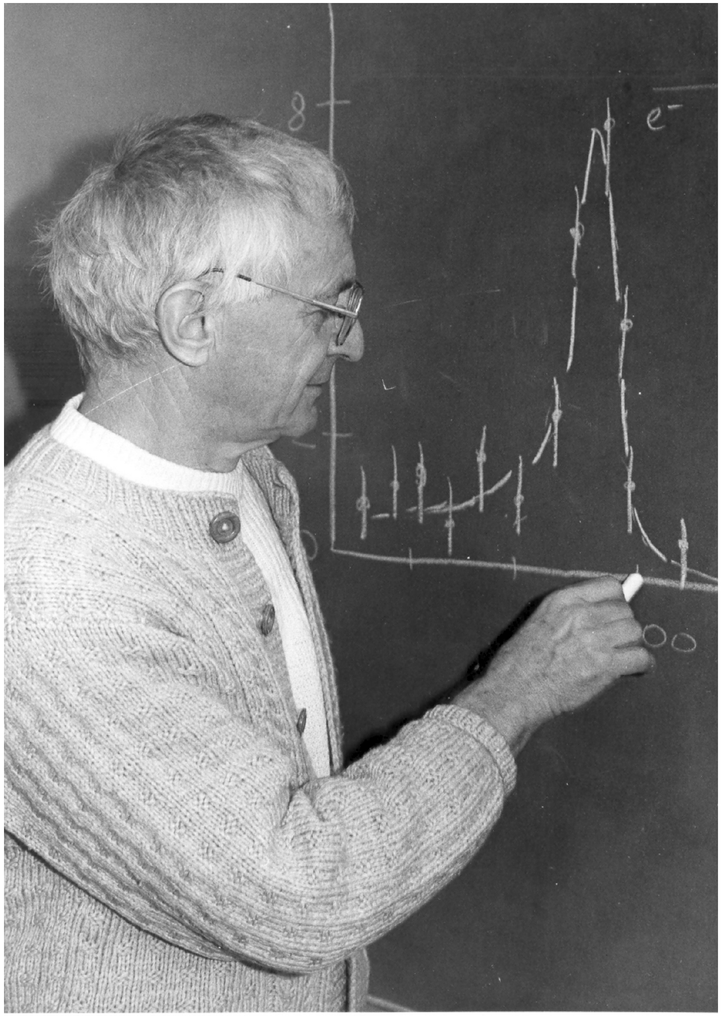
A brief history of F9

F9 retreat, Krvavec, Sept 29, 2026

- History of F9 started in F2 ☺ - until 1991

- Omicron experiment at CERN
- ARGUS experiment at DESY
- CPLEAR experiment at CERN
- DELPHI experiment at CERN
- HERA-B experiment at DESY
- ATLAS experiment at CERN
- Belle/Belle II experiments at KEK
- LHCb experiment at CERN
- Pierre Auger Observatory
- Detector R&D
- Medical imaging applications



It all started with a strong vision:
Gabrijel (Elko) Kernel (1932 – 2025)

Magnetic spectrometer Omicron at CERN

G. Kernel et al. / Magnetic spectrometer for $\pi p \to \pi\pi N$ reactions 369

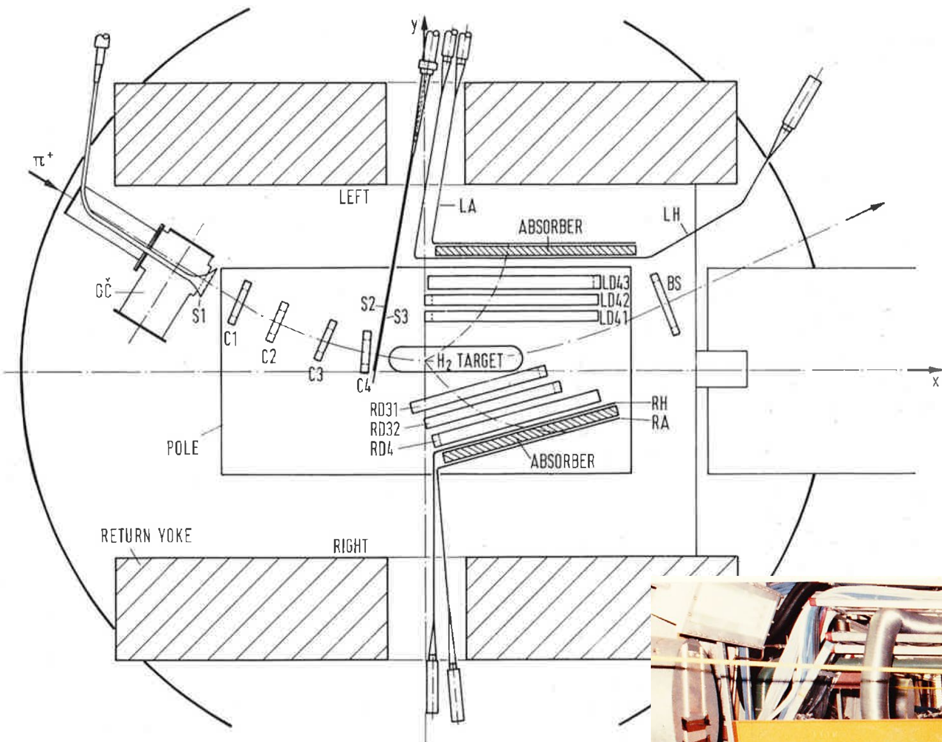
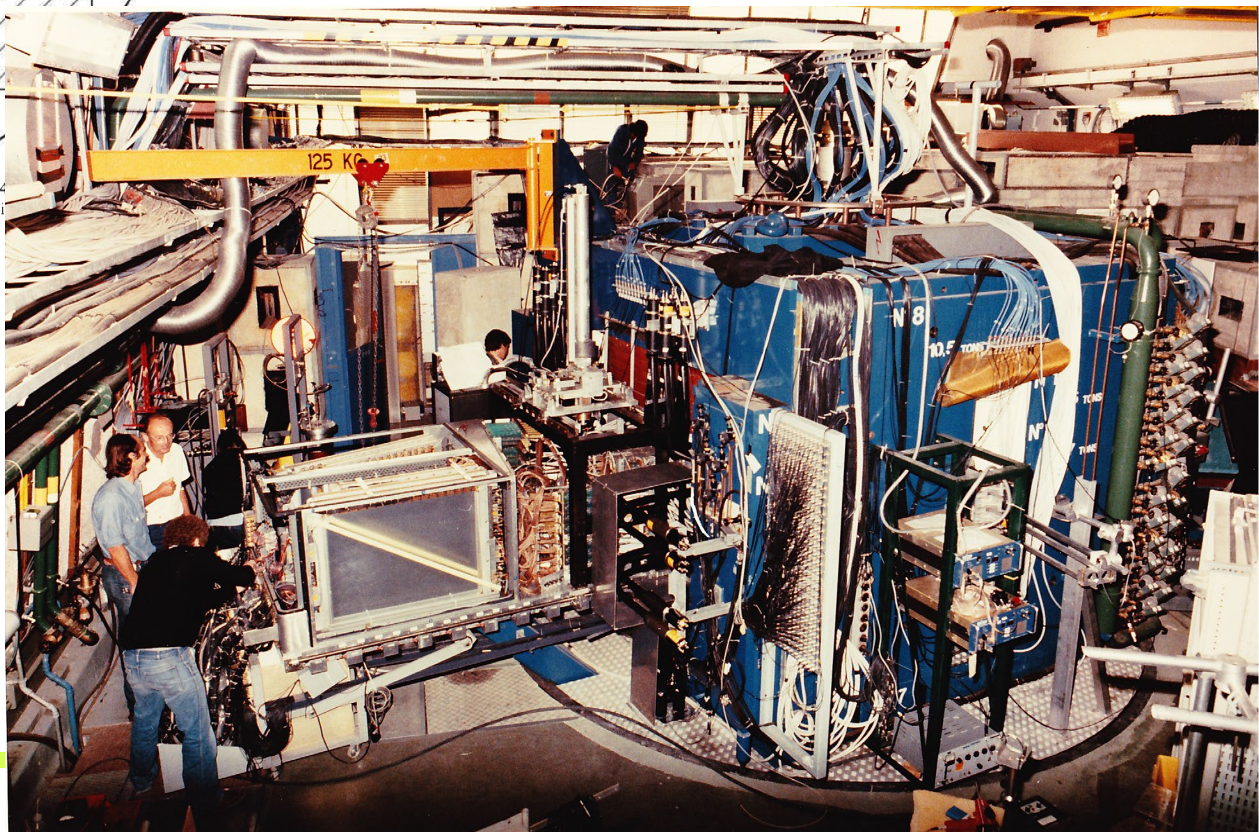
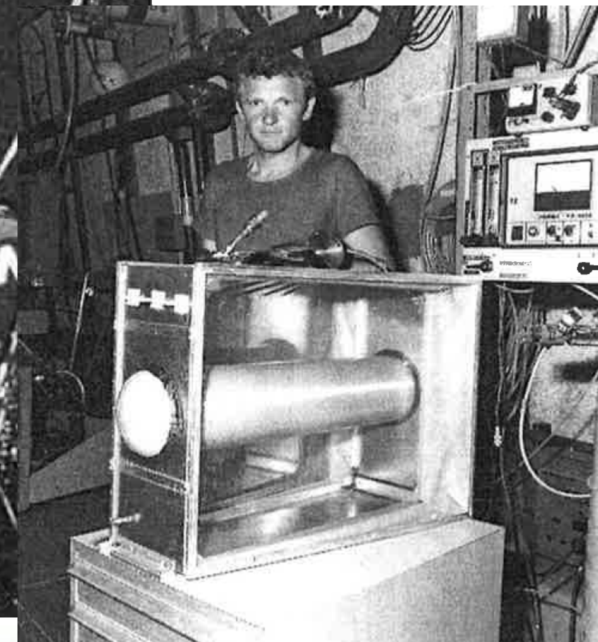
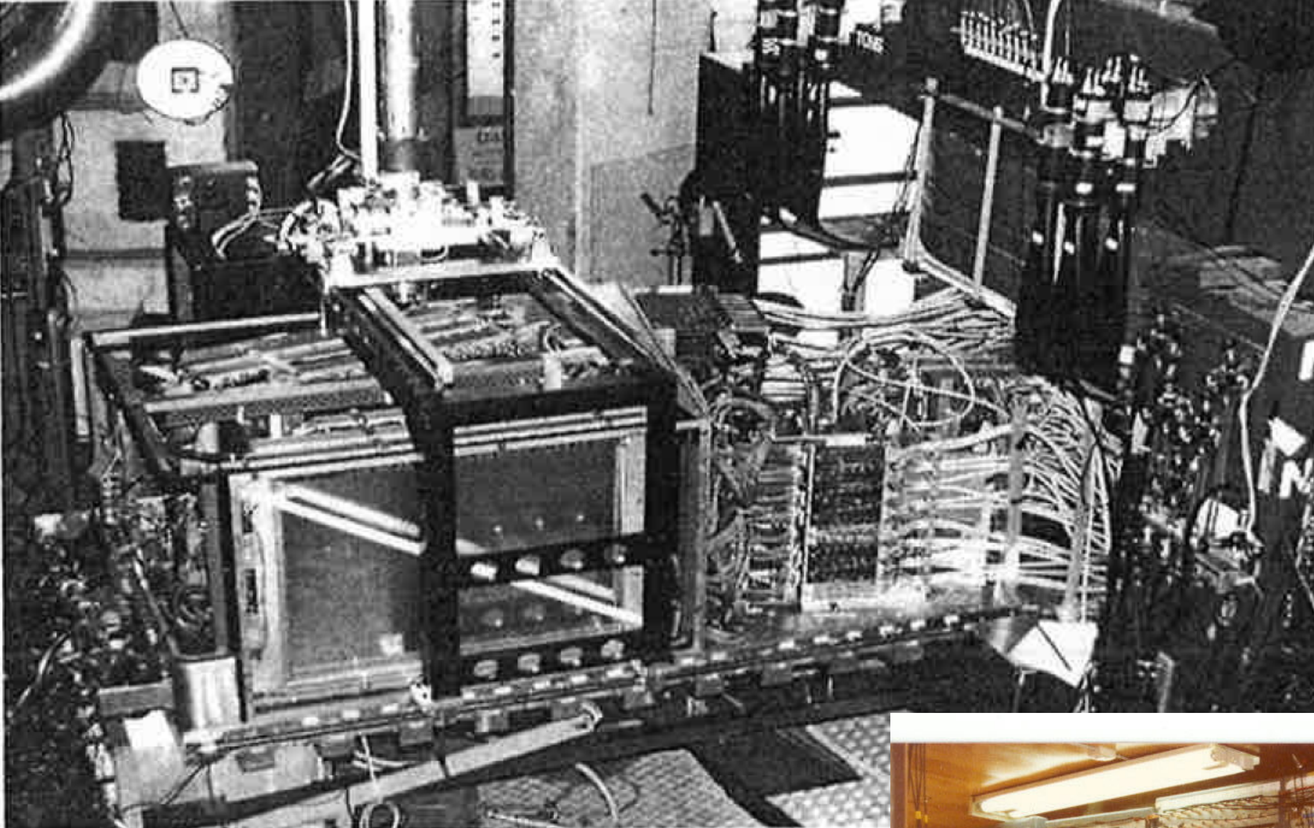


Fig. 2. Layout of detectors and target in the Omicron spectrometer for $\pi^+ p \to \pi\pi N$. C1–C4
RD32, RD4 are drift chambers, S1, S2, S3 scintillation counters and LH, LA, RH, RA sci

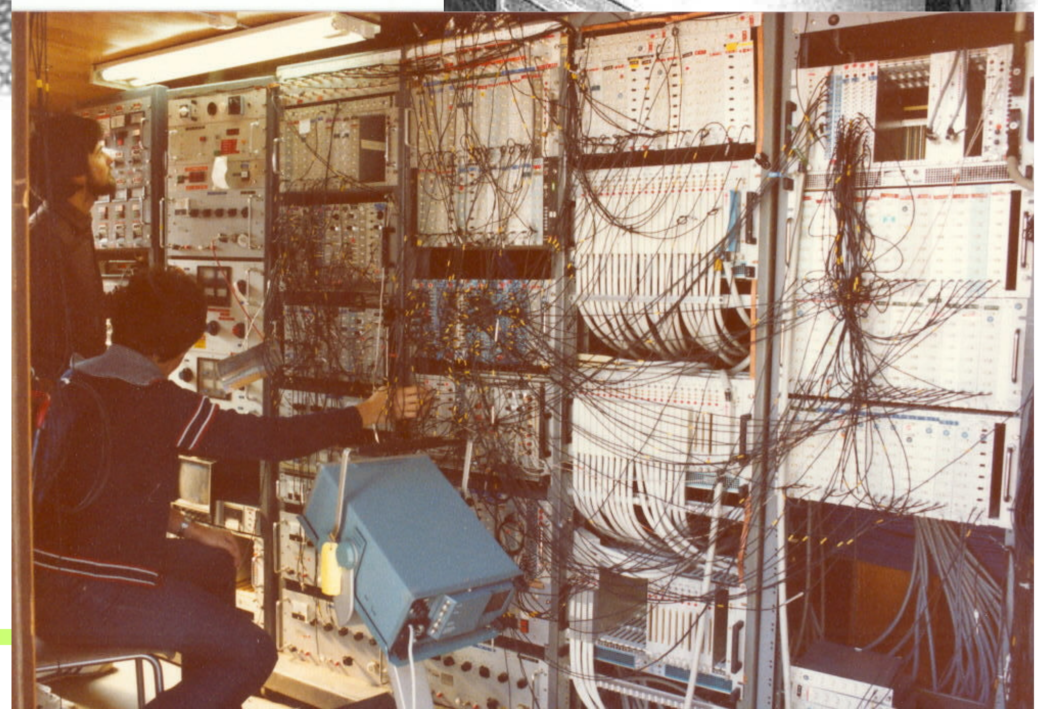


F. Sever with the H_2 target





The detector in the extracted position for installation, repair, and mechanical survey of detector components.



Control room (a container): all in one, trigger, DAQ, diagnostics, PhD students ☺

VOLUME 17, NUMBER 11 PHYSICAL REVIEW LETTERS 12 SEPTEMBER 1966

PION SCATTERING LENGTHS*

Steven Weinberg
Department of Physics, University of California, Berkeley, California
(Received 20 June 1966)

The current commutation relations[1] and partially conserved axial-vector current (PCAC) assumption[2,3] allow the calculation of the matrix elements for emission and absorption of any number of soft pions[4] and, therefore, in particular, determine the scattering length of a pion on any target particle. In this note we give a simple formula for pion scattering on any particle but a pion,[5] and then extend this result to the more difficult case of pion-pion scattering.

Motivation: measurement of the pion–pion scattering length through processes of the type π p → π π N near the reaction threshold

→ Elko proposer in spokesperson of the experiment SC94

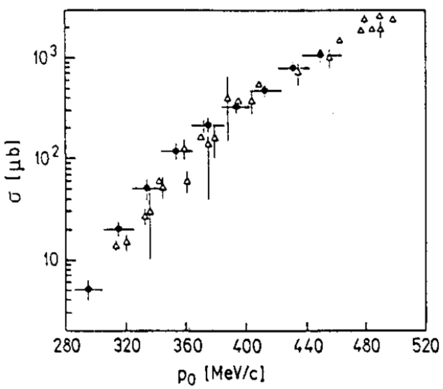
Omicron @ CERN

CERN, 1982

Omicron analysis meeting at JSI, followed by a barbeque at Elko's holiday house in the hills above Ljubljana

Omicron: some selected results

$\pi^- p \rightarrow \pi^- \pi^+ n$



$\pi^- p \rightarrow \pi^- \pi^0 p$

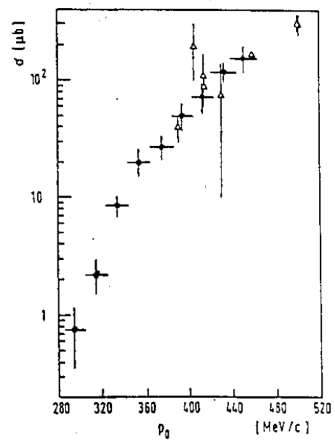
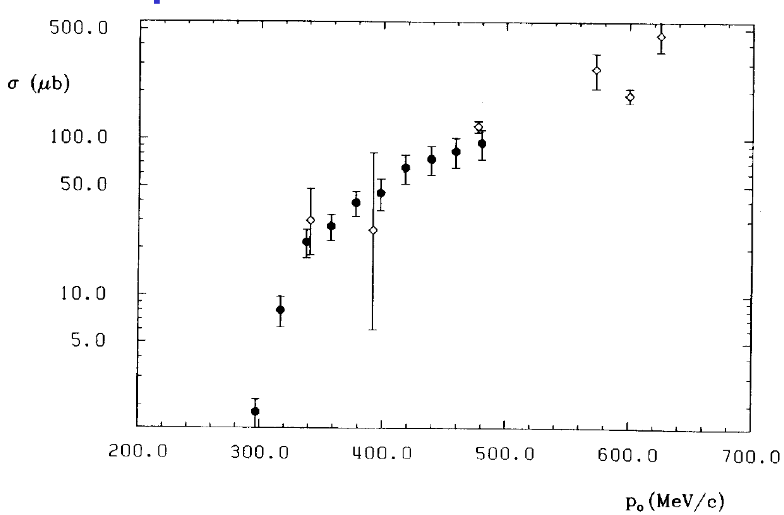


Figure 2: Integrated cross sections for $\pi^- p \rightarrow \pi^+ \pi^- n$ (left) and $\pi^- p \rightarrow \pi^- p \pi^0$ (right) as measured in this experiment (full circles) compared to previous experimental studies. Statistical and systematic errors have been summed in quadrature.

$\pi^+ p \rightarrow \pi^+ \pi^+ n$



Weekly meeting in Elko's office at the faculty – a photo from a newspaper report

Instrumentation in particle physics

Elko’s vision was that, for every international project we join, we should also contribute innovative instrumentation solutions.

For the OMICRON spectrometer:

- Multi-wire proportional chamber for measuring the incident beam (diploma of Marko Starič)
- Cherenkov detector for measuring the composition of the incident beam
- Trigger system using signals from the wire chambers
- Track-reconstruction methods

…

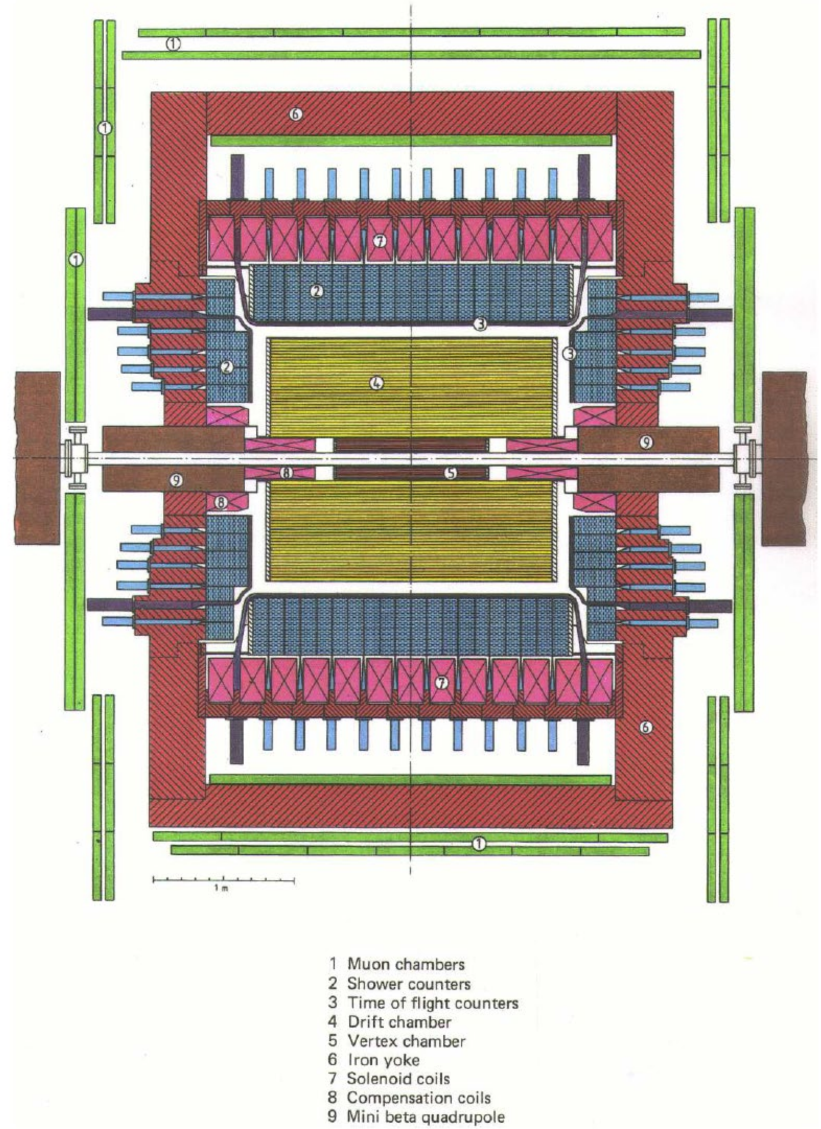
A springboard for the later development of detectors at F9 and their use in medical imaging.

ARGUS at the e^+e^- collider DORIS at DESY

A magnetic spectrometer with 5.3 GeV + 5.3 GeV beams

Large solid-angle coverage, excellent tracking system, particle identification (TOF, dE/dx, EM calorimeter, muon chambers).

A major success – one of the most successful experiments in the history of particle physics.

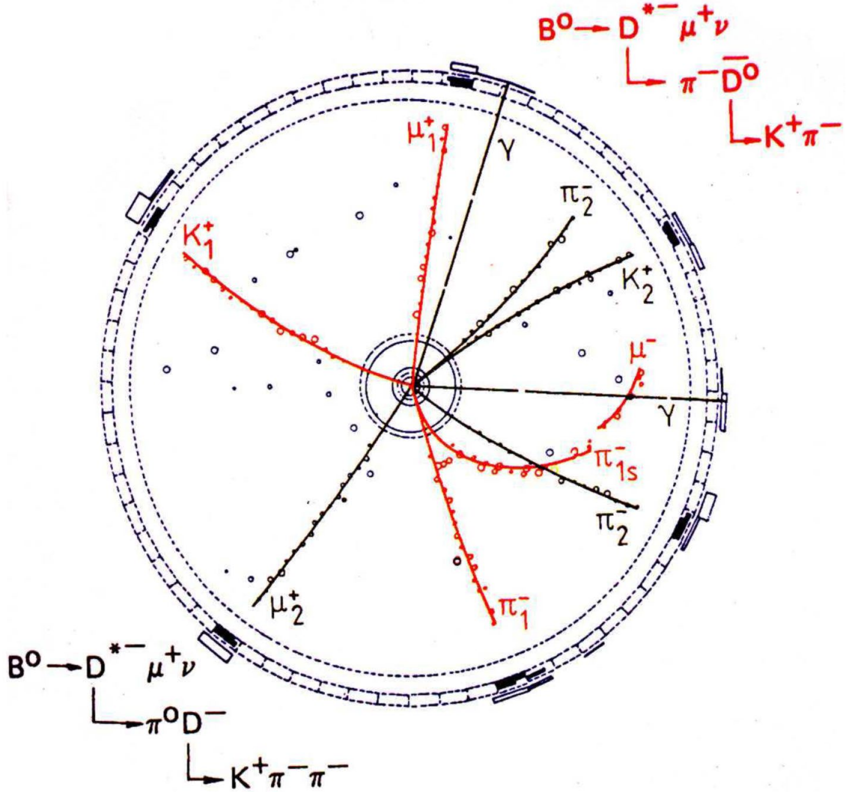


Most important discovery: mixing in the B^0-meson system

1987: ARGUS discovers mixing in the neutral B-meson system: B^0 transforms into anti-B^0 and vice versa

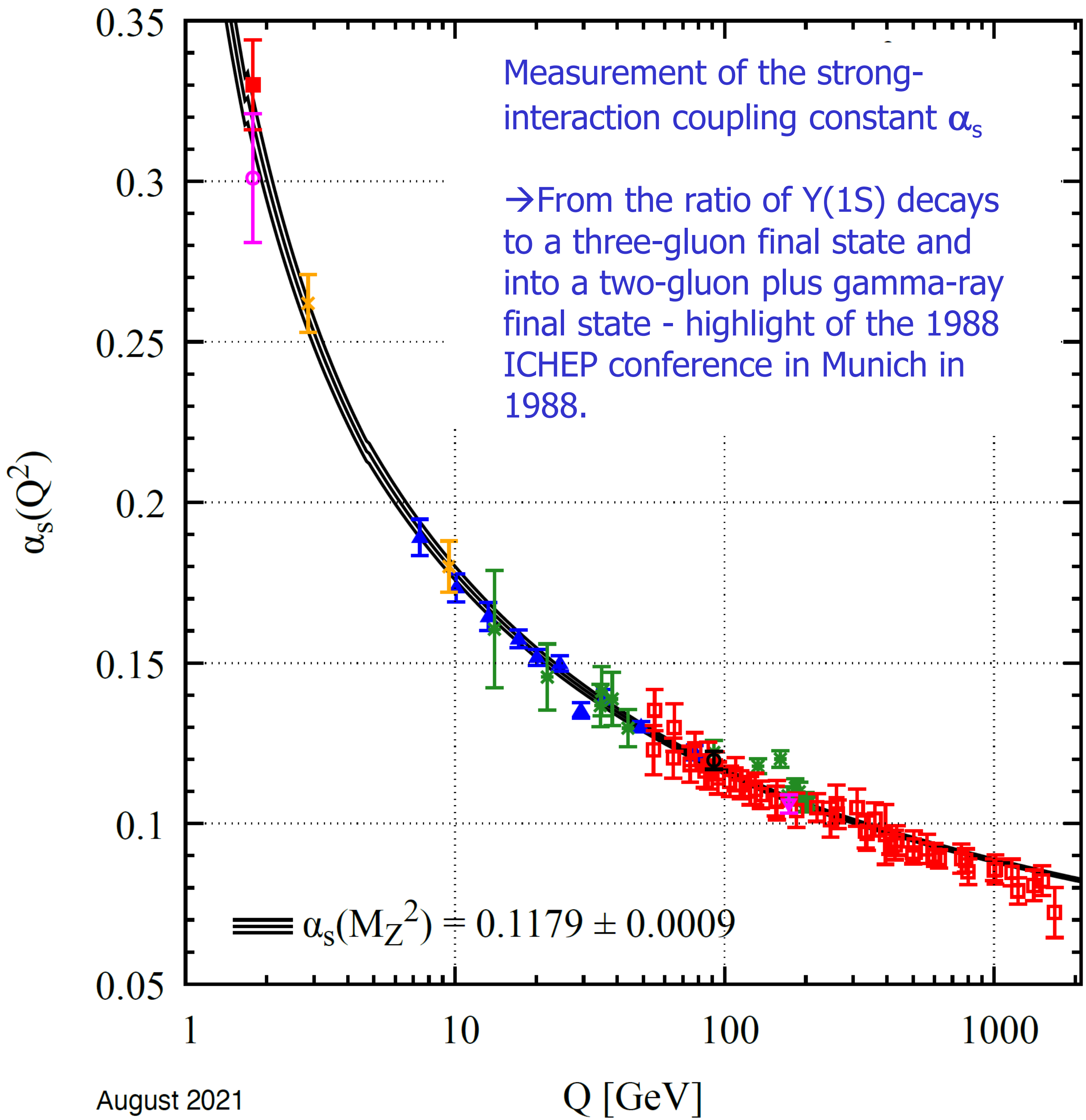
Reconstructed rare event: the final state contains the decay products of two B^0 mesons, although a B^0 and an anti-B^0 were produced → the anti-B^0 transformed into a B^0

→ Long-range implications: top mass is much heavier than originally assumed



→the Tristan collider that has just been commissioned at KEK became ~obsolete…

ARGUS 1987 Bled Meeting



Measurement of the strong-interaction coupling constant α_s

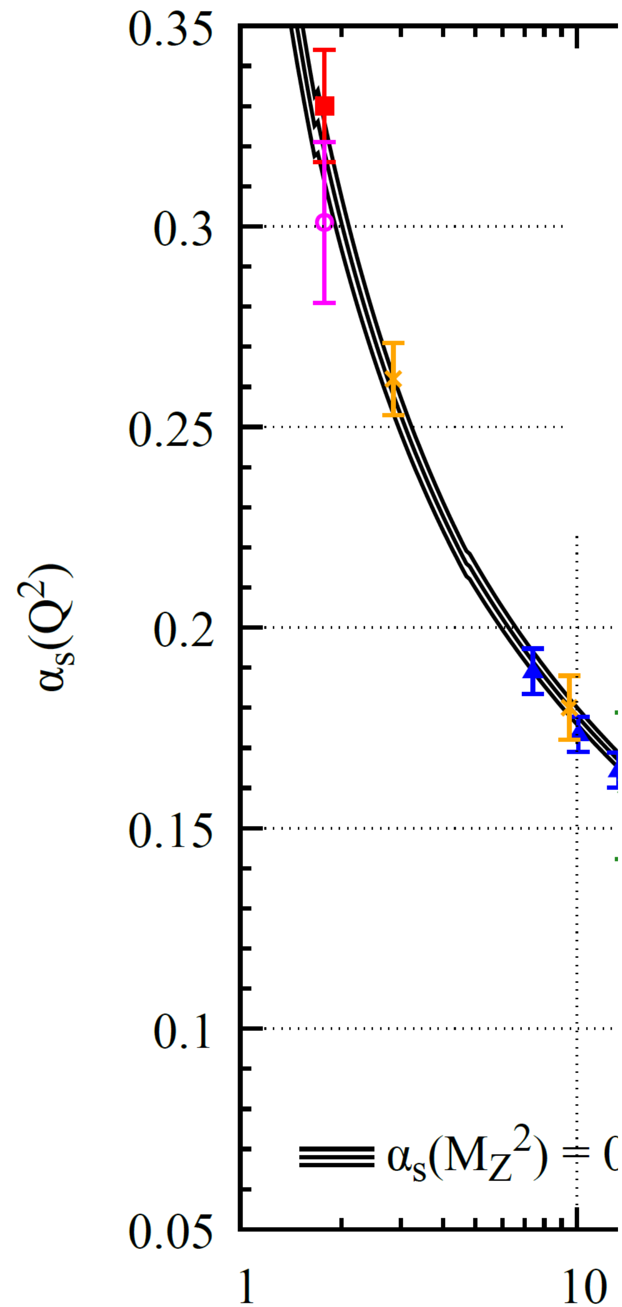
→From the ratio of Y(1S) decays to a three-gluon final state and into a two-gluon plus gamma-ray final state - highlight of the 1988 ICHEP conference in Munich in 1988.

$\alpha_s(M_Z^2) = 0.1179 \pm 0.0009$

$\alpha_s(Q^2)$

Q [GeV]

0.35
0.3
0.25
0.2
0.15
0.1
0.05
1
10
100
1000



August 2021

DETERMINATION OF α_s FROM A MEASUREMENT OF THE DIRECT PHOTON SPECTRUM IN Υ(1S) DECAYS

ARGUS Collaboration

H. ALBRECHT, A.A. ANDAM [1], U. BINDER, P. BÖCKMANN, R. GLÄSER, G. HARDER, A. NIPPE, M. SCHÄFER, W. SCHMIDT-PARZEFALL, H. SCHRÖDER, H.D. SCHULZ, R. WURTH, A. YAGIL [2,3]
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Institute of Theoretical and Experimental Physics, 117259 Moscow, USSR

R. CHILDERS, C.W. DARDEN and Y. OKU
University of South Carolina [15], Columbia, SC 29208, USA

Received 13 August 1987

CPLEAR at CERN

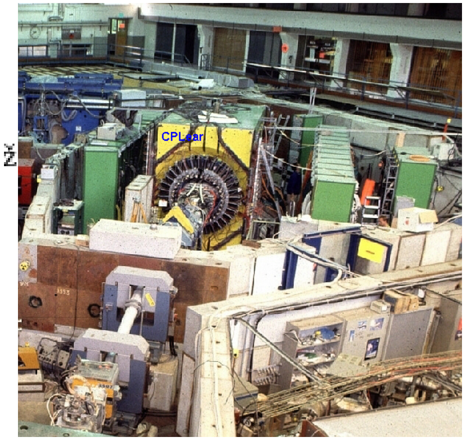
1985 – Slovenian physicists help prepare a proposal to measure time-reversal symmetry violation at the LEAR accelerator

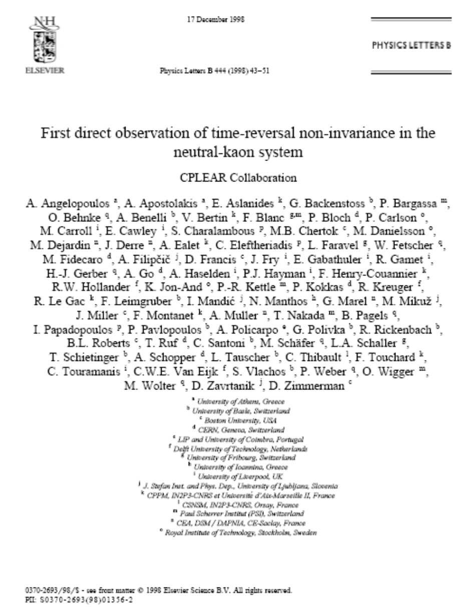
1986 – the proposal is deferred; the group is invited to merge with the competing CPLEAR experiment

1988 – the Slovenian group joins CPLEAR and helps complete the detector

1989–1996 – successful measurements of CP, T and CPT symmetry violation in the neutral-kaon system
First direct measurement of time-reversal symmetry violation in the microscopic world

2004 Zois Award for Marko Mikuž and Danilo Zavrtanik





ELSEVIER
17 December 1998
Physics Letters B 444 (1998) 43–51
PHYSICS LETTERS B

First direct observation of time-reversal non-invariance in the neutral-kaon system

CPLEAR Collaboration

A. Angelopoulos [a], A. Apostolakis [a], E. Aslanides [k], G. Backenstoss [b], P. Bargassa [m], O. Behnke [q], A. Benelli [b], V. Bertin [k], F. Blanc [g,m], P. Bloch [d], P. Carlson [o], M. Carroll [i], E. Cawley [i], S. Charalambous [p], M.B. Chertok [c], M. Danielsson [o], M. Dejardin [n], J. Derre [n], A. Ealet [k], C. Eleftheriadis [p], L. Faravel [g], W. Fetscher [q], M. Fidecaro [d], A. Filipčič [j], D. Francis [c], J. Fry [i], E. Gabathuler [i], R. Gamet [i], H.-J. Gerber [q], A. Go [d], A. Haselden [i], P.J. Hayman [i], F. Henry-Couannier [k], R.W. Hollander [f], K. Jon-And [o], P.-R. Kettle [m], P. Kokkas [d], R. Kreuger [f], R. Le Gac [k], F. Leimgruber [b], I. Mandić [j], N. Manthos [h], G. Marel [n], M. Mikuž [j], J. Miller [c], F. Montanet [k], A. Muller [n], T. Nakada [m], B. Pagels [q], I. Papadopoulos [p], P. Pavlopoulos [b], A. Policarpo [e], G. Polivka [b], R. Rickenbach [b], B.L. Roberts [c], T. Ruf [d], C. Santoni [b], M. Schäfer [q], L.A. Schaller [g], T. Schietinger [b], A. Schopper [d], L. Tauscher [b], C. Thibault [l], F. Touchard [k], C. Touramanis [i], C.W.E. Van Eijk [f], S. Vlachos [b], P. Weber [q], O. Wigger [m], M. Wolter [q], D. Zavrtanik [j], D. Zimmerman [c]

[a] University of Athens, Greece
[b] University of Basle, Switzerland
[c] Boston University, USA
[d] CERN, Geneva, Switzerland
[e] LIP and University of Coimbra, Portugal
[f] Delft University of Technology, Netherlands
[g] University of Fribourg, Switzerland
[h] University of Ioannina, Greece
[i] University of Liverpool, UK
[j] J. Stefan Inst. and Phys. Dep., University of Ljubljana, Slovenia
[k] CPPM, IN2P3-CNRS et Université d'Aix-Marseille II, France
[l] CSNSM, IN2P3-CNRS, Orsay, France
[m] Paul Scherrer Institut (PSI), Switzerland
[n] CEA, DSM / DAPNIA, CE-Saclay, France
[o] Royal Institute of Technology, Stockholm, Sweden

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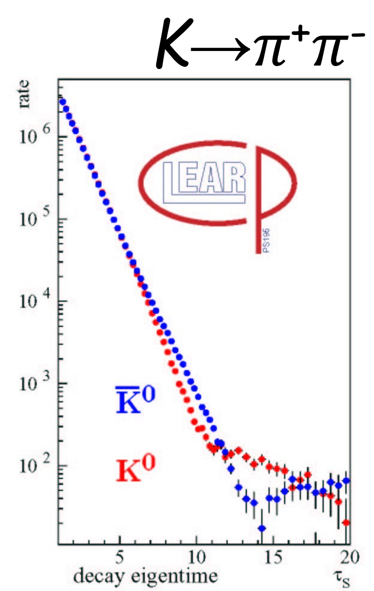
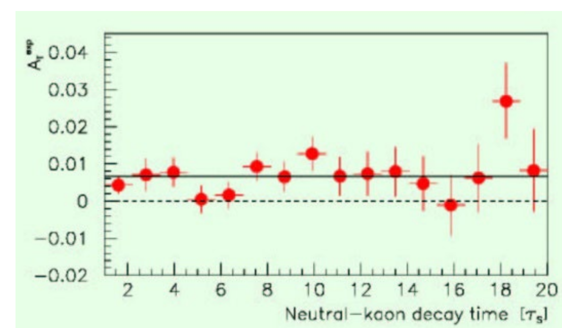
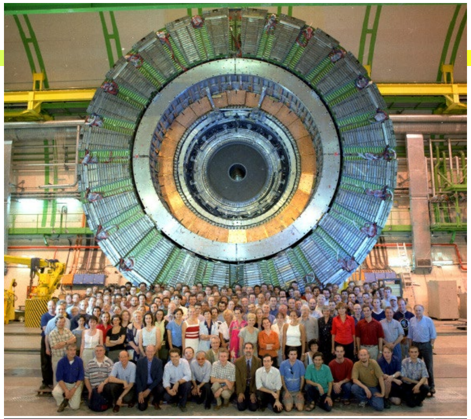
PII: S0370-2693(98)01356-2

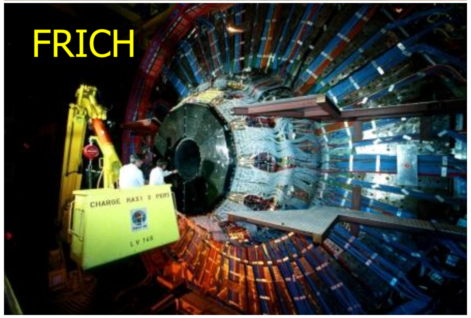


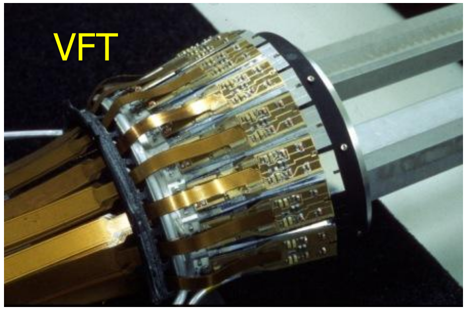


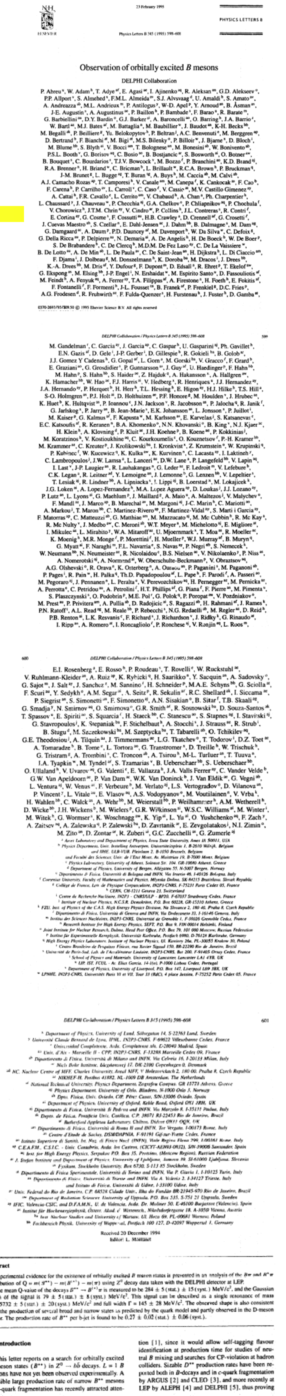
Peter Križan, Ljubljana

DELPHI at CERN








Observation of orbitally excited B mesons

DELPHI Collaboration

1992 – Danilo Zavrtanik is invited to join the DELPHI collaboration

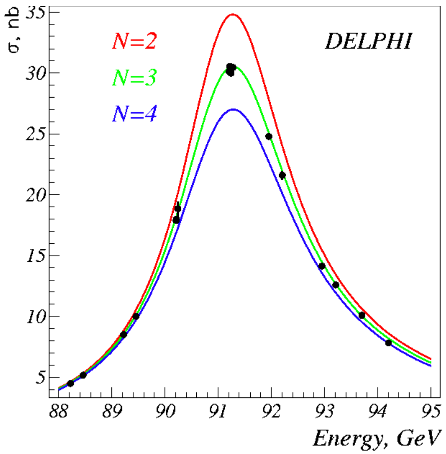
Until 2000 – participation in one of the most successful experiments in the history of particle physics

Numerous precision measurements of the Standard Model by DELPHI, published in more than 300 papers

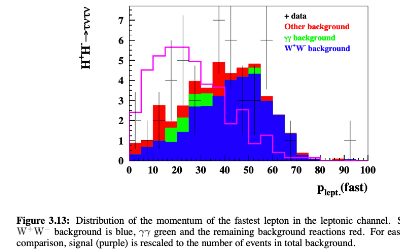
More than 12,800 Web of Science citations; 11 papers with more than 100 citations (2 with more than 1,000)

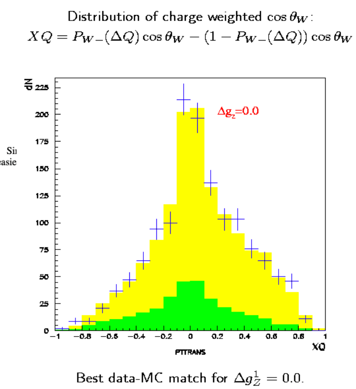
In addition to physics analyses, the Slovenian group contributed to the end-cap Ring Imaging Cherenkov detector and to the forward silicon-tracker upgrade

DELPHI at CERN



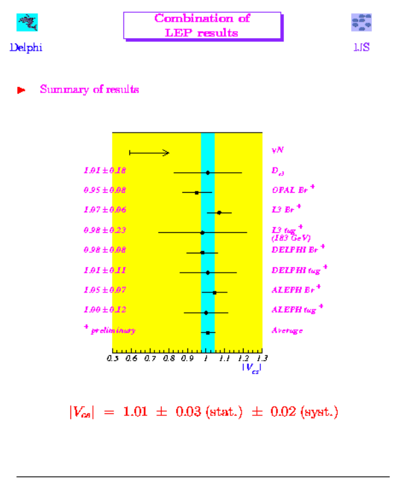
Number of neutrinos

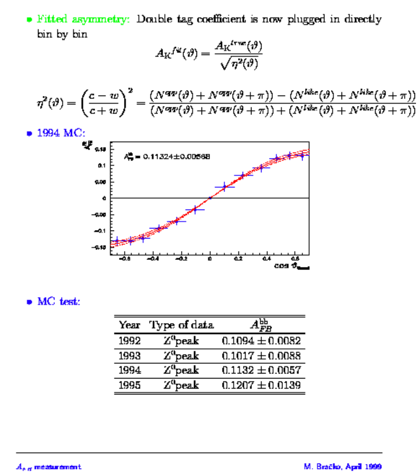




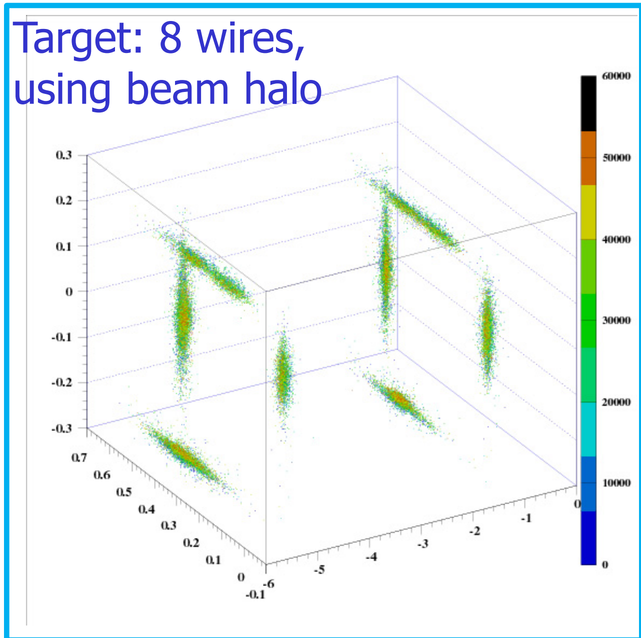
Some selected F9 analyses

- Measurement of Vcs in the CKM matrix
- Search for charged Higgs bosons
- Measurement of the forward–backward asymmetry
- Measurement of trilinear weak-boson couplings

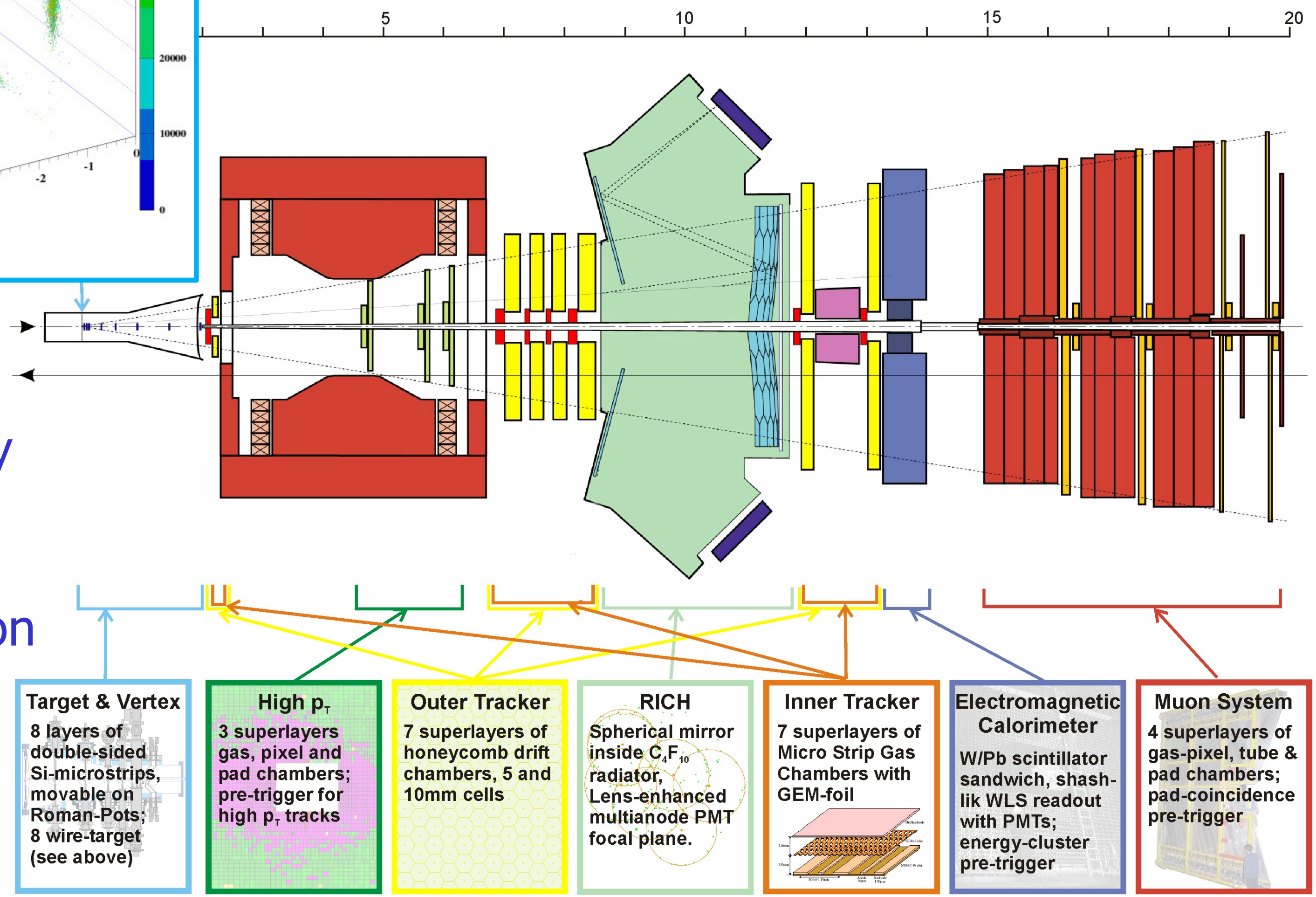


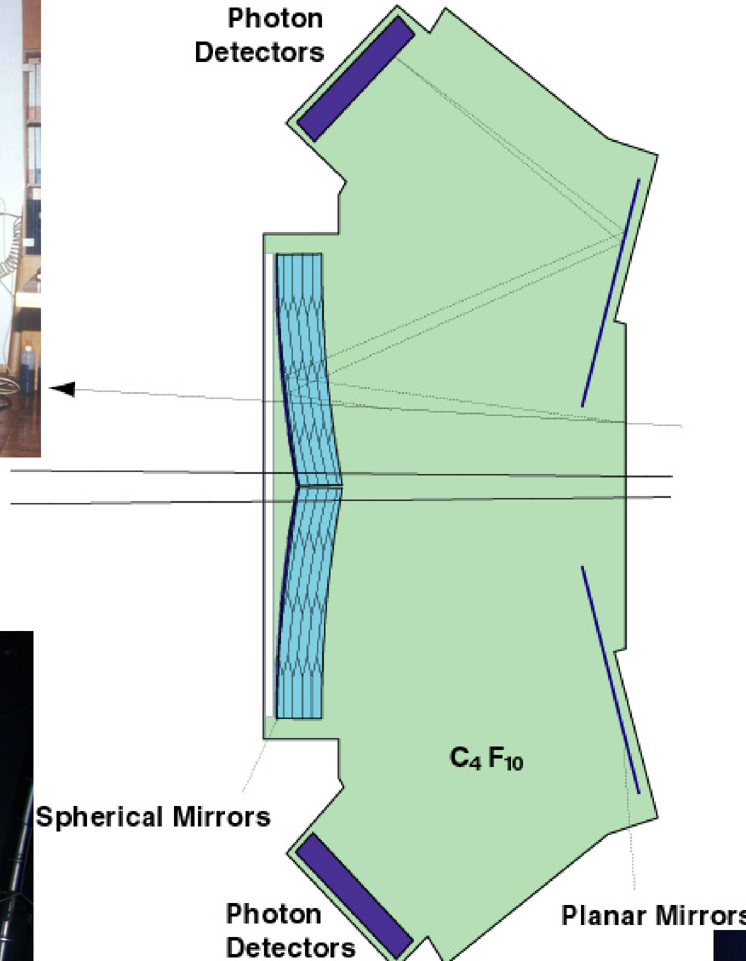


HERA-B spectrometer at DESY



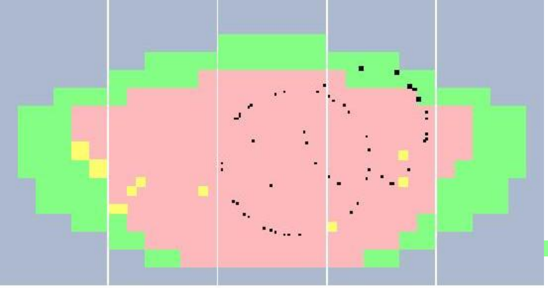
Idea: fixed target production of heavy flavours - with the ultimate goal to measure CP violation in the B system

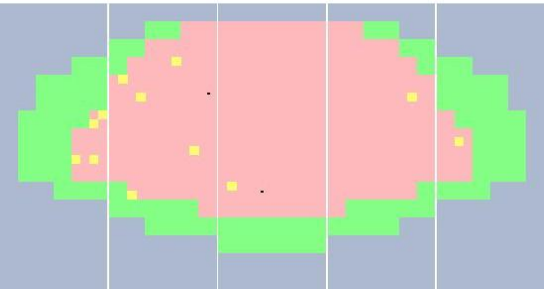




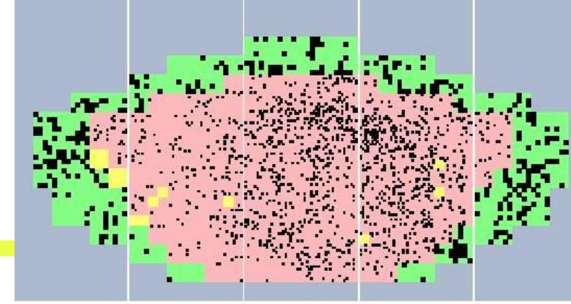
Main responsibility of the Slovenian team: RICH

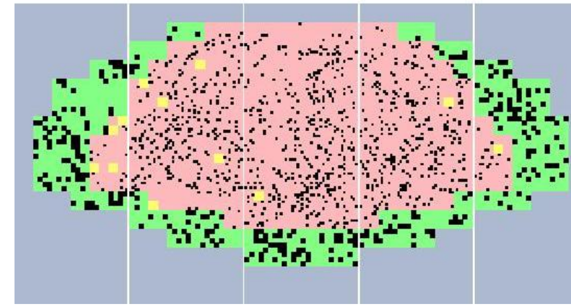
HERA-B RICH





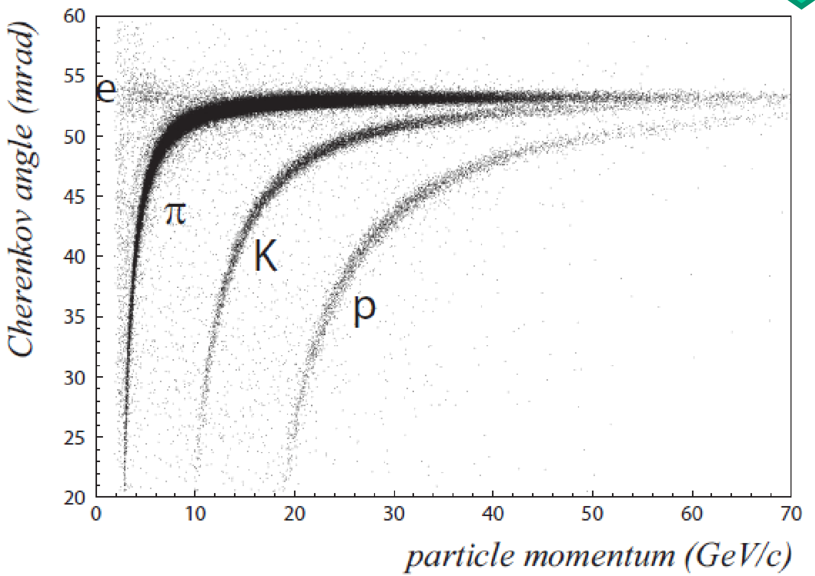
← Little noise, ~30 photons per ring

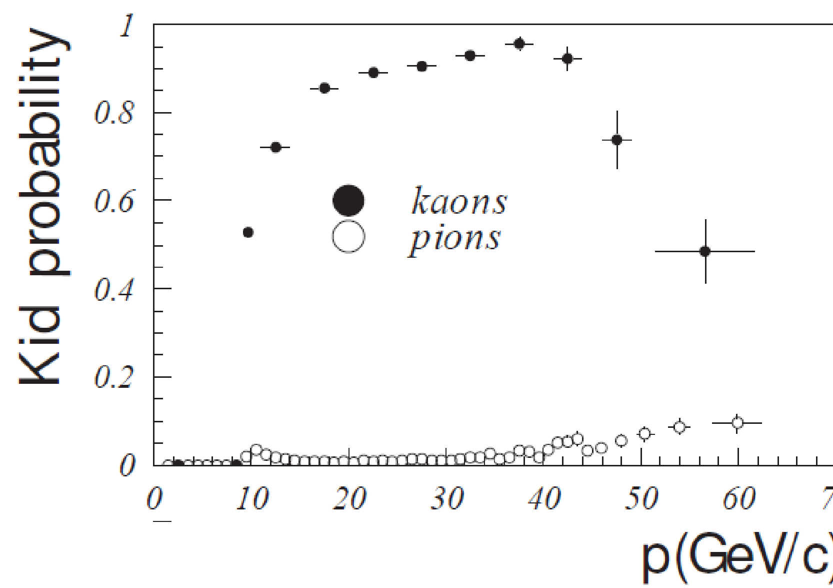




Typical event →

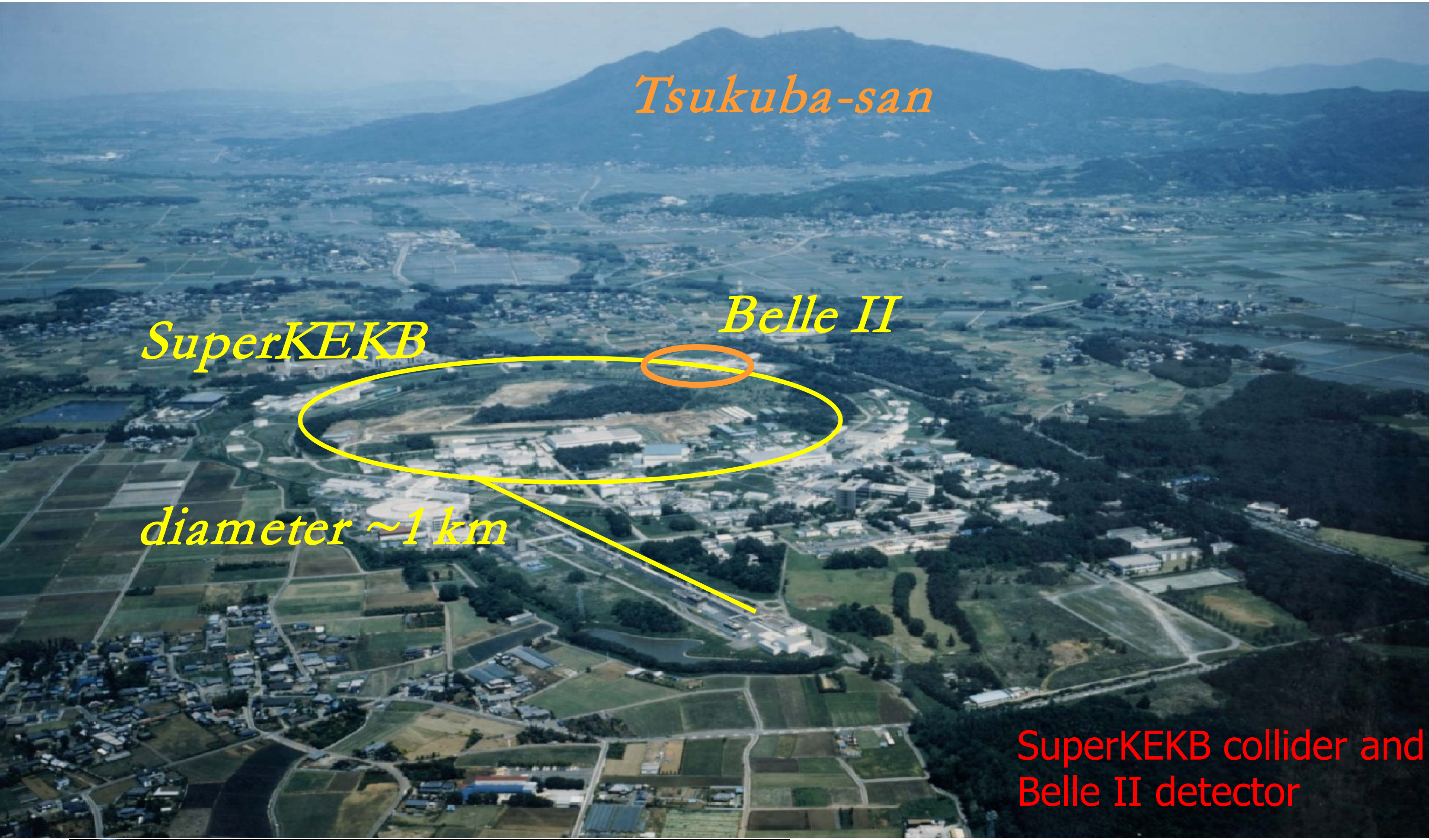
Worked very well!





Kaon efficiency and pion fake probability

Belle / Belle II at KEK

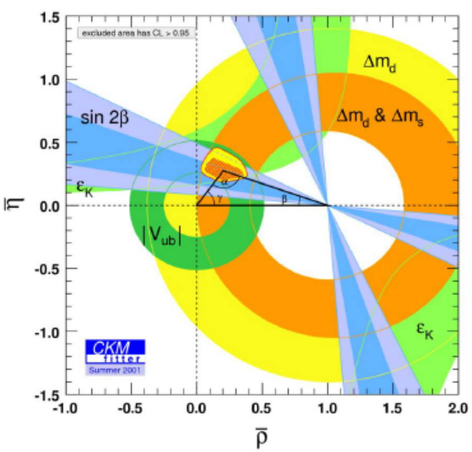


Belle / Belle II at KEK

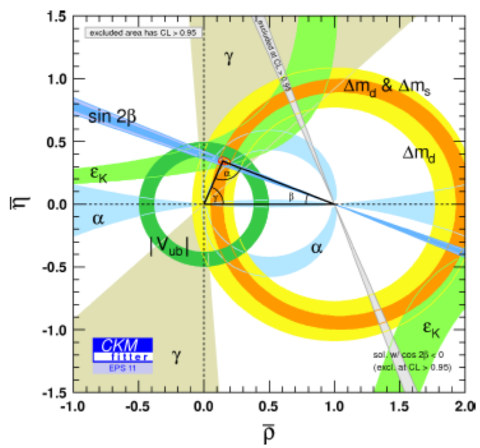
Discoveries and precision measurements in matter / anti-matter asymmetry → remarkable agreement with the predictions of Kobayashi and Maskawa.

→ Nobel prize 2008

EPS 2001



EPS 2011

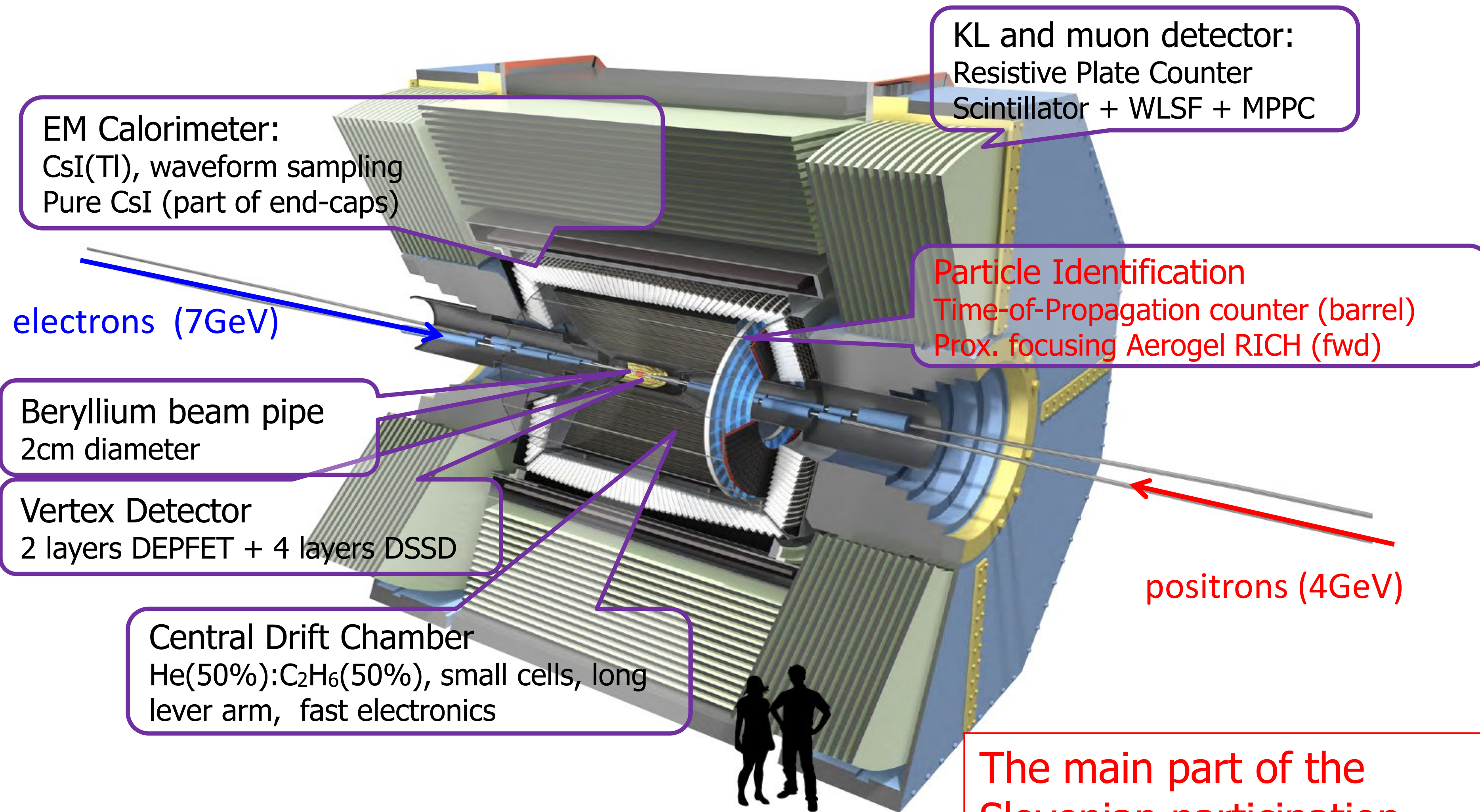


KEKB and Belle operated from 1999 to 2010 → Many exciting results

About 500 scientific papers summarized in a book published by Springer
Foreword: Nobel laureates M. Kobayashi and T. Maskawa
One of the five editors: Boštjan Golob, Authors: several members of the Slovenian team

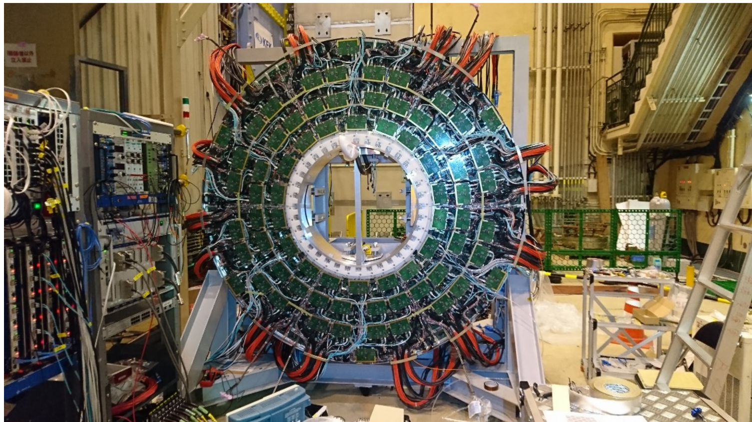
Zois award 2008 for Peter Križan,
Zois distinction 2011 for Boštjan Golob, Samo Korpar and Marko Starič

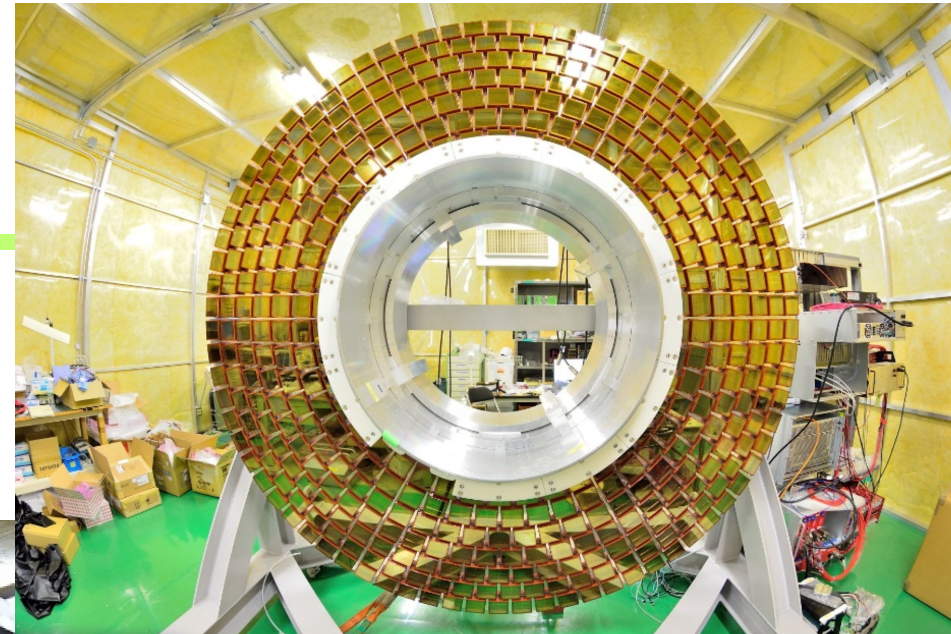
Belle II: Detectors for particle identification



The main part of the Slovenian participation

The 'big eye' of ARICH





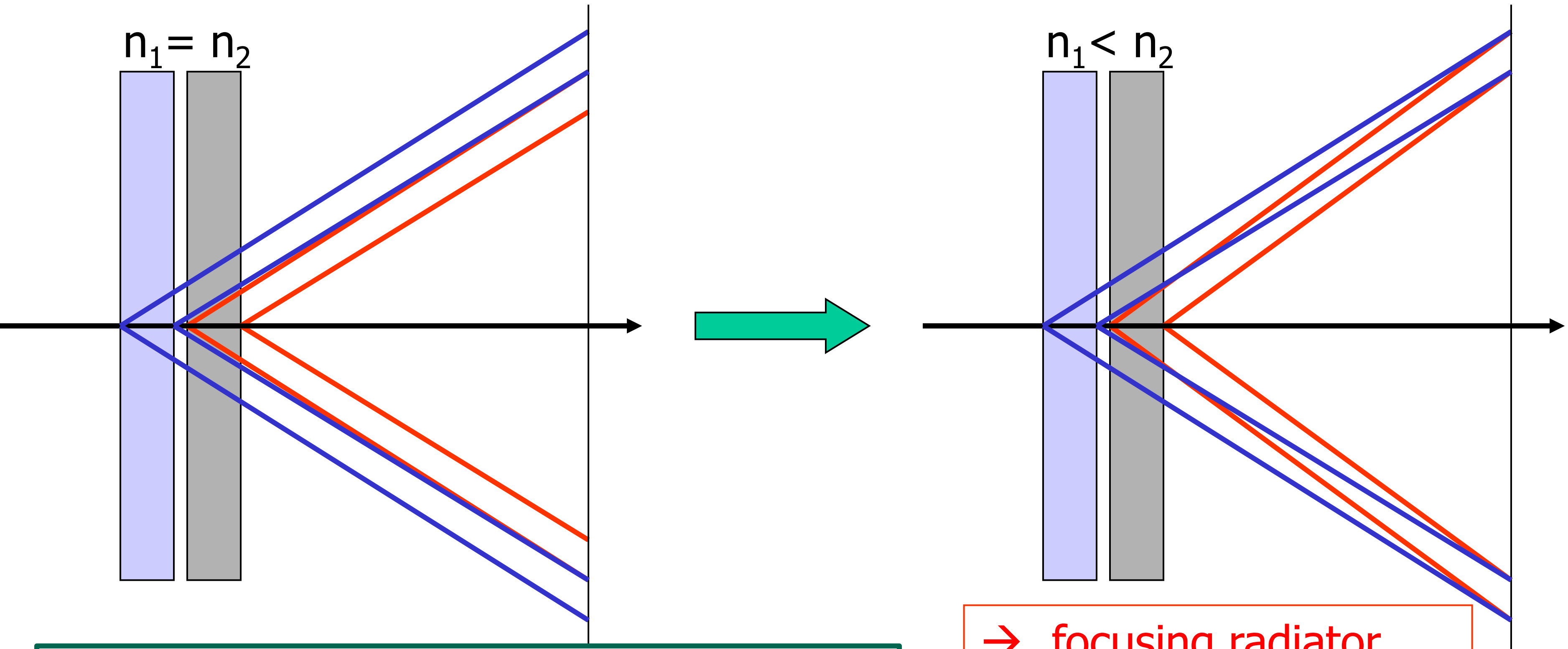
ARICH: a major innovation, radiator with multiple refractive indices

Small number of photons from aerogel → need a thick layer of aerogel.

How to increase the same number of photons with degrading the resolution?

→ stack two tiles with different refractive indices: "focusing" configuration

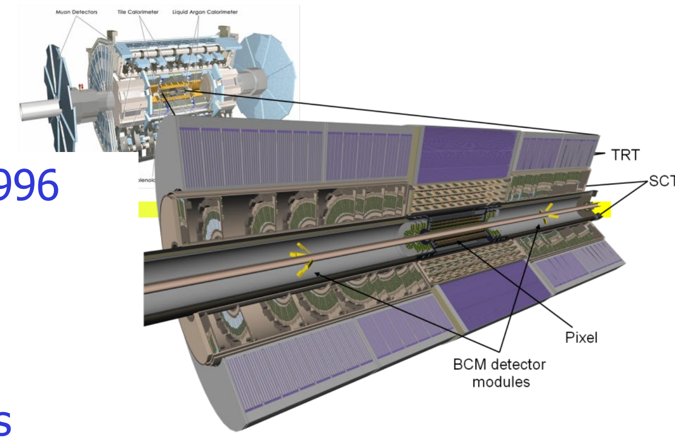
normal



→ focusing radiator

Invented by Samo Korpar and Toru Iijima

ATLAS at CERN



The Slovenian group has participated in the project since June 1996

Detector construction:

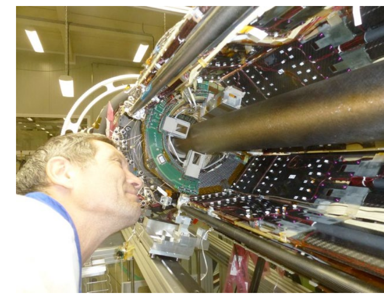
<u>Silicon tracker – SCT</u>

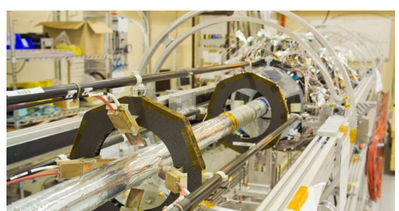
- Central tracker: 30 cm < r < 55 cm, 4 barrels, 2×9 disks
- The full detector has 63 m² of silicon wafers, divided into 6.3 million individual sensors (80 μm strip pitch) in 4,088 modules
- The 4,088 modules consume ~40 kW; freon cooling and about 150 "refrigerators" cool the SCT to −7°C

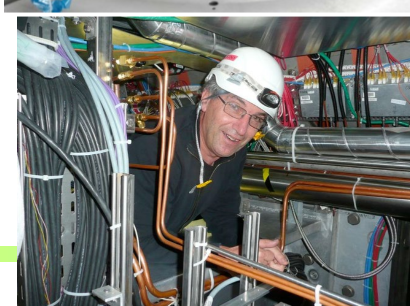
<u>Beam Conditions Monitor – BCM</u>

- Fast system: 8 diamond detectors with response below 1 ns
- Real-time processing interacts with the LHC in case of beam anomalies → beam dump
- The Slovenian group had a leading role in building the system

<u>Strong participation of Slovenian companies in the construction of SCT</u>

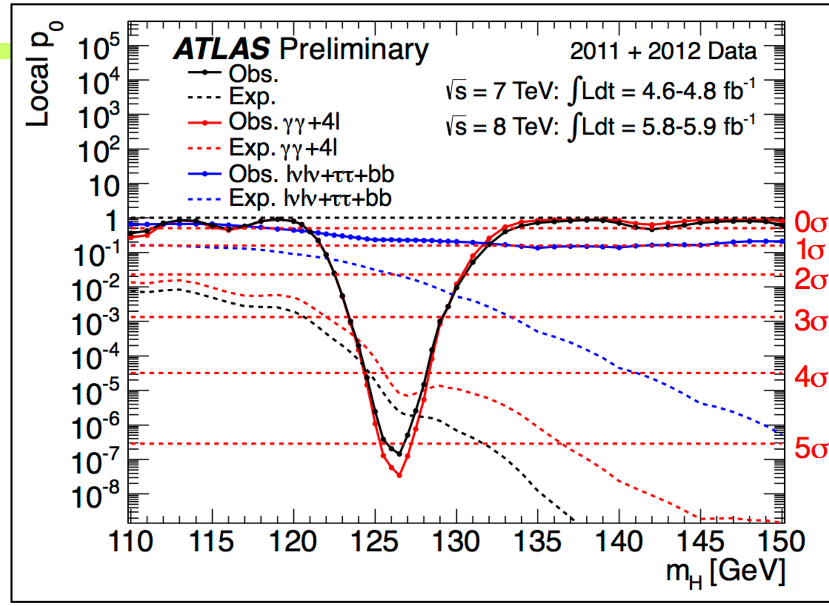






ATLAS at CERN


First collissions



Discovery of the Higgs boson, July 2012

Signal in 3 decay channels

- "Golden" decay: $H \to ZZ \to 4\ell$
- $H \to \gamma\gamma$
- $H \to WW \to \ell\nu\ \ell\nu$

Combined significance above 5 sigma

In 2016, the President of Slovenia awarded the Order of Merit of the Republic of Slovenia to "the group of Slovenian scientists participating in the ATLAS experiment at CERN"

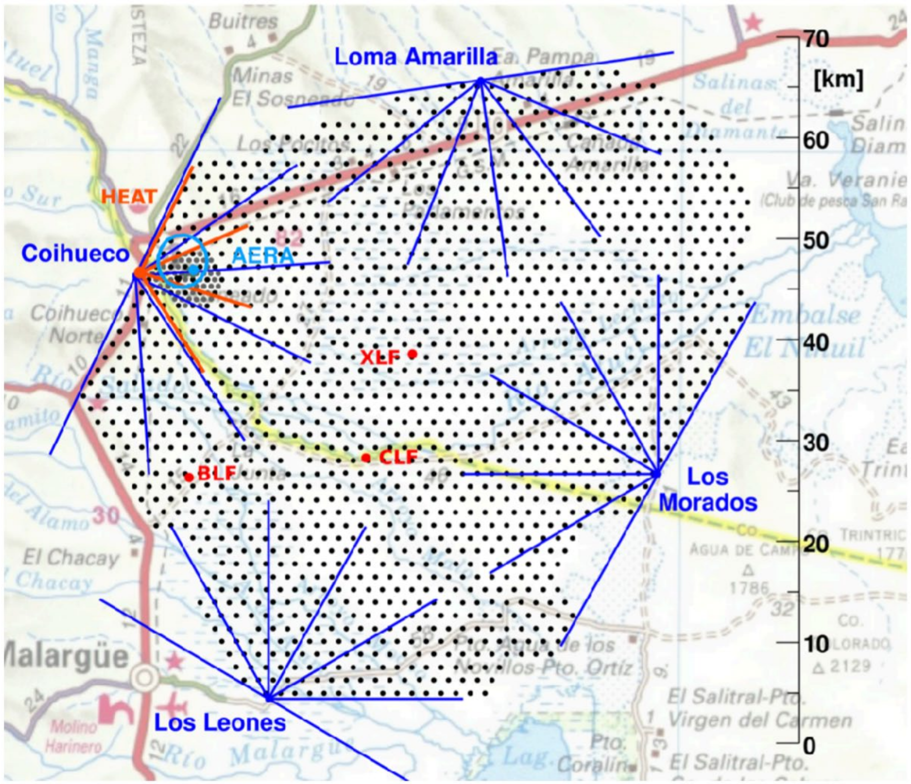
LHCb experiment at CERN

Discussion about a possible technical collaboration started while Peter Križan was a member of LHCC (~2016), responsible for reviewing the LHCb experiment; the idea was to initially get involved in the LHCb RICH upgrade R&D, in synergy with Belle II ARICH upgrade R&D. Spoke (C. Parkes) and CB chair (B. Spaan) were very positive, and in 2018 JSI joined as an associate member, with Rok Pestotnik as the team leader.

Rok then successfully led the negotiations to upgrade the status in the collaboration.

2026: JSI full member.

Pierre Auger Observatory



3000 km^2

Ground detector

- Fundamental mesh (1660 Čerenkov detectors, triangular geometry, distance 1.5 km, Total surface 3000 km^2, sensitivity >2x10^{18} eV)
- "Infill" mesh (71 detectors, distance 750 m, surface 23.5 km2, sensitivity >2x10^{17} eV)

Fluorescence detector

- 24 telescopes v 4 buildings (FOV 30^o) + 3 telescopes in HEAT (FOV 30^o - 60^o)
- Radio detectors (AERA)
- 153 antenas, surface 17km^2

Monitoring of the atmosphere

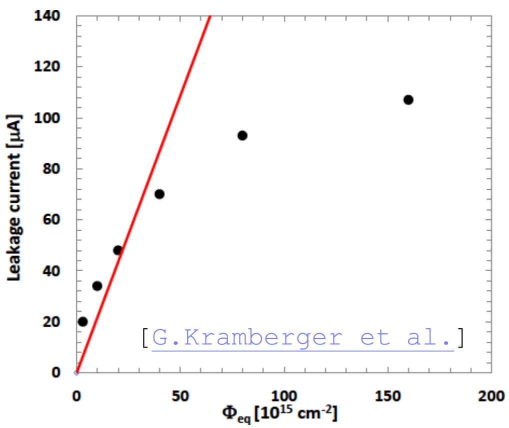
Slovenian groups (UNG, JSI): Monitoring of the atmosphere (LIDAR), detailed simulations of the system response.

Zois award 2020 for Marko Zavrtanik, Andrej Filipčič, Samo Stanič

Detector R&D

Mainly related to the experiments we were involved in

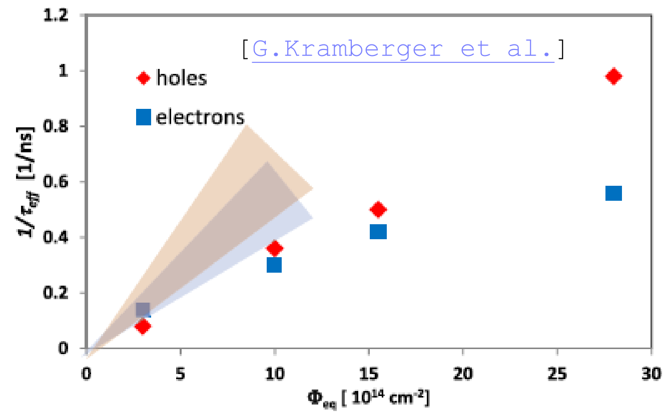
- Semiconductor devices
- RICH detectors and low-light-level photosensors



Leakage current saturation

$I = \alpha V \Phi$

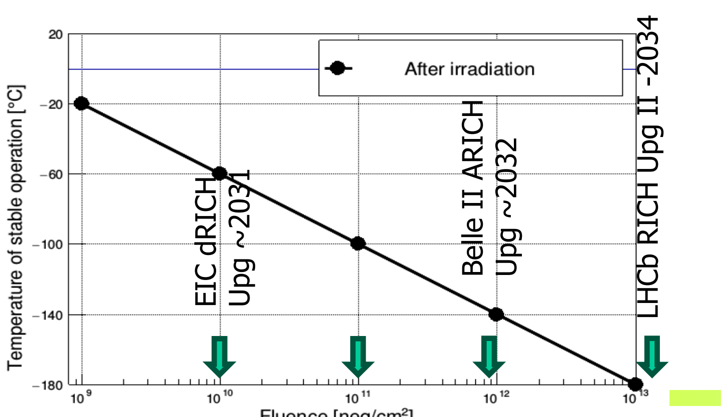
α from linear to logarithmic

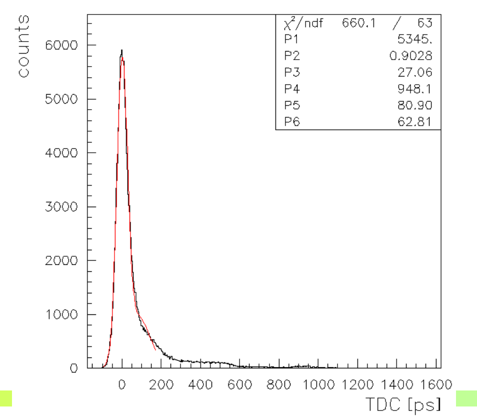


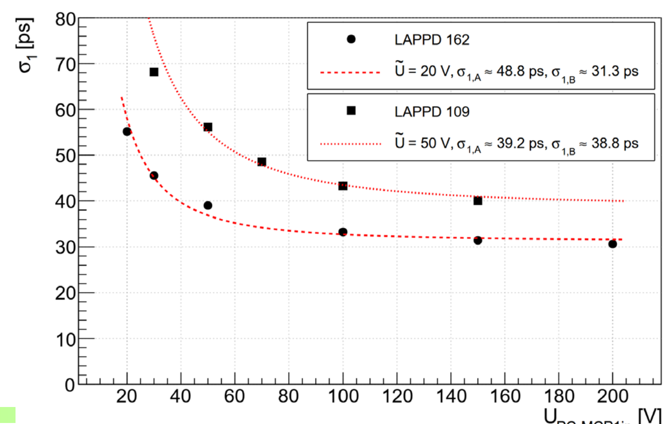
Trapping probability saturation

$1/\tau_{\text{eff}} = \beta\Phi$

β from linear to logarithmic







D. Consuegra-Rodrigez et al., Eur. Phys. J. C 84, 970 (2024)

S.Korpar et al, NIM A1088 (2026) 171466

Detector R&D

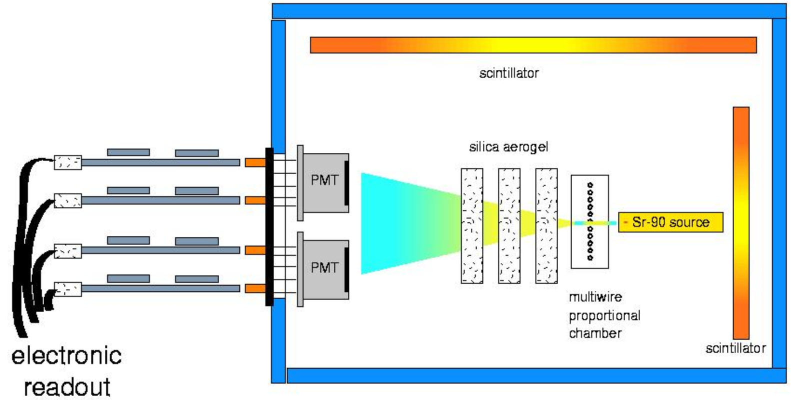
Towards Europe-wide organized detector R&D for future projects

- ECFA Detector R&D Roadmap: Gregor Kramberger and Peter Križan
- 2023-2024 preparation of DRD collaborations (Peter Križan and Christian Joram coordinators of proto-DRD4)
- 2024: DRD collaborations established
- DRD3: spoke Grego4 Kramberger
- DRD4: management team member and WG1 leader Rok Pestotnik

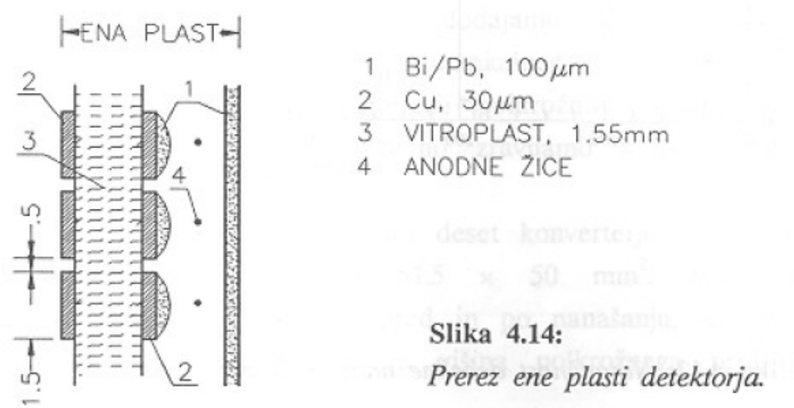
Application of our research to societal challenges

Instrumentation for advances in PET medical imaging, environmental monitoring

- Aerogel-based detector of Sr90, a pure beta-emitter, a radiotoxic product in fission, gets to the environment in reactor accidents



- Positron emission tomography (PET) with a multi-layer MWPC-based detector of annihilation gamma rays – PhD Thesis of Marko Starič



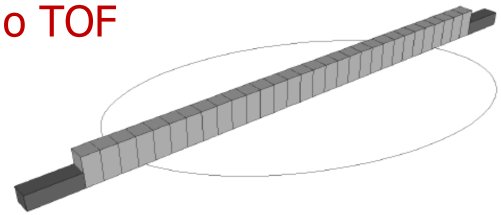
Slika 4.14:
Prerez ene plasti detektorja.

- PET module with LYSO crystals and SiPM read-out – one of the early studies

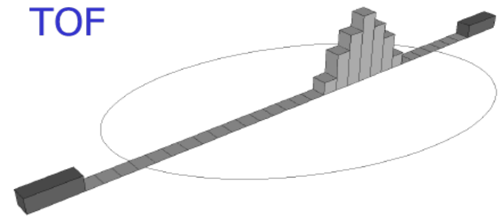
Application of our research to societal challenges

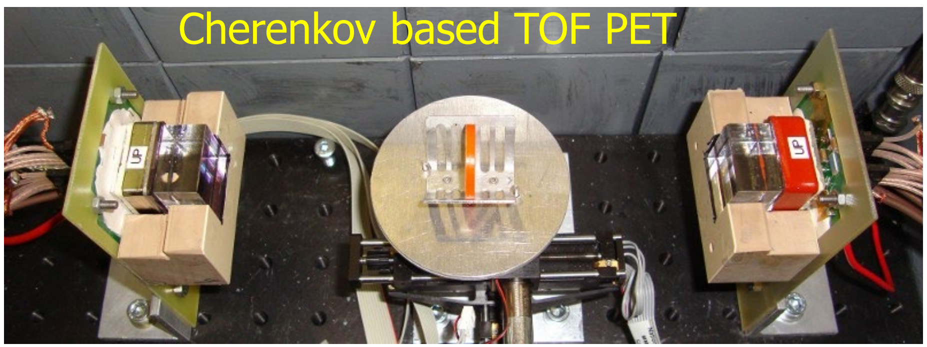
Instrumentation for advances in PET medical imaging

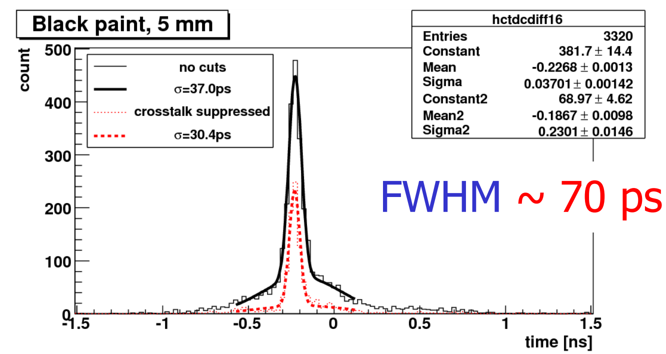
No TOF

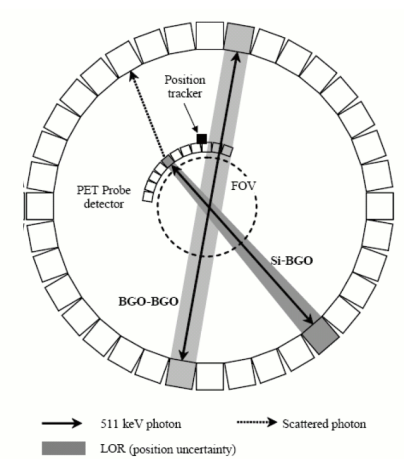


TOF

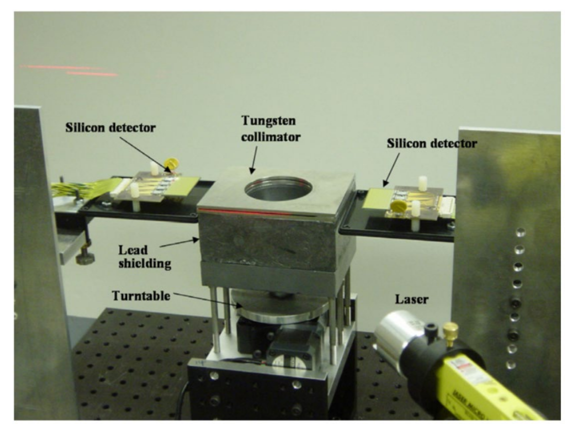








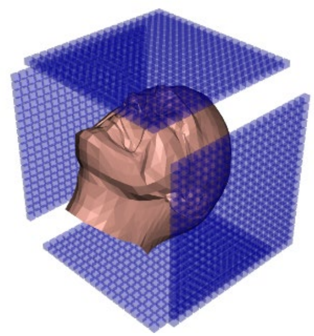
PET + Compton probe

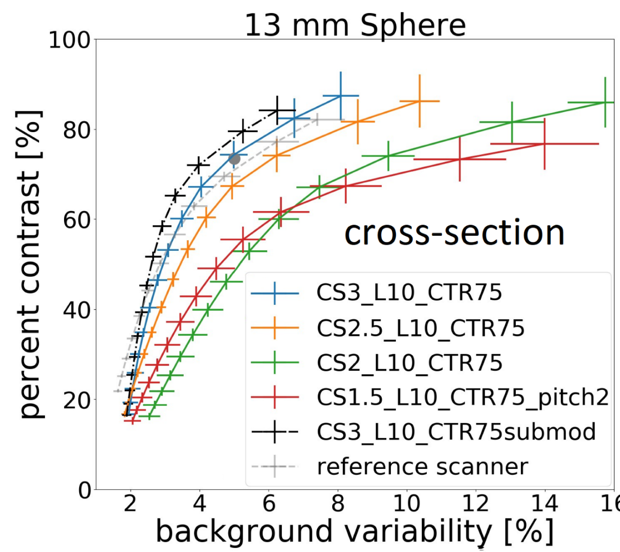


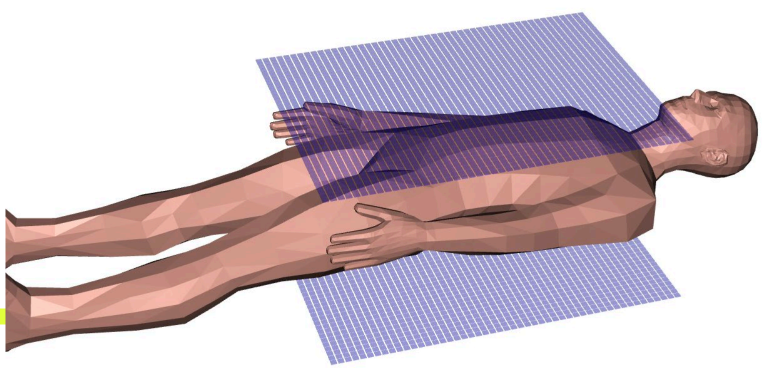
Application of our research to societal challenges

Instrumentation for advances in PET medical imaging

Challenges: cheaper devices, flexible, full body







PetVision & ARIS PET

F9 has a rich history – and for sure a rich future!

… and it is up to all of us to make it happen ☺