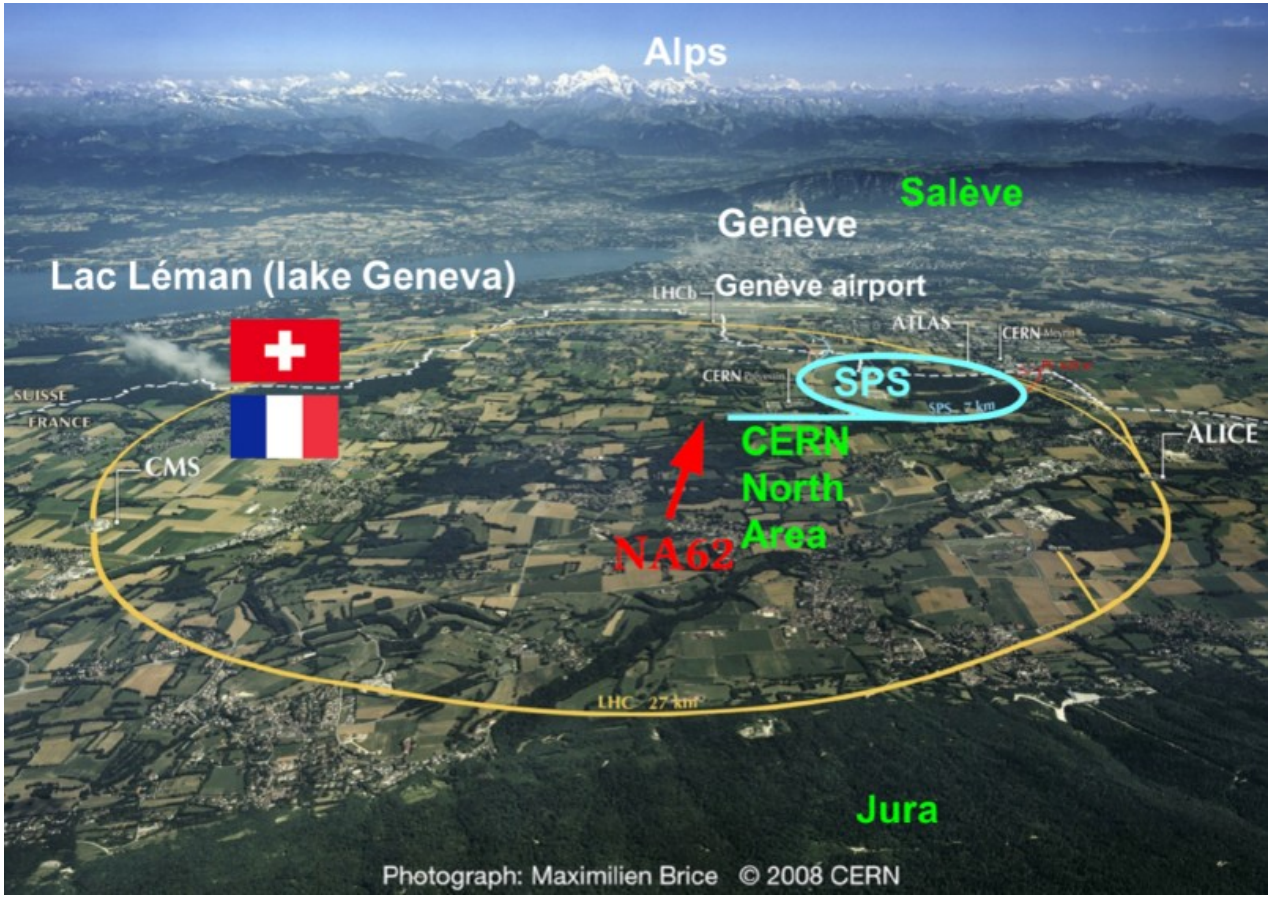
K^+ decays in flight

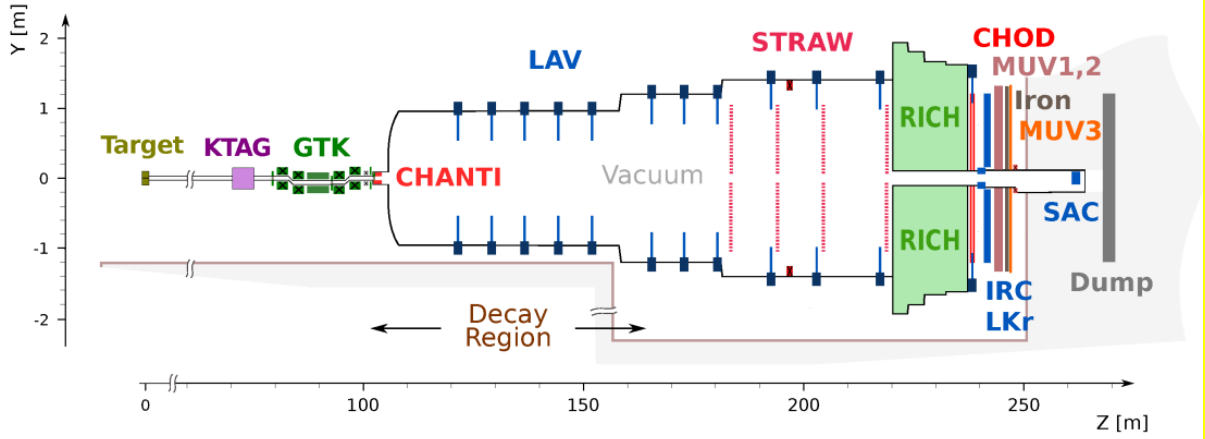
Primary goal: measure $\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu})$

Other rare or SM forbidden K+ decays

Beam Dump Mode - Exotics searches

NA62 Experiment





- primary beam 400 GeV from the SPS
- secondary beam 75 GeV positive particles
  - 6% K^+, 24% protons, 70% π
- K+ decay inside the detector

Comenius University contribution

- Local Trigger Unit software (dominant contribution by *V. Černý*)
- Data Acquisition
- Straw spectrometer: experts, efficiency improved, 2025 update
- GTK experts, coordinator (*A. Kleimenova, Z. Kučerová*)
- Dalitz π0 decay analysis (*PhD. M. Koval'*)
- K to πμμ analysis (*PhD. L. Bičian*)
- K+ π+ matching and K+ to π+ νν-bar (*Phd. Z. Kučerová*)
- K to πX analysis (*R. Volpe*)
- Exotics searches (*A. Kleimenova*)

NA62 Physics

$$BR(K^+ \to \pi^+ \nu\bar{\nu}) = (10.6\ ^{+4.0}_{-3.8}|_{stat} \pm 0.9_{syst}) \times 10^{-11}$$

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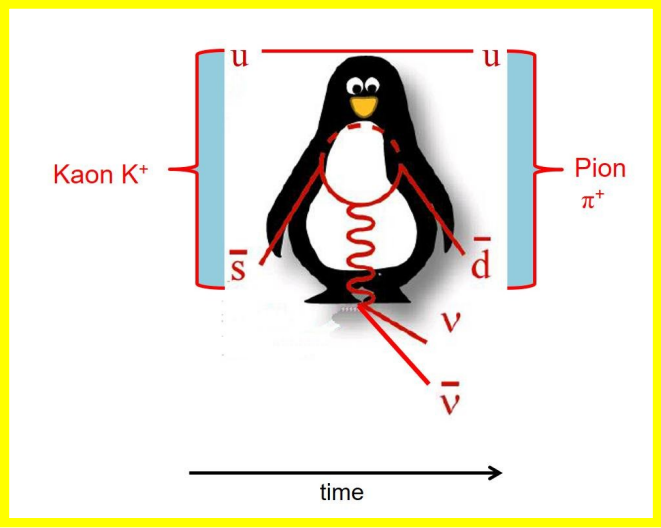
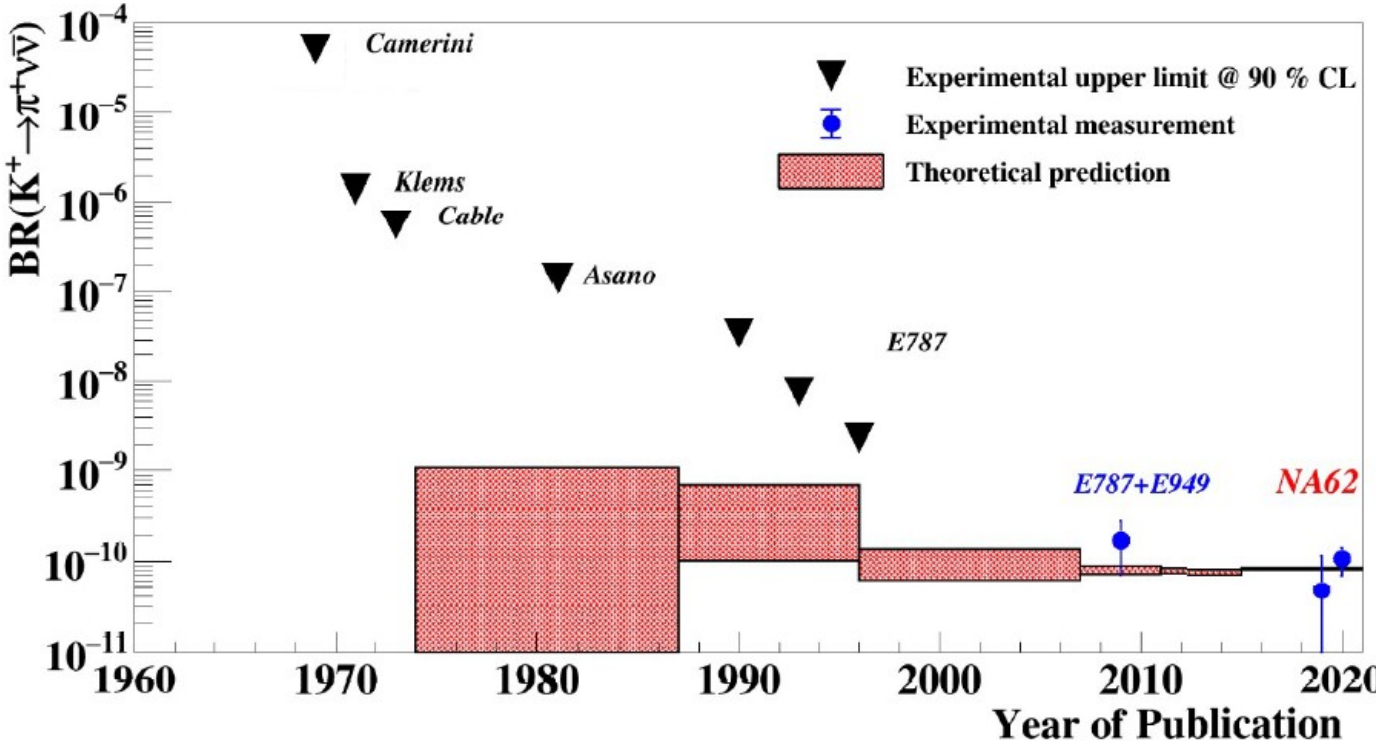
- In 2016-8: 20 signal events
- More to come 2021-5

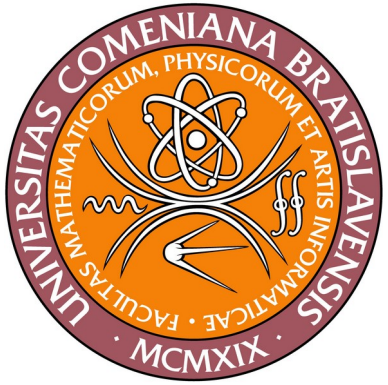


In SM, BranchRatio < 10^{-10} dubbed „Golden Channel“, since theoretically very clean.
In SUSY: Blažek, Maták ,*Int.JModPhys*




SAV

ISOLDE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Dramatis personæ

- **FU SAV**
- **Martin Venhart**
- *Martin Veselský*
- Ján Kliman
- Stanislav Hlaváč
- Vladislav Matoušek
- Andrej Herzáň
- Anton Repko

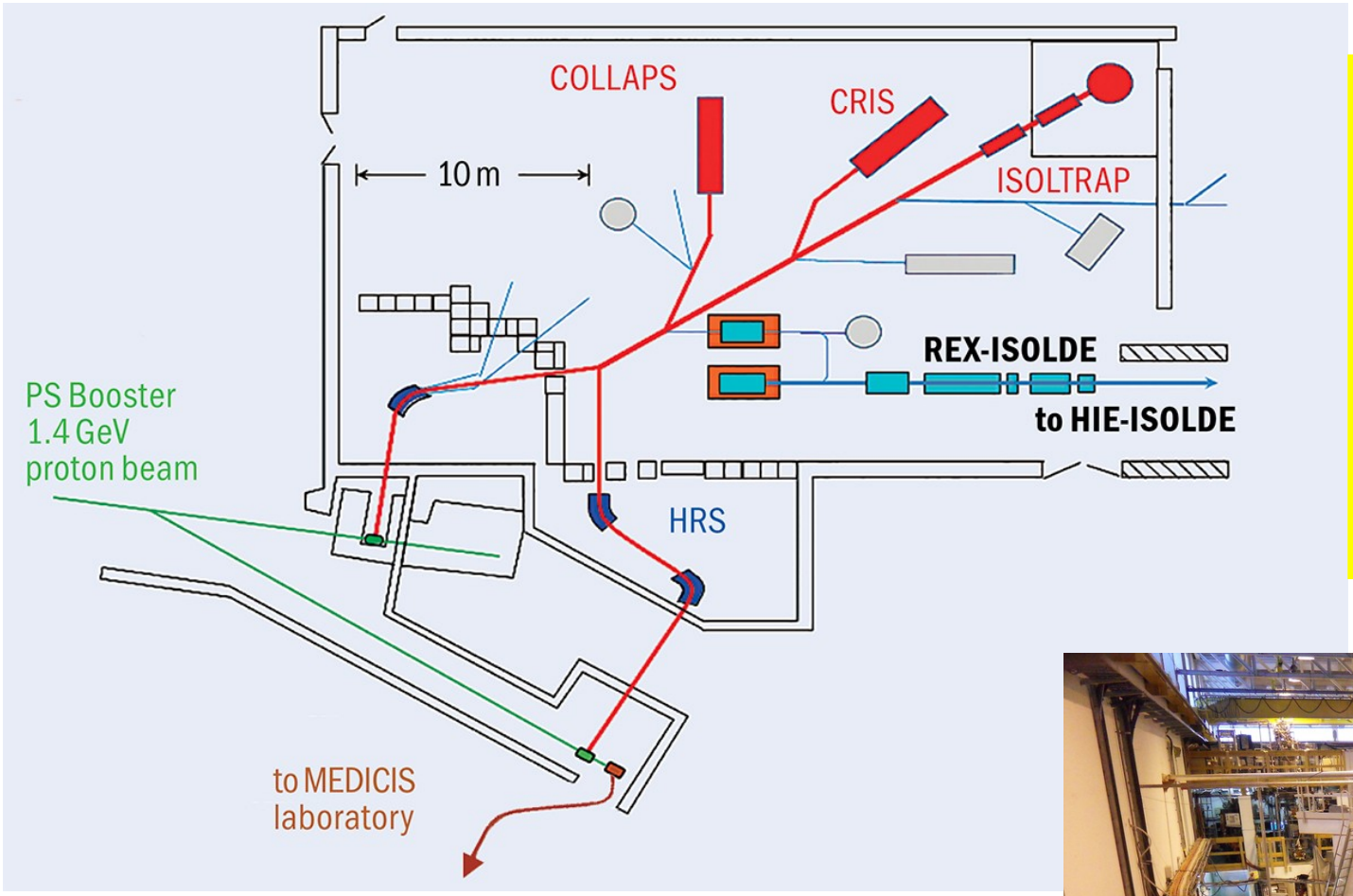
- *Paresh Prajapati*
- Andrej Konopka
- Sebastian Vielhauer
- *Matúš Sedlák*
- *Matúš Balogh*

- Tatiana Grečnárová
- Magdaléna Šolcová
- *Erika Jajčišinová*
- *Robert Urban*
- *Jozef Klimo*
- Monika Bírová
- Andrej Špaček
- *Lukáš Holub*
- *Jakub Krajňák*
- Gulnur Kantay
- *Natália Ďzalaiová*
- *Sára Bánovská*
- *Jakub Lušnák*
- *Július Bačkai*
- *Jakub Lietavec*

- **FMFI UK**
- Stanislav Antalic

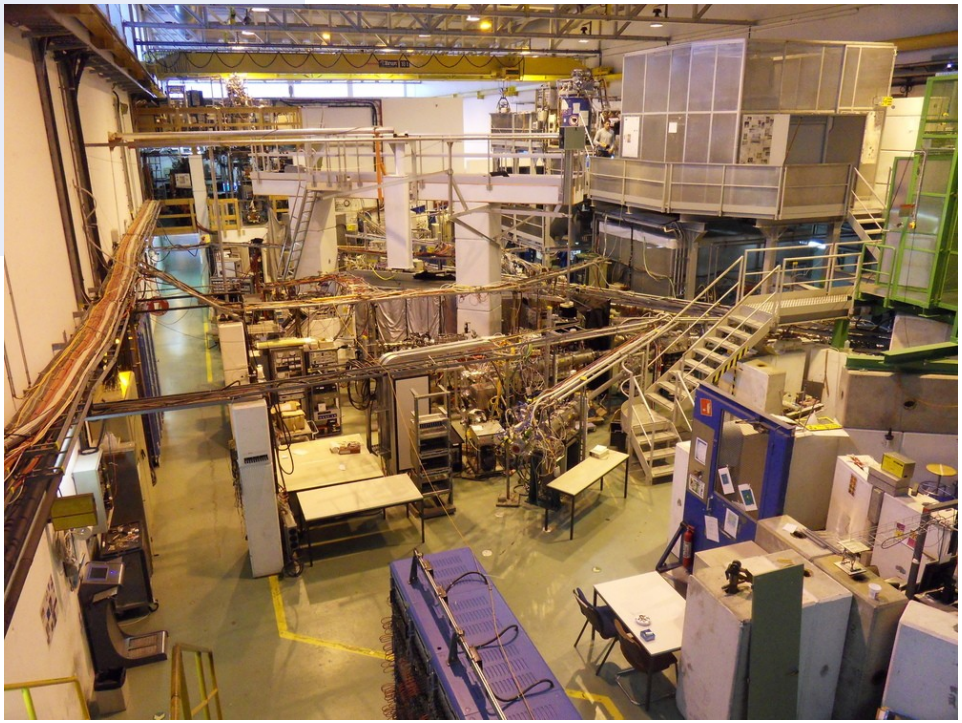
Slovak republic became a full member of ISOLDE in 2016

Isotope Separation On-Line DEvice



Very intensive 1.4 GeV beam from the PS booster is used for production of beams consisting of exotic unstable isotopes.

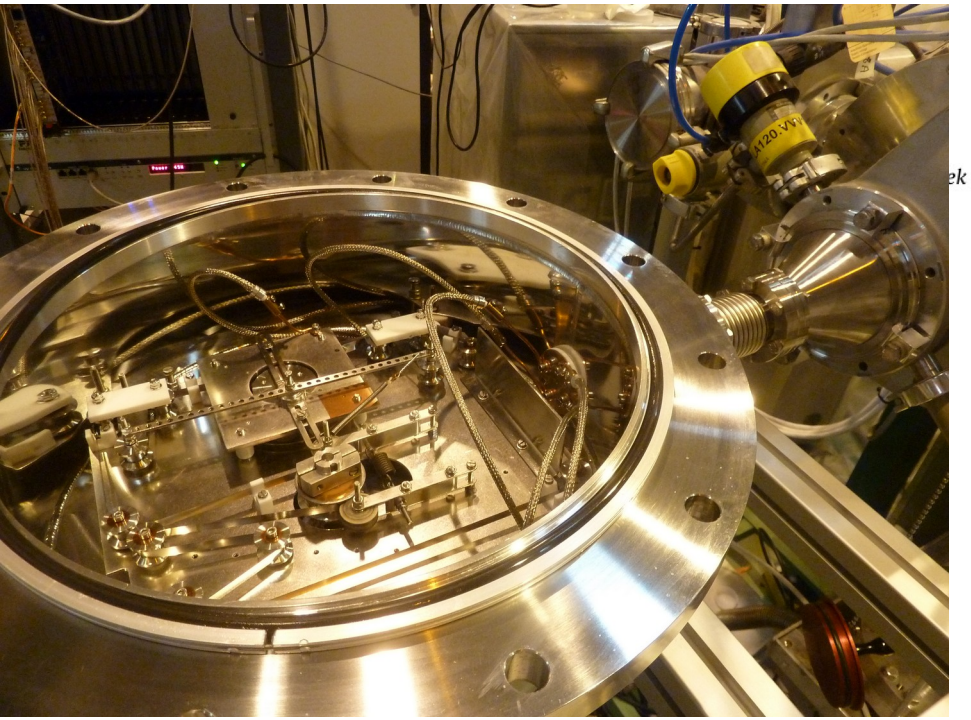
Magnetic mass separators transport individual isotopes to experiments



Small detection systems built outside CERN in national laboratories can be installed in the experimental area.

This schema has been exploited by Slovak labs so far.

IS521 experiment: TApe TRAnsport



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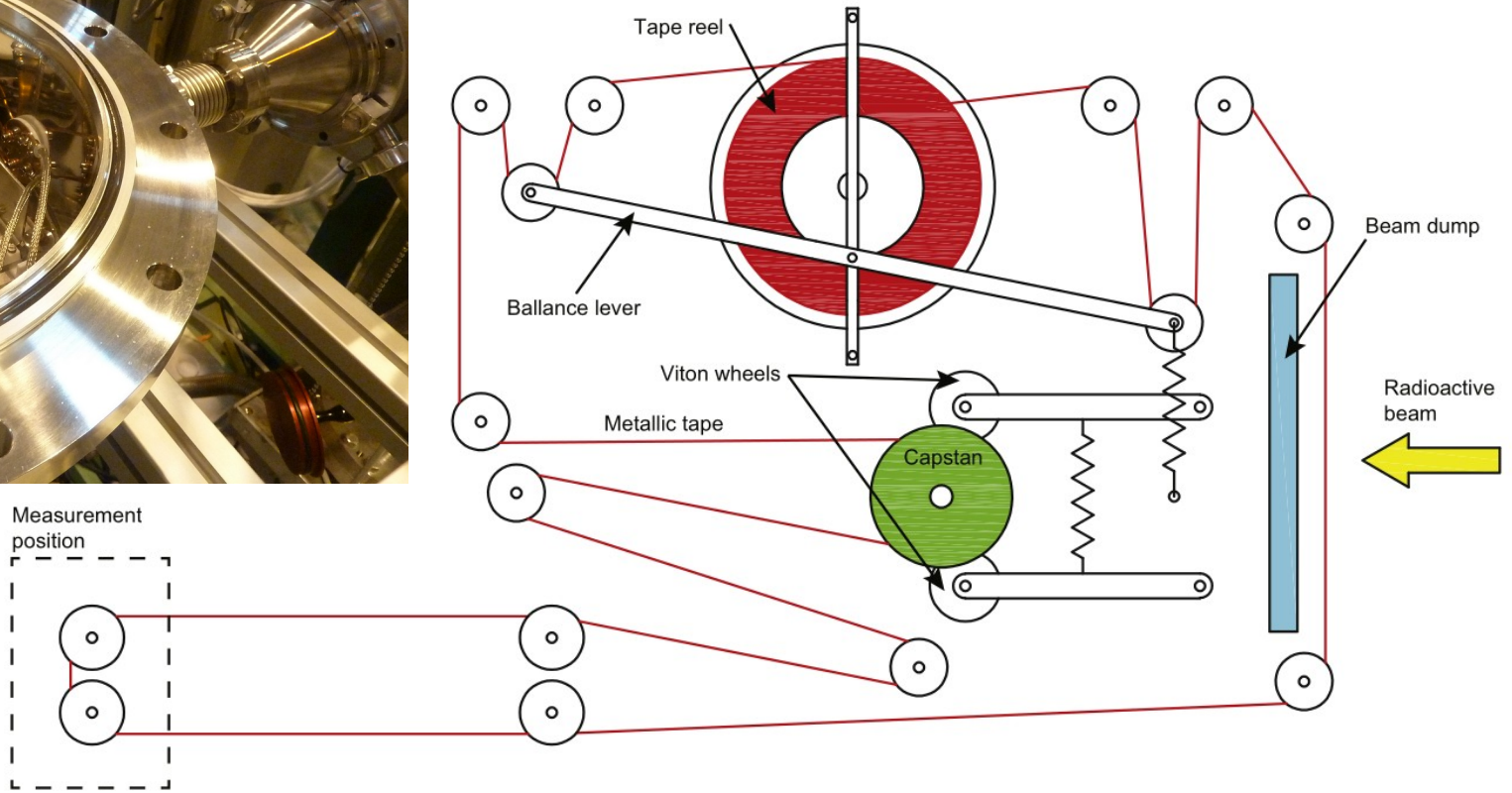
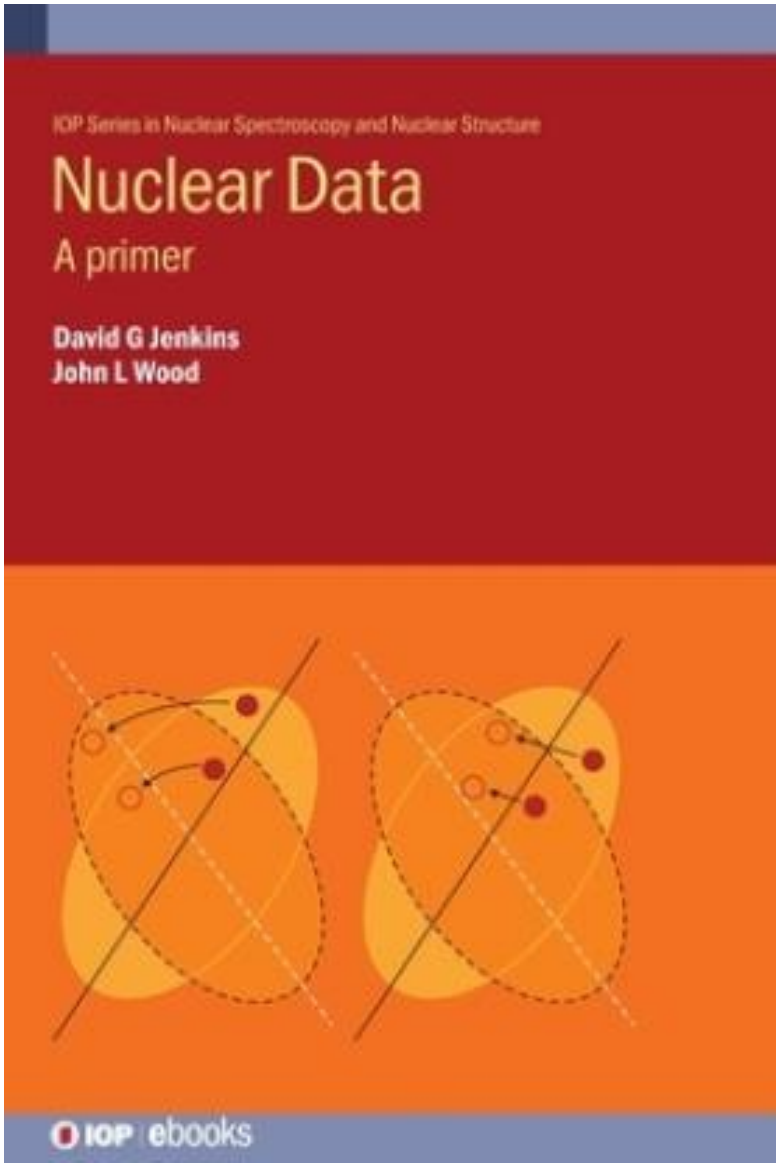


- Rapidly quenched material: metallic glass is used to transport radioactive samples (deposition of ISOLDE beam)
- Operated at 3 x 10^{-8} mbar
- Windowless LN_2 cooled detector was used
- Very good resolution for conversion electrons

Nuclear structure of odd-mass Au isotopes programme

- Several new deformed configurations observed
- **Most important:** extremely deformed structure in ^{177}Au
- Resolution of TATRA for both conversion electrons and gamma rays is crucial – new beam time approved at CERN
- **This methodology appeared in new text book on nuclear physics**



Closing remarks

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- Experience gained at DELPHI and the heavy ion experiments at the SPS was tranfered to the ALICE experiment at the CERN LHC
- Smaller experiments with much less energetic beams are equally challenging and may provide cornucopia of information on aspects of objective reality not accesible otherwise.