

I FEEL
SLOVENIA



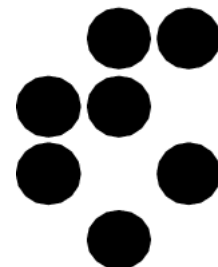
GREEN.
CREATIVE.
SMART

Overview of Slovenian Participation in CERN Experiments



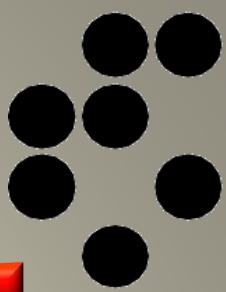
Marko Mikuž

University of Ljubljana & Jožef Stefan Institute





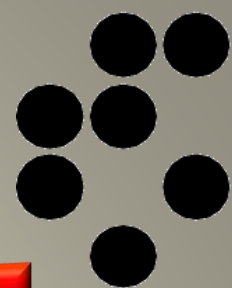
Outline



- History of Slovenian HEP in CERN
 - Experiments
 - Industrial participation
- SiHEP@CERN today
- Prospects

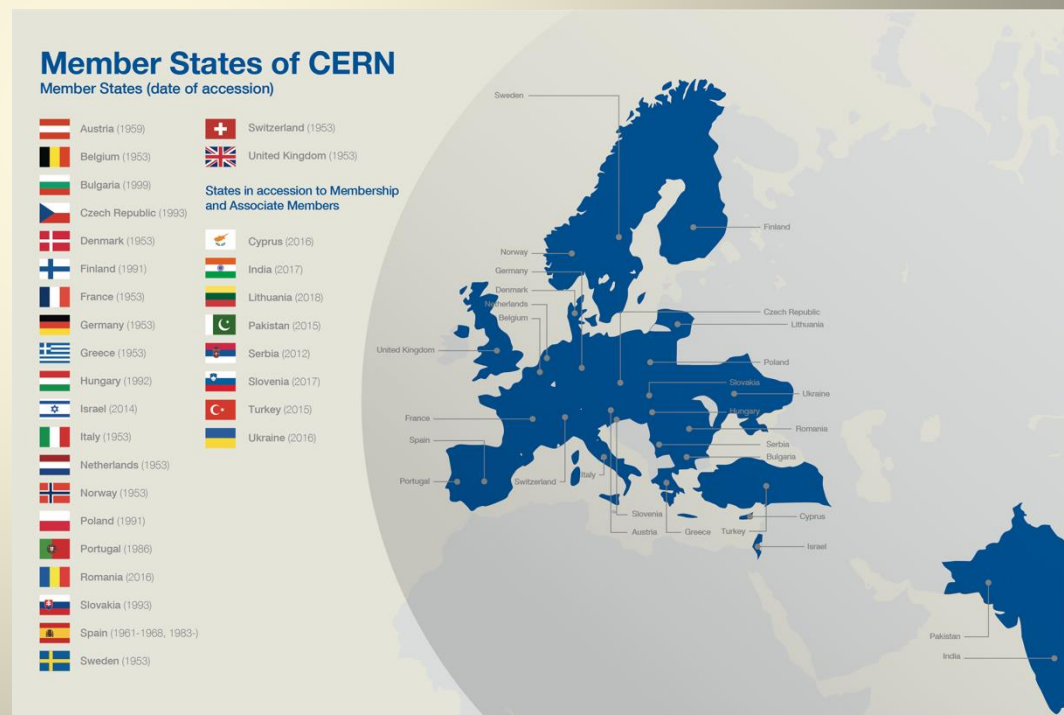


Slovenia at CERN



- Long struggle leading to Slovenia's adherence as *Associate Member State of CERN in the pre-stage to Membership* was successfully concluded on *July 4th 2017* (5y after Higgs discovery, 241y after US independence declaration)

- First *LoI* in 1992
 - Two CERN fact-finding missions
 - Stalled
- Second *LoI* in 2009
 - Council task force visit 2010
 - Negotiations started
 - Stalled
- Process resumed 2015 and brought to successful completion

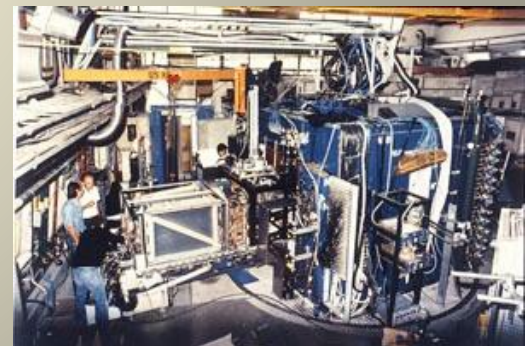


History of Si@CERN - OMICRON

1975-1991

- Prof. G. Kernel invited by Oxford colleagues to join the OMICRON collaboration at CERN SC
- Up to 1982 the OMICRON collaboration conducts a series of experiments on pion scattering
- Prof. Kernel is joined by several PhD students and the Slovenian group becomes a full member of the OMICRON collaboration
- For the last experiment, threshold pion production (CERN SC-94), the Slovenian group assumes a leading role with Prof. Kernel the spokesperson of the experiment

➤ Thus this year we are celebrating 44 years of Slovenian collaboration with CERN!



CROSS SECTION MEASUREMENT OF THE $\pi^-p \rightarrow \pi^- \pi^+ n$ REACTION NEAR THRESHOLD

OMICRON Collaboration

G. KERNEL, D. KORBAR, P. KRIZAN, M. MIKUŽ, F. SEVER, A. STANOVNIK, M. STARIČ, D. ZAVRTANIK

J. Stefan Institute and Department of Physics, E. Kardelj University, JU-61111 Ljubljana, Yugoslavia

C.W.E. VAN EIJK, R.W. HOLLANDER, W. LOURENS¹

Delft University of Technology, Delft, The Netherlands

E.G. MICHAELIS²

CERN, CH-1211 Geneva 23, Switzerland

N.W. TANNER

Nuclear Physics Laboratory, Oxford University, Oxford OX1 3RH, UK

S.A. CLARK

Rutherford and Appleton Laboratory, Chilton, Didcot OX11 0QX, UK

J. JOVANOVIČ

Department of Physics, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

J.D. DAVIES, J. LOWE and S.M. PLAYFER³

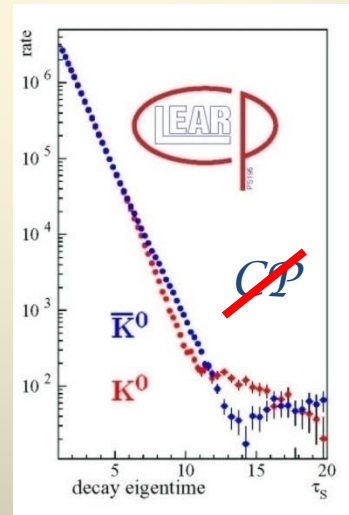
Department of Physics, University of Birmingham, Birmingham B15 2TT, UK

Received 24 October 1988

Result of cross section measurements for the reaction $\pi^-p \rightarrow \pi^- \pi^+ n$ are presented. They cover a range of incident pion momenta between 295 and 450 MeV/c. It is the first time that the cross section has been measured so close to threshold. The experiment was performed with Omicron, a large-solid-angle spectrometer, which enables a measurement of the full set of kinematic variables. In the region of overlap there is a good agreement with other experiments. The extracted value for the chiral-symmetry-breaking parameter ξ is seen to be largely extrapolation dependent but the measured value of -0.5 ± 0.8 leaves Weinberg's prediction of $\xi=0$ the only remaining choice.

History of Si@CERN - CPLEAR

- 1988-2003
 - 1985 – Slovenian physicists participate in a proposal to measure time reversal violation at LEAR (PSCC P-88)
 - 1986 – the proposal is postponed, the collaboration is proposed to merge with the approved CPLEAR experiment (CERN PS-195)
 - 1988 – Slovenian group joins CPLEAR in the final stage of detector preparation
 - 1989 – 1996 successful measurements of CP, T and CPT violation in the neutral kaon system, featuring the first direct observation of time reversal non-invariance



17 December 1998

ELSEVIER

PHYSICS LETTERS B

Physics Letters B 444 (1998) 43–51

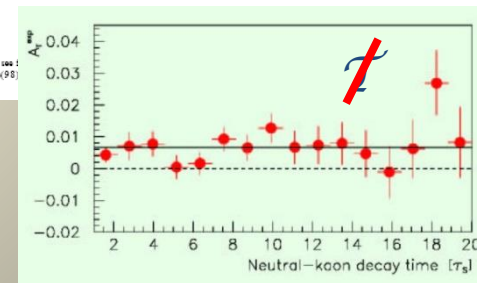
First direct observation of time-reversal non-invariance in the neutral-kaon system

CPLEAR Collaboration

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

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^e LEP 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
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^k CPPM, IN2P3-CNRS at Université d'Aix-Marseille II, France
^l CERN, IN2P3-CNRS, Orsay, France
^m Paul Scherrer Institut (PSI), Switzerland
ⁿ CEA, DSM / DAPNIA, CE-Saclay, France
^o Royal Institute of Technology, Stockholm, Sweden

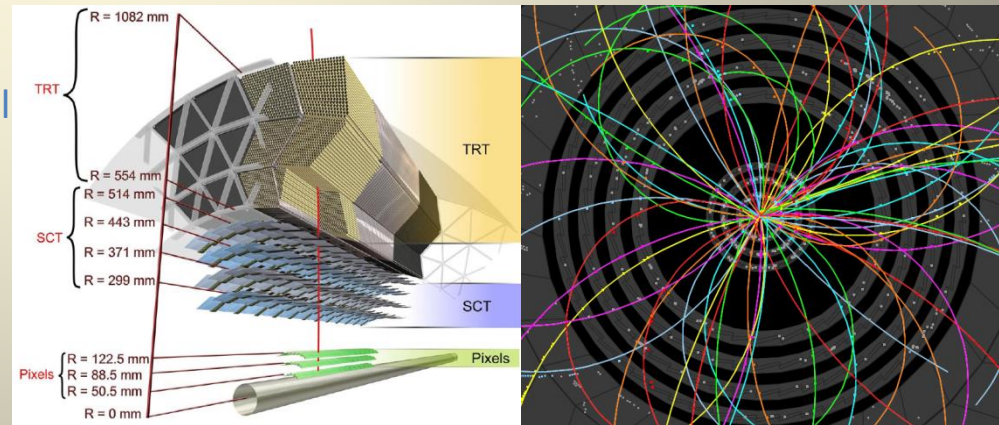
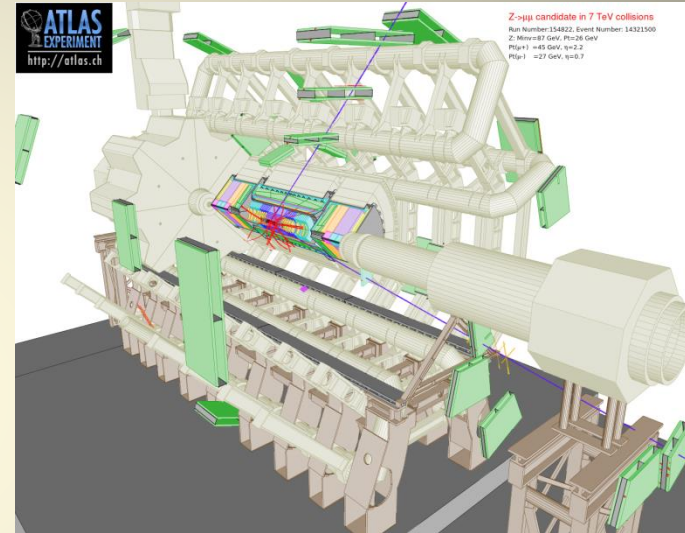
0370-2693/98/\$ - see front matter © 1998 Elsevier B.V. All rights reserved.



History of Si@CERN– ATLAS

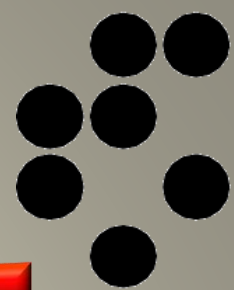
1996-

- With CPLEAR completed looked for opportunities for the future
- Discussions with CMS and ATLAS tracking
 - Opted for ATLAS
- Slovenian group member of ATLAS collaboration since 1996 (148th institution admitted)
- Main construction effort – building the SemiConductor Tracker - SCT, part of the particle tracking system - Inner Detector
- CORE investment ~1.7 MCHF
- After completing SCT taken on additional responsibilities
 - Beam Conditions Monitor
 - Beam Loss Monitor
 - Radiation Monitor

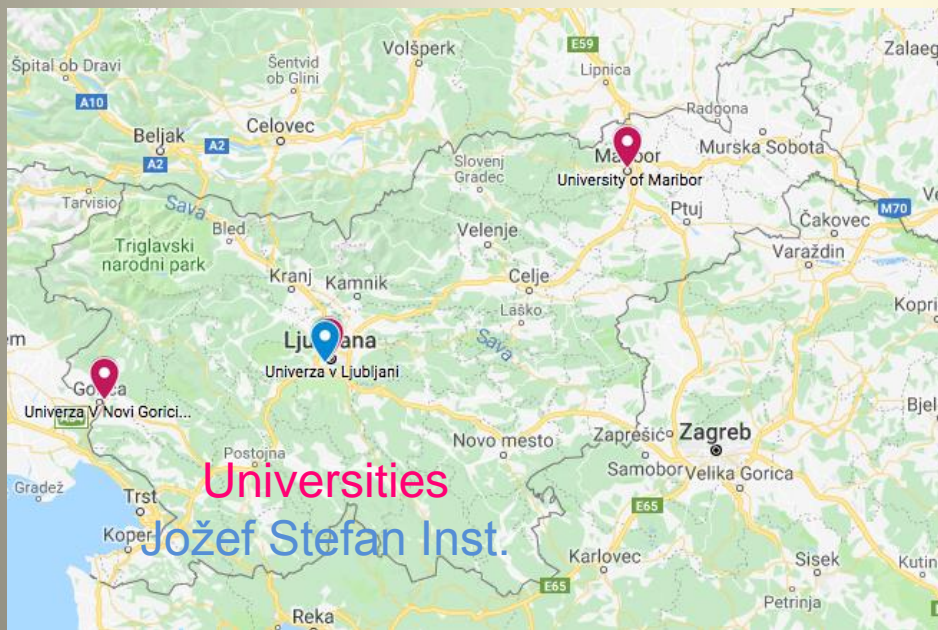




HEP in Slovenia Today



- The Slovenian HEP community is composed of researchers from Jožef Stefan Institute and three Universities (Ljubljana, Maribor, Nova Gorica)
 - Experimental and Theoretical Particle Physics effort led by JSI
 - Astro-Particle by University of Nova Gorica (spawned off PP)



- Experiment (PP&AP):
~40 researchers, including
~10 faculty and ~10 PhD
students
- Theory: ~10 researchers,
4 faculty, 4 students
- Faculty staff holds part-
time positions at JSI



SiHEP Today: Experiment

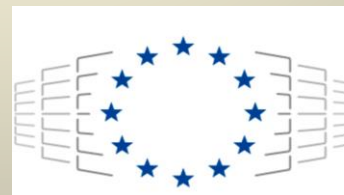


- Led by Experimental Particle Physics Department of JSI
 - Head count: ~30 researchers
- Currently active in two major HEP collaborations
 - ATLAS at the LHC in CERN
 - Belle2 at Super-KEKB in KEK (recognized exp. @CERN)
- Detector development
 - Also as part of two R&D collaborations at CERN
 - RD-42: diamond detectors, RD-50: radiation-hard silicon detectors
 - Technical associates of LHC-B
- Computing



SiHEP@CERN: Computing

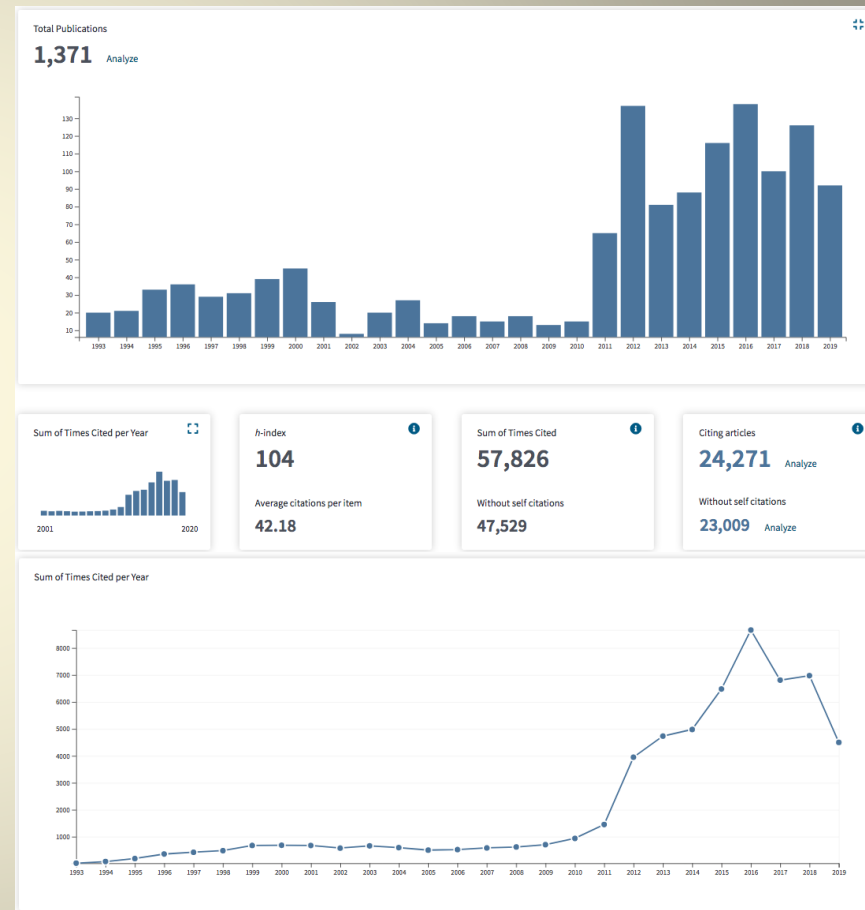
- Joined WLCG in 2003
 - Participation in EGEE I, II, III, EGI projects
 - Member of Nordugrid since 2010
- Establishment of Slovenian National Grid Initiative SLING in 2010
 - To promote grid/distributed computing in Slovenia
 - General purpose cluster/HPC at ARNES using grid middleware to serve Slovenian science
- SiNET TIER-2 Centre
 - Site dedicated to ATLAS and Belle2
 - 6700 cores, storage: 4.2 PB as a part of Nordic Tier-1 dCache (~40% ATLAS space), 1.2 PB for Belle2
 - 20Gb/s connectivity to Geant LHCONE
 - Contributing 2-3% to ATLAS
- EuroHPC Vega
 - 30M EUR project to establish a national competitive HPC centre (RIVR) in Slovenia
 - Sourced from EC cohesion funds 2018-2020, located in Maribor
 - All SLING members participate in design, procurement and operation
 - A significant part will be used by HEP experiments,

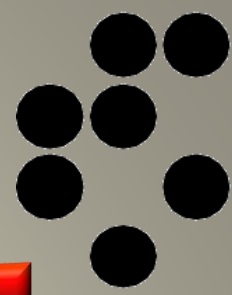


EuroHPC
Joint Undertaking

SiHEP@CERN: Scientific Return

- During the 44 years of scientific collaboration with CERN
 - ~1400 scientific papers published
 - >900 by ATLAS
 - ~58000 citations in SCI database
 - 22 BSc, 16 MSc and 24 PhD theses
 - Participation in CERN-led EU FP
 - EGEE, MC-PAD, AIDA, AIDA-2020
 - Several fellowships and associate-ships granted
- CERN initiated Slovenian HEP and although no longer CERN-exclusive, Slovenian HEP has benefitted enormously from this collaboration

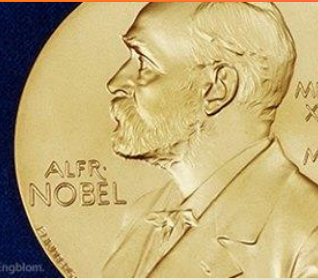




Nobel Prize

2013 NOBEL PRIZE IN PHYSICS

François Englert
Peter W. Higgs



© The Nobel Foundation, Photo: Lovisa Engblom.

“for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN’s Large Hadron Collider”.



François Englert and Peter W. Higgs first met at the seminar in CERN on July 4th 2012, when ATLAS and CMS revealed their results on the evidence of a new boson with properties consistent with the Higgs boson of the Standard Model.



SiHEP@CERN: Industrial Participation



- Limited to experiments where Slovenia participated
- ATLAS experience
 - About 1.2 MCHF out of 1.7 MCHF CORE investment returned to Slovenia
 - Almost exclusively to **Elgoline** Ltd.
 - Low-mass tapes
 - Large scale heater pads
 - Conventional patch panels
- Adequate industrial return thus possible
 - Requires major effort by researchers to identify and help developing the products
- Longer term return as CERN member state ?
 - Continued contribution to experiments (ATLAS)
 - Contribution to machine and its upgrades (follow-up talk by ILO)



SCT: Large Dimension FPC

- SCT modules need supply for sensors readout and optical transmission
 - 16 lines up to 1 A current and 500 V voltage rating
 - No space available for round cables
 - Solution – supply by Flexible Printed Circuit tapes
- Additional requirements
 - Radiation dose up to 100 kGy – radiation hard materials: Kapton®
 - Minimal material in tracker – aluminium as conductor (4x better than Cu)
 - Length up to 4 metres
- Show-stopper(s)
 - Few manufacturers of FPC on aluminium-Kapton® laminates
 - Technology for sizes over 1.8 m not available

Solution

- Custom technology development for FPC production on aluminium-Kapton® laminates
- Developed by JSI and ELGO-LINE, Cerknica in collaboration with several local partners

NTC JSI

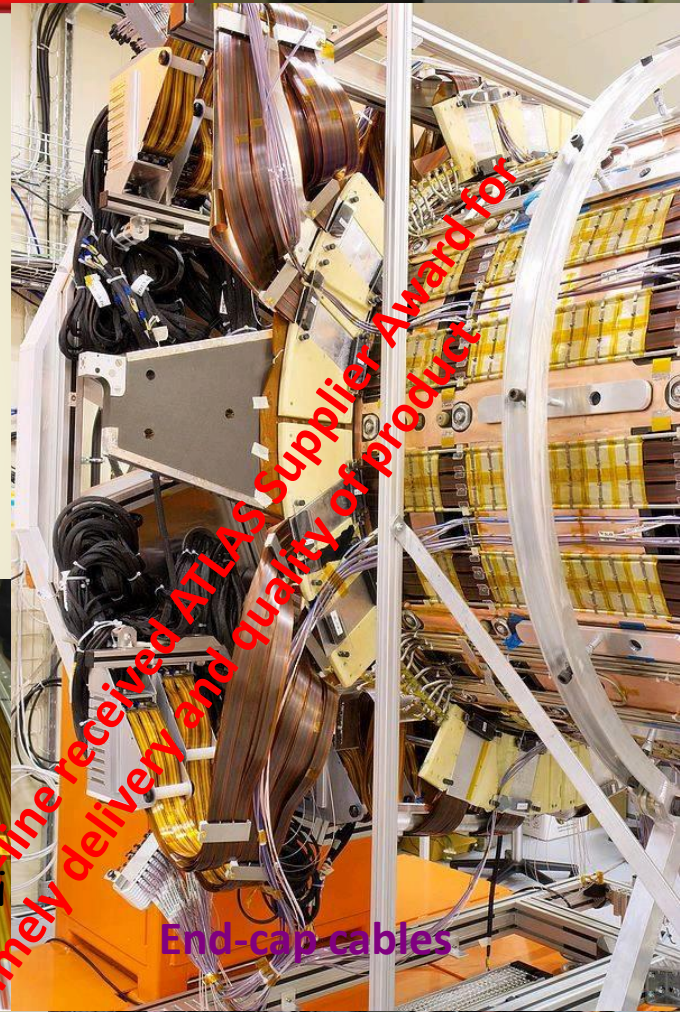
Balder Ltd., Ljubljana

FDS Research Ltd., Trzin

Apel Ltd., Ljubljana

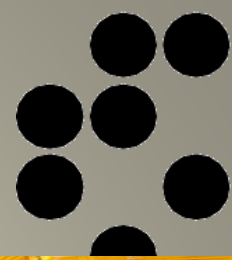


Cutti
Apel



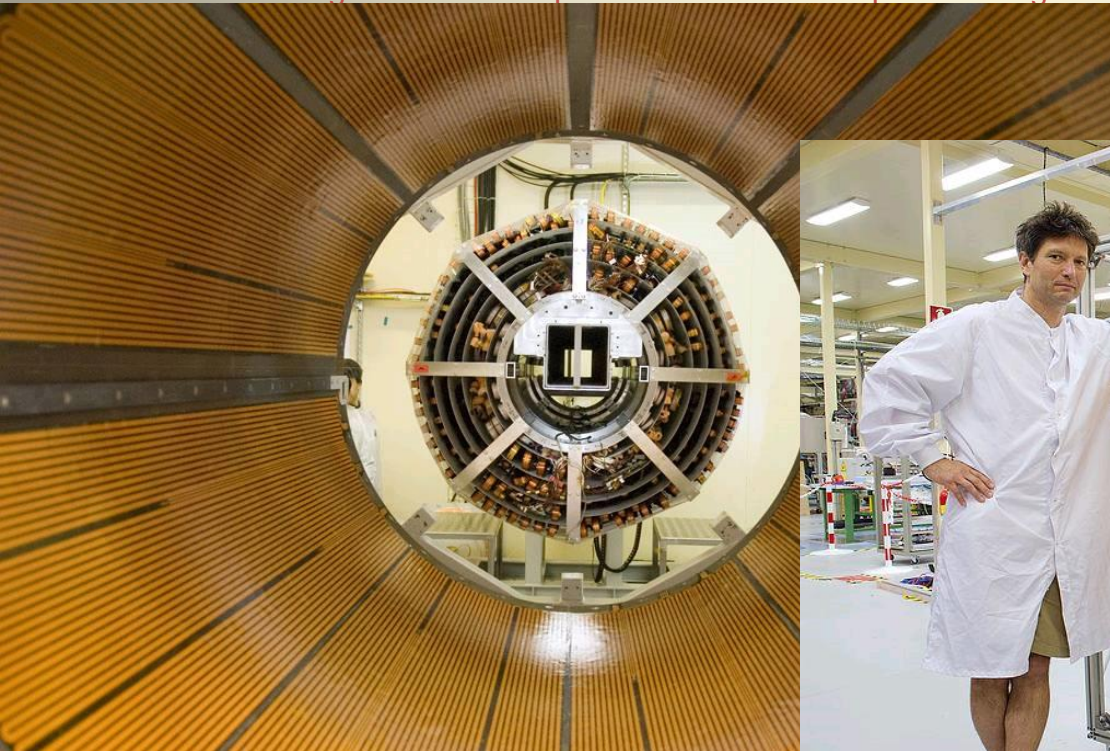
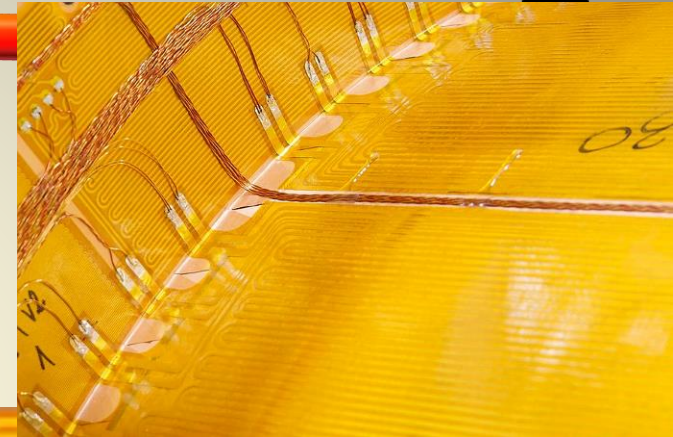
End-cap cables

ELGO-LINE received ATLAS Supplier Award for timely delivery and quality of product



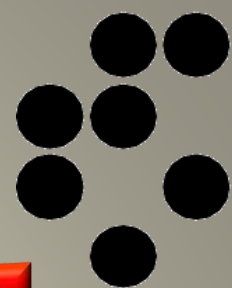
SCT: Large Scale Heater Pads

- SCT operates at -7°C , TRT at 20°C
 - Thermal barrier between the two detectors
 - Thermal neutrality required
 - Enclosure cooled to -7°C on SCT, heated to 20°C on TRT side
 - Need large scale heater pads with $\sim 200\text{ W/m}^2$ power rating





Elgoline: Financial Return

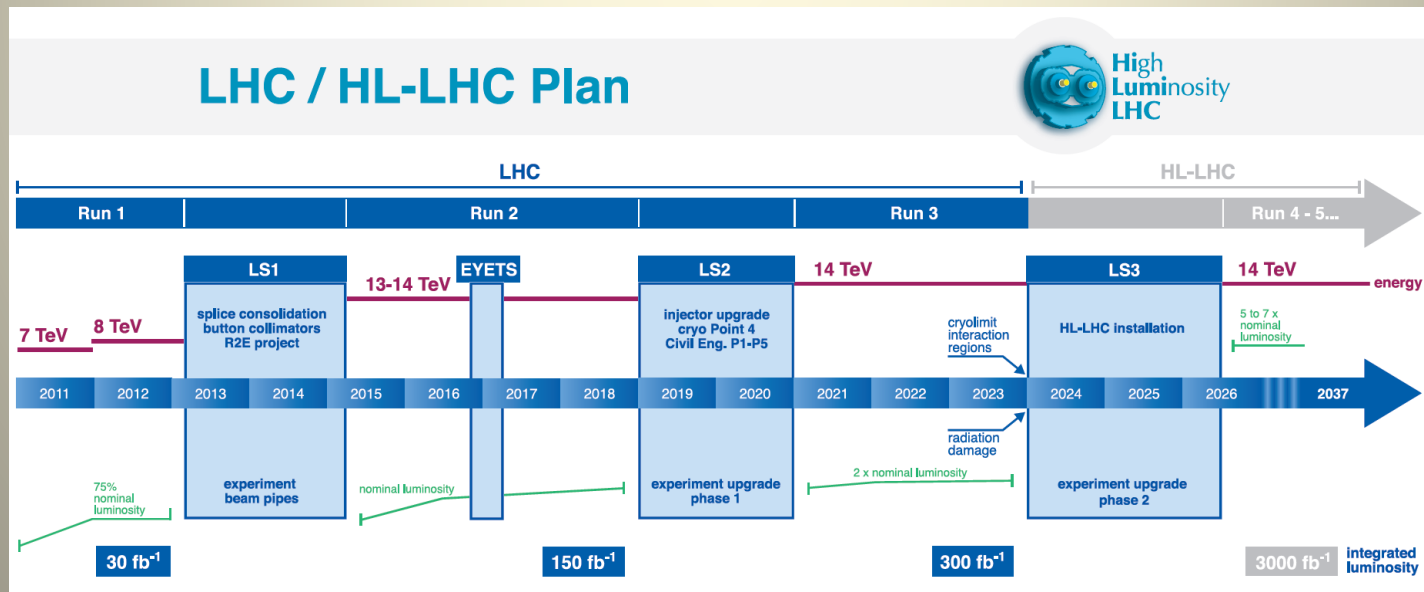


* @	Number	Type	Short Description	Creator	Created	Budget Codes	Assigned to	Total
☒	5655028	DAI	Spare heater pads for IDEPs	David ROBINSON (EP-UAT)	30.04.2014	T577010		16,119.22
☒	5546594	DAI	Flexible circuits	Marko MIKUŽ	22.01.2014	T549500		4,253.40
☒	5449196	DAI	Flexible circuits	Marko MIKUŽ	11.10.2013	T549500		3,548.25
☒	5258252	DAI	Flexible boards for VATA chip	Marko MIKUŽ	04.04.2013	T148200		4,763.24
☒	4324615	DAI	Multilayer flexible/rigid boards	Vladimir CINDRO	18.03.2010	T148200		4,441.68
☒	4215049	DAI	Rigid/flex circuits	Marko MIKUŽ	19.10.2009	T148200		4,770.99
☒	4106732	DAI	Flexible interconnect boards	Marko MIKUŽ	25.05.2009	T148200		4,698.36
☒	2906713	DAI	NINO PC boards	Marko MIKUŽ	26.11.2008	T148200		4,551.11
☒	2898880	DAI	PC boards	Marko MIKUŽ	17.11.2008	T549500		4,637.23
☒	2683631	DAI	Beam pipe bellow heater pads	Marko MIKUŽ	15.02.2008	T577010		1,679.68
☒	2674627	DAI	IDEP CP heater pads	Marko MIKUŽ	06.02.2008	T577010		13,645.91
☒	2674572	DAI	IDEP outer anular plate heater pads	Marko MIKUŽ	06.02.2008	T577010		13,645.91
☒	2488893	DAI	IDEP outer anular plate heater pads	Marko MIKUŽ	28.05.2007	T577010		27,877.59
☒	2307593	DAI	SCT TE heater pads - replacement	Marko MIKUŽ	23.10.2006	T577030		1,595.00
☒	2284538	DAI	SCT TE heater pad - replacement	Marko MIKUŽ	26.09.2006	T577030		715.50
☒	2222549	DAI	Atlas SCT DPPF1 - add. order	Marko MIKUŽ	07.07.2006	T549500		2,234.58
☒	2186532	DAI	heaters for ID services feedthroughs	Marco OLCESE	29.05.2006	T577010		1,323.00
☒	2124371	DAI	Atlas SCT OTE heaters - add. order	Marko MIKUŽ	17.03.2006	T549500		11,225.50
☒	2082119	DAI	Atlas SCT EC TE heaters	Marko MIKUŽ	02.02.2006	T549500		44,267.08
☒	2017344	DAI	Atlas SCT EC OTE heaters	Marko MIKUŽ	09.11.2005	T549500		21,381.25
☒	2011316	DAI	Atlas SCT patch pannels DPPF1	Marko MIKUŽ	02.11.2005	T549500		15,273.05
☒	1995339	DAI	Atlas SCT patch pannels PPF1	Marko MIKUŽ	15.10.2005	T549500		13,477.18
☒	1918390	DAI	ATLAS SCT Low Mass Tapes Etching	Beniamino DI GIROLAMO	07.07.2005	T549500		197,683.98
☒	1894750	DAI	ATLAS SCT Low Mass Tapes Etching	Beniamino DI GIROLAMO	10.06.2005	T549500		40,614.07
☒	1892271	DAI	ATLAS SCT Low Mass Tapes Etching	Beniamino DI GIROLAMO	08.06.2005	T549500		39,865.27
☒	1827183	DAI	(DR-01061/EP/ATLAS) ATLAS SCT LM F-tapes - additional order	Marko MIKUŽ	11.03.2005	T549500		15,622.00
☒	1791755	DAI	TRT Heaters	Jane WAYWELL	27.01.2005	T541010		7,392.00
☒	1658185	DAI	Atlas SCT patch pannels TPPF1-C	Marko MIKUŽ	02.07.2004	T549500		11,009.00
☒	1554548	DAI	Atlas SCT patch pannels PPF1	Marko MIKUŽ	11.02.2004	T549500		25,200.00
☒	1488586	DAI	(DR-01061/EP/ATLAS) ATLAS SCT LM B-tapes - additional order	Marko MIKUŽ	20.11.2003	T549500		9,180.00
☒	1186007	DAI	(DR-01061/EP/ATLAS) ATLAS SCT Low-Mass Tapes	Marko MIKUŽ	17.12.2002	T549500		407,974.00

original ATLAS SCT order 407,974.00

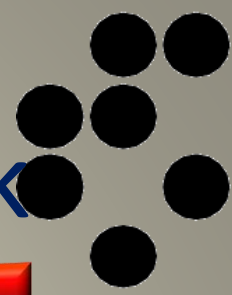
SiHEP@CERN: Prospects

- Long term experimental HEP commitments at CERN
- ATLAS and its upgrades
 - Expect at least 15y of successful physics at (HL)LHC
 - R&D for HL-LHC finished
 - TDR's approved, upgrade MoU's about to be signed

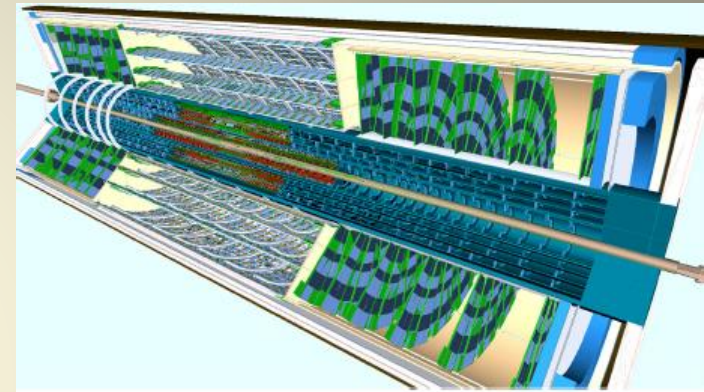


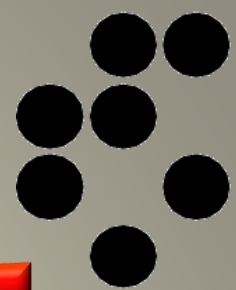


SiHEP contribution to ATLAS ITk



- ITk Strips about 2x larger than ATLAS SCT
 - 165 m² of instrumented silicon wafers
 - Focus on end-cap
- Bus tapes – flexible circuits
 - Cu/Kapton[®], double-sided, dimensions 65x35 cm²
 - Used to route the power (HV and LV), data, ground, clock and some control to silicon strip modules on a end cap petal
 - Specification drawn by the ATLAS ITk strip upgrade project
 - The circuit has to exhibit a 1/1000 dimensional stability, and be radiation hard up to 660 kGy
 - The data transmission line has to be 100 +/- 10 Ohm and the signal attenuation less than 14 dB
- Developed by Jožef Stefan Institute in collaboration with Elgoline Ltd.
 - Expected procurement in the following 3 years





Conclusion

- Slovenian scientists perfectly integrated into the CERN community
- Science can ease in the industrial participation through active collaboration of industry with scientists
- Past achievements, present engagements and future directions guarantee stable and sustainable development in the decade to come