EIC interest from Czech republic perspective

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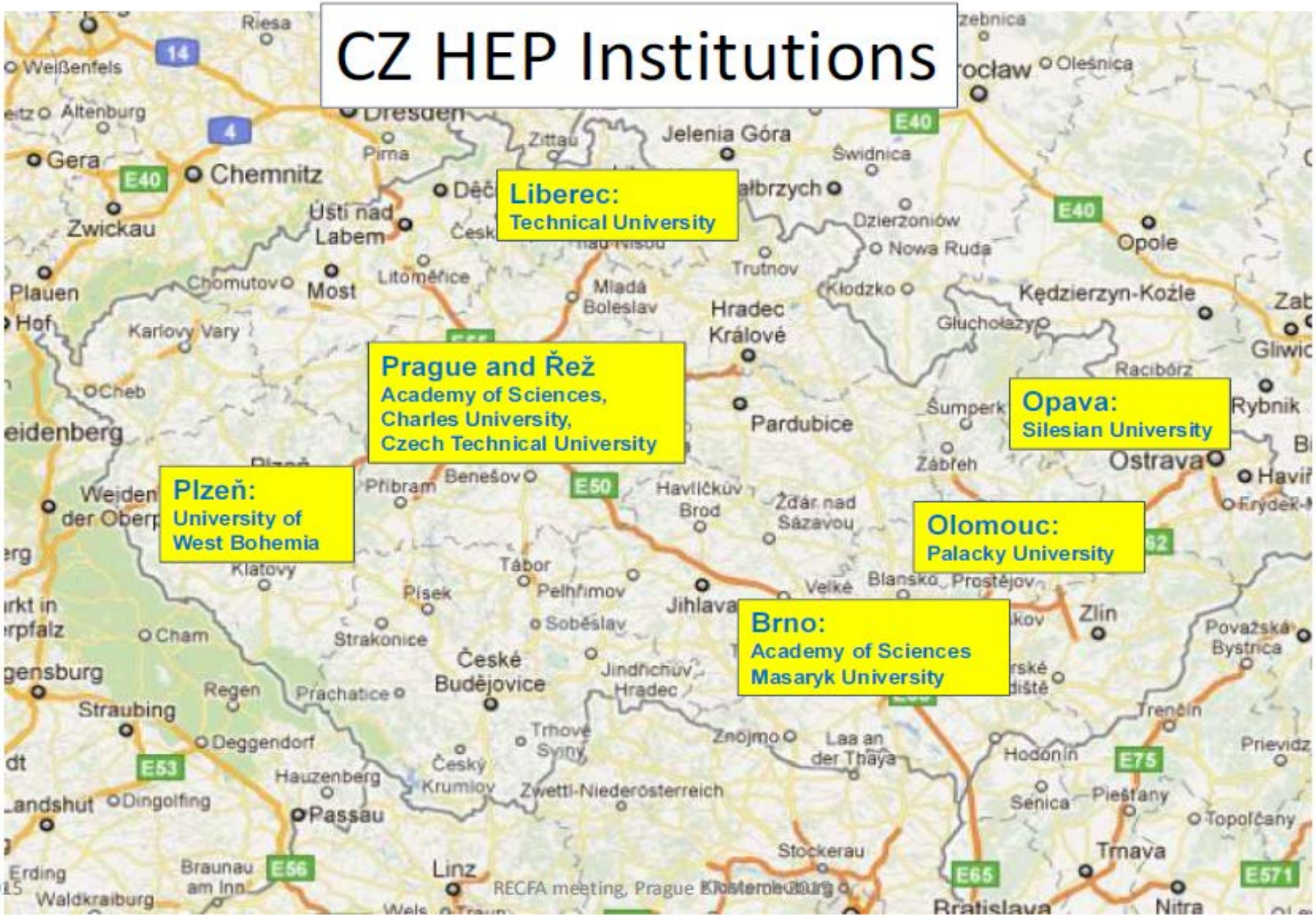
Czech Technical University in Prague

EIC Users Group Meeting, 15.-17. July 2020

CZ HEP Institutions



Landscape of Czech particle physics comunity

- **Czech Technical University in Prague** (ATLAS, ALICE, **STAR, sPHENIX** D0, COMPASS, NOVA, FAIR, neutrinos, phenomenology)
- **Charles University** (ATLAS, CMS, **sPHENIX**, FAIR, BELLE, D0, theory)
- **Physics Insitute** of Czech Academy of Sciences (ATLAS, AUGER, ALICE, D0, neutrinos, phenomenology)
- **Nuclear Physics Institute** of Czech Academy of Sciences (**STAR**, ALICE, FAIR, neutrinos, phenomenology)
- individual interest in universities in Olomouc, Opava, Plzeň

- In total about 300 czech scientists involved in particle physics
- ICHEP2020 28.7 – 6.8. 2020 http://ichep2020.org/

Current membership in EIC User Group

- **Czech Technical University in Prague** (Jaroslav Bielčík)

  11 experimentalists + 3 phenomenology
- **Charles University** (Miroslav Finger)

  7 experimentalists

- **Nuclear Physics Institute of Czech Academy of Sciences** (Jana Bielčíková)

  4 experimentalists

- Main Physics Interest: jets, heavy flavor and quarkonia
- Detector development: $PbWO_4$ based EMC and microvertex detectors
- Phenomenology of eA/ep collisions

Current funding

- Czech participation in the EIC project is a continuation of participation of Czech groups in present RHIC BNL experiments

- Main funding for Czech – BNL collaboration is from Large Research Infrastructure project LM2018109 and scientific grants

  Brookhaven national laboratory – participation of the Czech republic (BNL-CZ)

  (2016-2019) 2020-2022

- Part of goverment priority programme operated by Min. Youth Education Science Roadmap of Large Research Infrastructures of the Czech Republic 2016-2022

https://www.vyzkumne-infrastruktury.cz/en/roadmap-of-large-research-infrastructures-of-the-czech-republic/

Potential for EIC detector development

Teams from:

- Charles University and
- Czech Technical University in Prague, Center of Applied Physics and Advanced Detection System (CAPADS@CTU Prague) can be involved in the R@D, design and development of:

➢ Electromagnetic Calorimetry (EMC) based on Lead Tungstate Crystals - $PbWO_4$ (PWO) in cooperation with production company CRYTUR Turnov

PWO quality requirements are driven by request for

- high light output
- radiation hardness
- no slow components
- optimum homogeneity

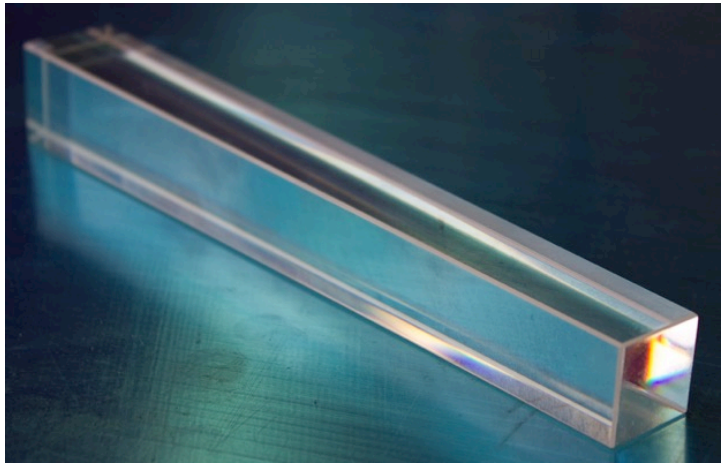
for calorimetry of CERN, FAIR (PANDA), JLab, RHIC, EIC …experiments.

➢ Micro Vertex Detector (MVD), Pixel-Subsystem, the electronics for tracking detectors

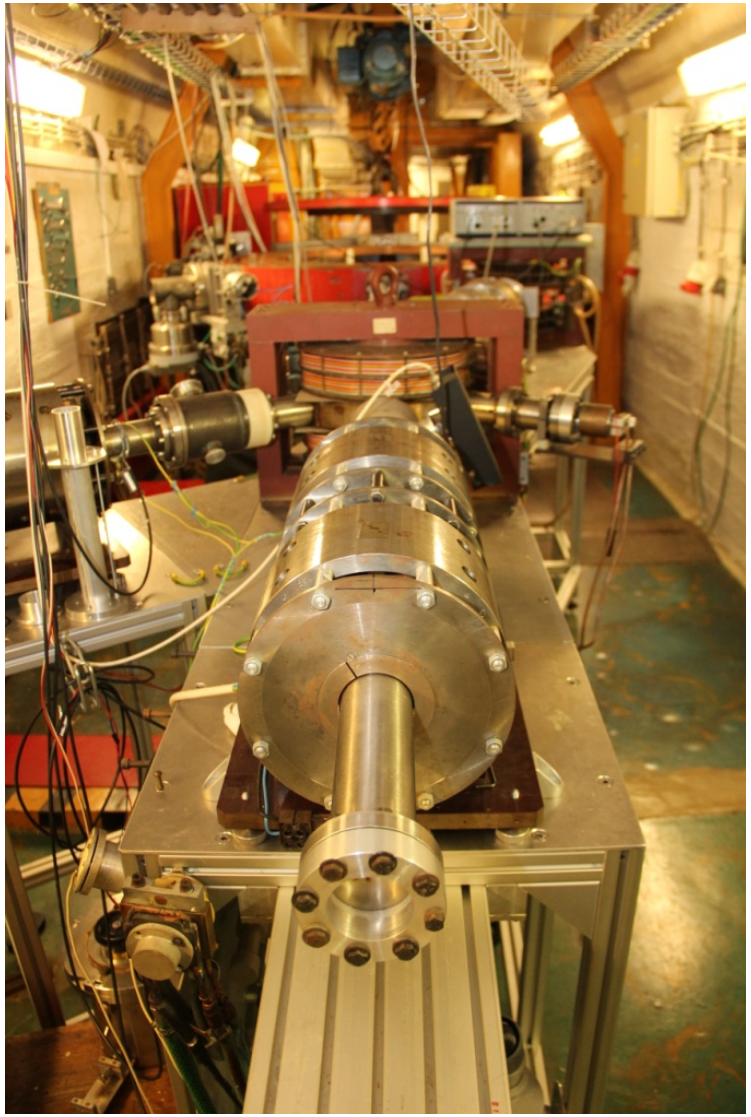
Production of PWO crystals at CRYTUR – Turnov, Czech Republic

- long tradition in the production of inorganic scintillators. Restart of PWO production in 2014
  - ➢ production based on Czochralski technology
  - ➢ network: close collaboration with:

  Charles U. Prague, RINP Minsk, UNI Giessen, JLab Newport News, IPNO Orsay



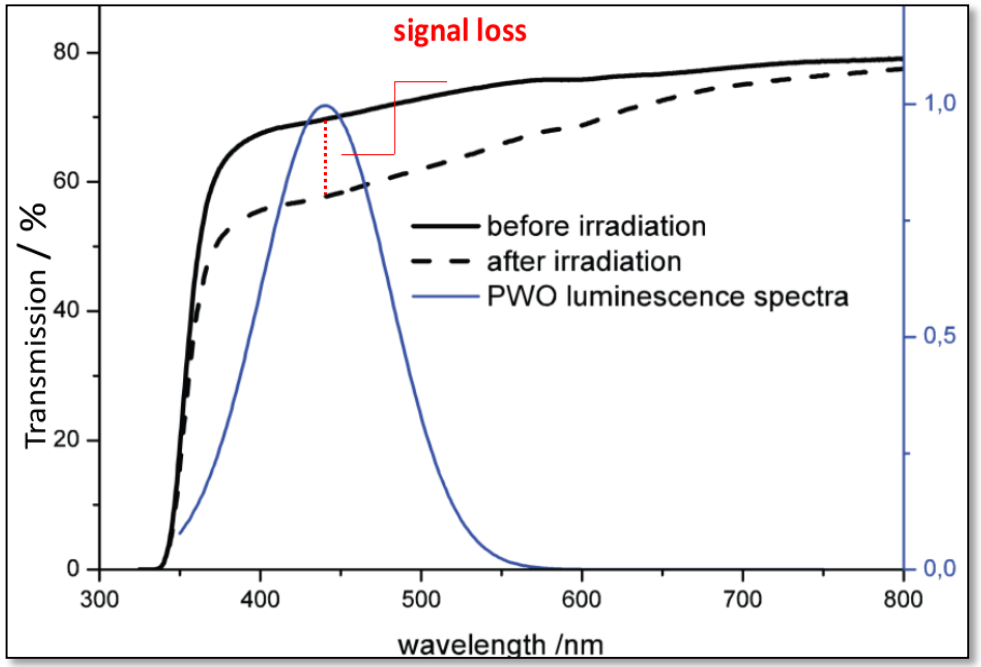
Radiation hardness tests of PWO ingots @ Microtron Lab of NPI, Prague



electrons: 5.5 MeV < E_e < 16.6 MeV

- to create illumination with Bremsstrahlung homogeneous illumination of the (rotated) sample
- integral beam intensity adjusted to radiation damage caused by illumination with g-rays (^{60}Co, 30Gy)
- illumination for 5-10 minutes immediate measurements of the optical transmission before and after irradiation)

Radiation hardness testing

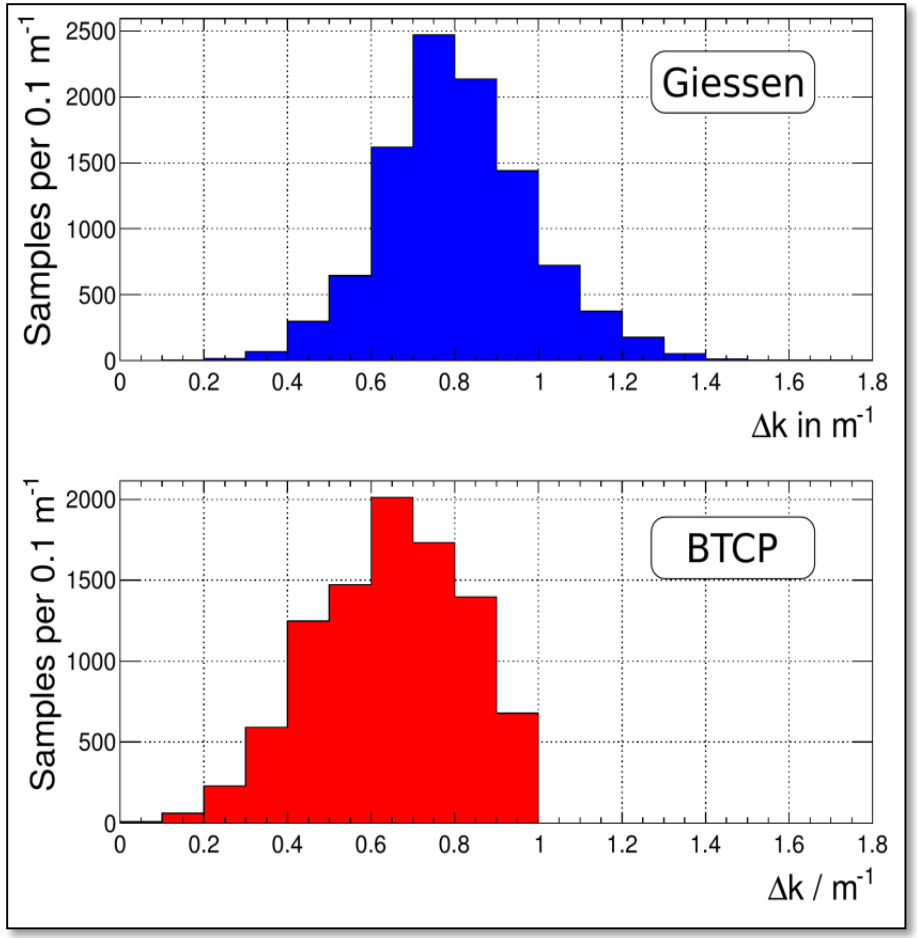


tested using γ-rays: ~ 1.2 MeV ^{60}Co

integral dose: 30Gy

$$\Delta k = \ln\left(\frac{T_{bef}}{T_{after}}\right)\cdot\frac{1}{d}$$

radiation-induced coefficient

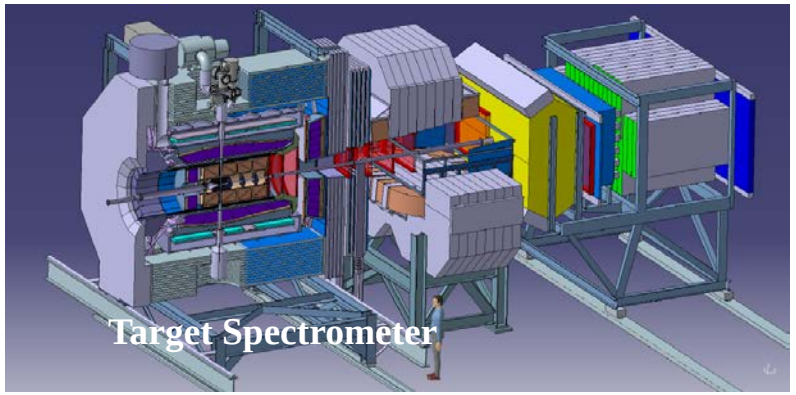


acceptance limit: Δk < 1.1 m^{-1}

most critical parameter due to operation at -25°C

Target Spectrometer @ PANDA

based on high-quality PWO-II



- physical goals of PANDA require further development

	PWO-I (CMS)	PWO-II (PANDA)
luminescence maximum, nm	420	420
La, Y concentration level, ppm	100	40
expected energy range of EMC	150MeV - 1TeV	10MeV - 10GeV
light yield, phe/MeV at room temperature	8-12	17-22
EMC operating temperature, °C	+18	-25
energy resolution of EMC at 1GeV, %	3,4	2,0

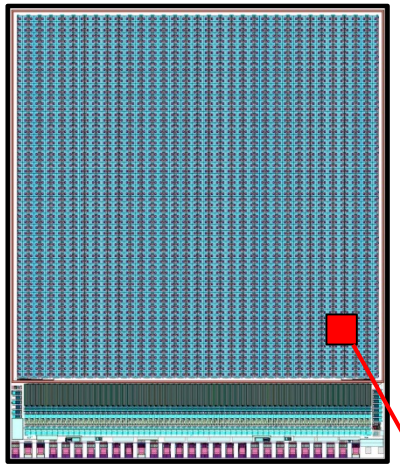
Pixel detector development

X-CHIP-03

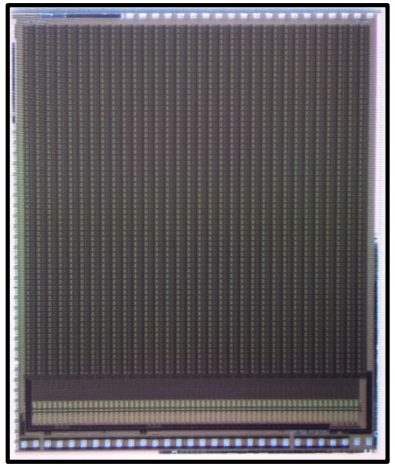
Sensor parameters

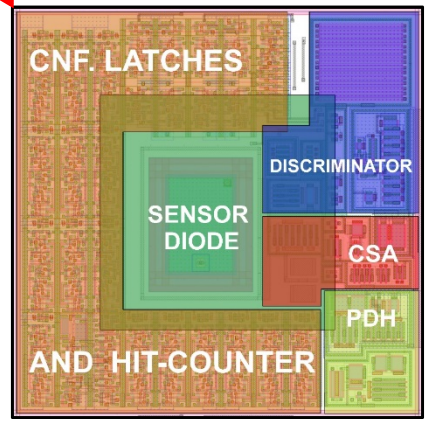
Matrix dimensions:	64×64 pixels
Pixel size:	60×60 µm^2
Hit counting range:	16 bit
ADC resolution:	10 bit
Readout speed:	400 Mbit/s* (LVDS)
Readout modes:	CMOS and LVDS
Technology:	SOI CMOS 180 nm
Supply voltage:	1.8 V
Sensor bias voltage:	-150 V
Chip dimensions:	3.96×4.76 mm^2
Power consumption:	< 50 mW (depends on configuration)

design submitted 05/2017



chips received 12/2017



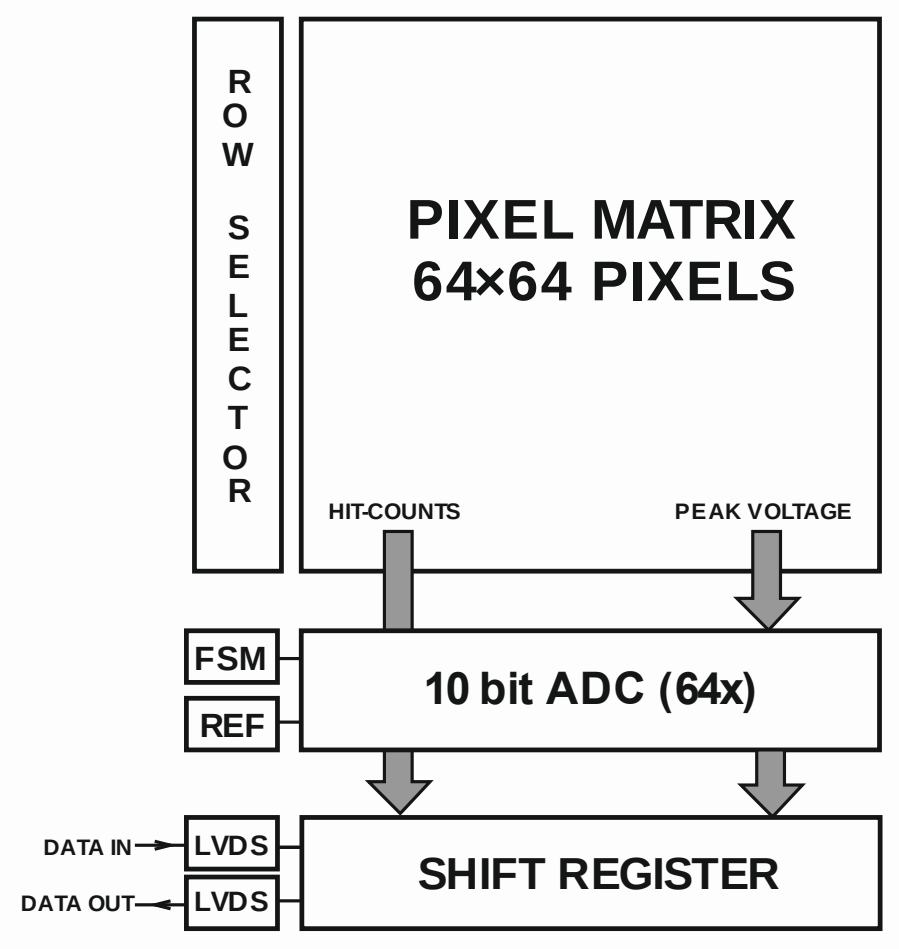


Submitted publication:

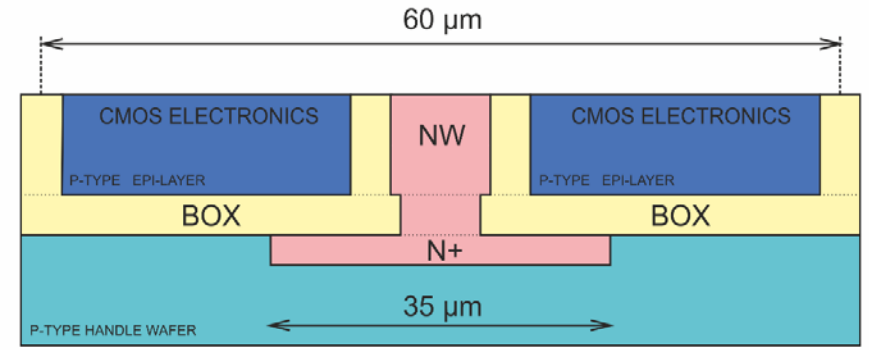
M. Havranek et al.: X-CHIP-03: *SOI MAPS Radiation Sensor with hit-counting and ADC mode*, IEEE NSS-MIC Conference Record, 2018.

Sensor architecture

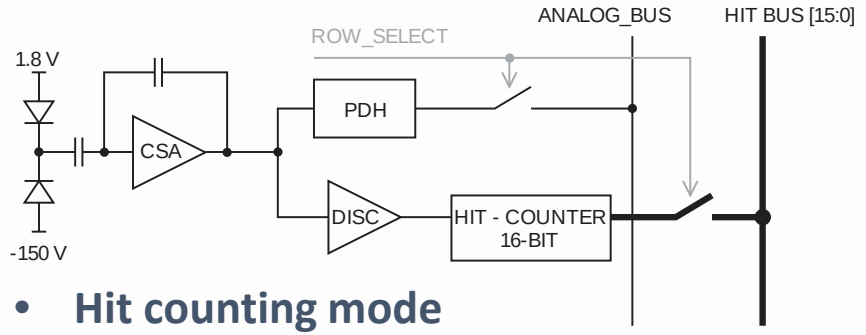
sensor schematic



pixel cross section

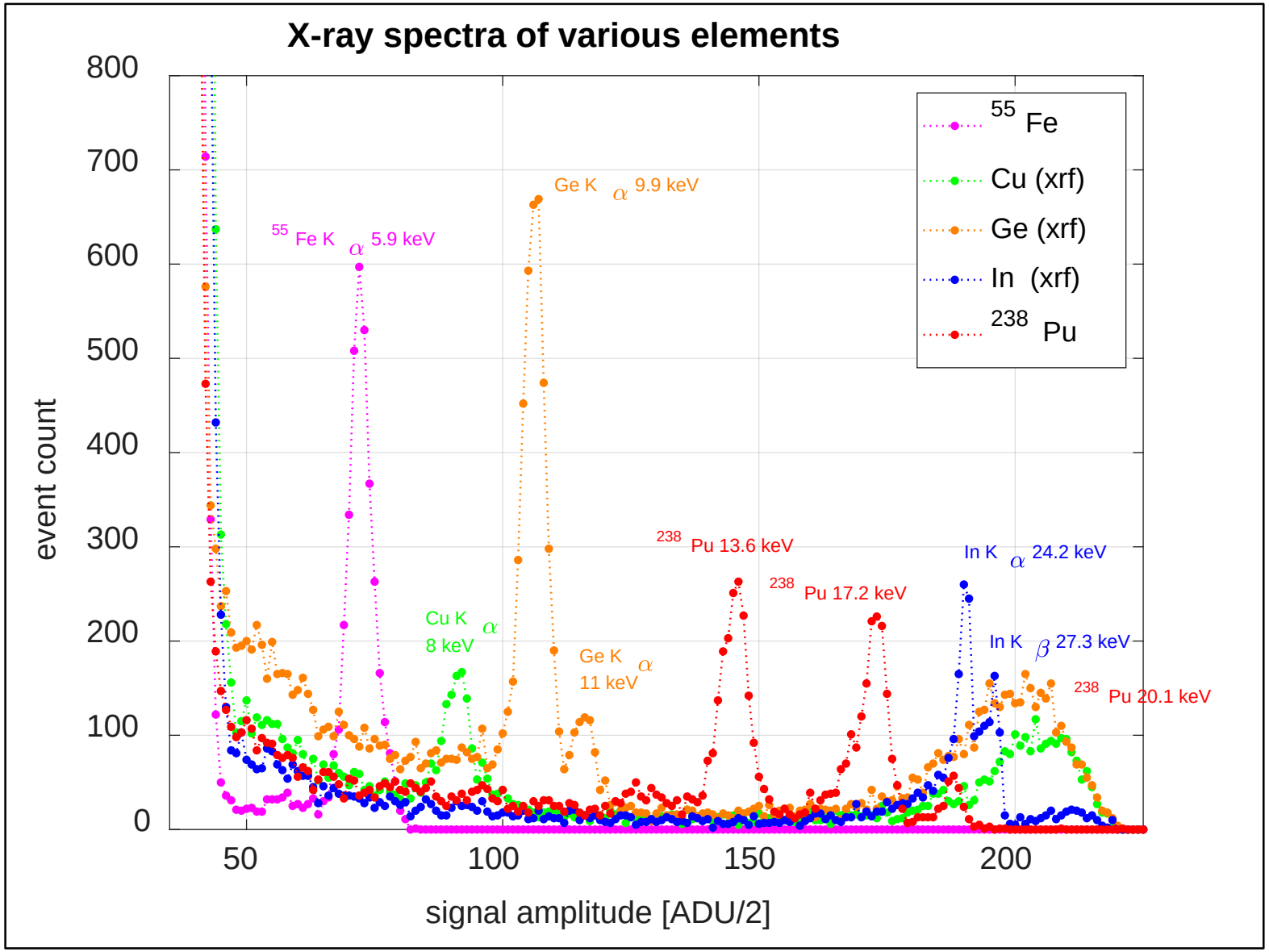


pixel block schematic



- Hit counting mode
- ADC mode measuring deposited energy in the pixel (spectrometry)

Spectrum measurement in ADC mode



Detector R&D references

X-CHIP-03: SOI MAPS Radiation sensor with hit-counting and ADC mode
M. Havranek, T. Benka, M. Hejtmanek, Z, Janoska, D. Lednicky, V. Kafka, M. Marcisovska, M. Marcisovsky, G. Neue, P, Svihra,L. Tomasek, P. Vancura, V. Vrba
IEEE Nuclear Science Symposium and Medical Imaging Conference, Sydney 2018

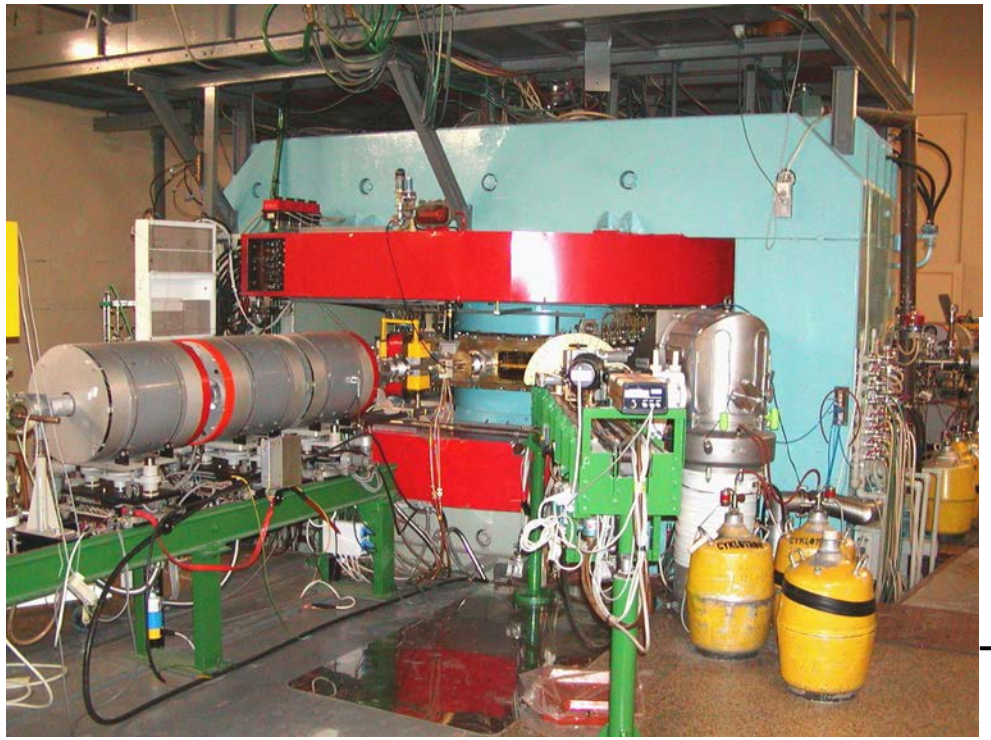
High-Quality Lead Tungstate Crystals for PANDA Produced at CRYTUR
R.W. Novotny. K.-T. Brinkmann, V. Dormenev, et al.
IEEE TRANSACTIONS ON NUCLEAR SCIENCE Volume:65 Issue:8 Pages 1998-2003 Part:2, Published **AUG 2018**

High-Quality Lead Tungstate Crystals for PANDA Produced at CRYTUR
R.W. Novotny. K.-T. Brinkmann, V. Dormenev, M. Finger, J. Houzvicka, M. Korjik, P. Krist, S. Ochesanu, D. Petrydes and H.-G. Zaunick
IEEE NSS/MIC 2017

High-Quality Lead Tungstate Crystals Available for EM-Calorimetry in High-Energy Physics
R. W. Novotny, K.-T. Brinkmann, D. Chvatil, V. Dormenev, M. Finger Jr., M. Finger, J. Houzvicka, P. Krist, M. Korjik, S. Ochesanu, D. Petrydes, I. Prochazka, H.-G. Zaunick
IEEE NSS/MIC 2016

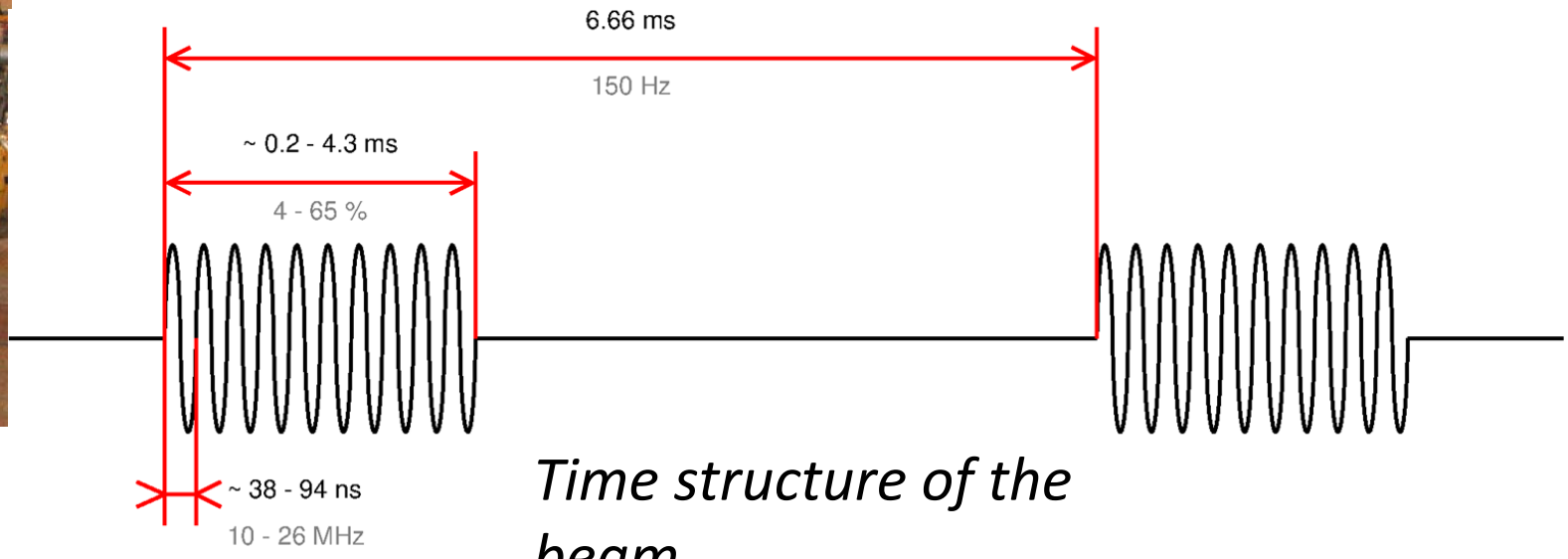
Radiation hardness testing of electronics

at the U-120M cyclotron of the Nuclear Physics Institute of CAS



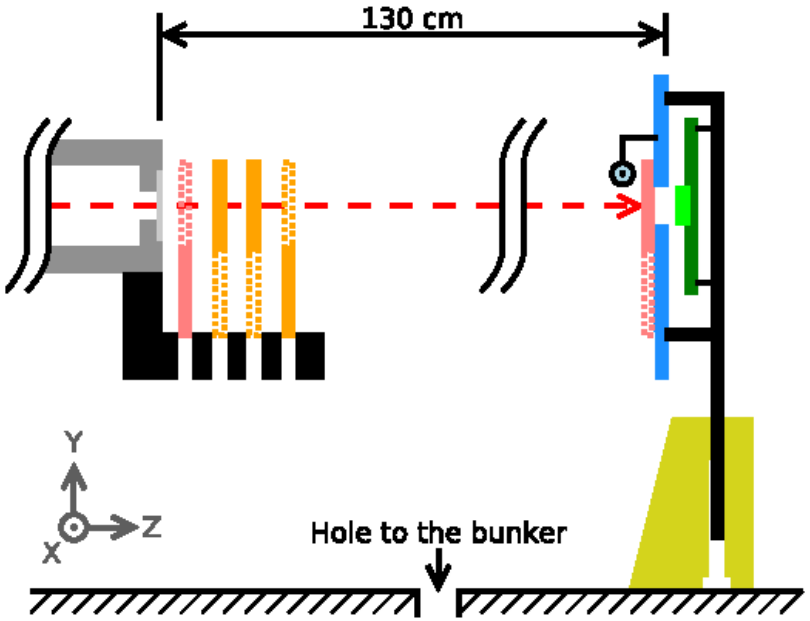
Beam parameters of the negative mode:

- protons
- Energy up to 35 MeV
- Current up to 50 µA
- RF 10-26 MHz with duty cycle 4%-65%

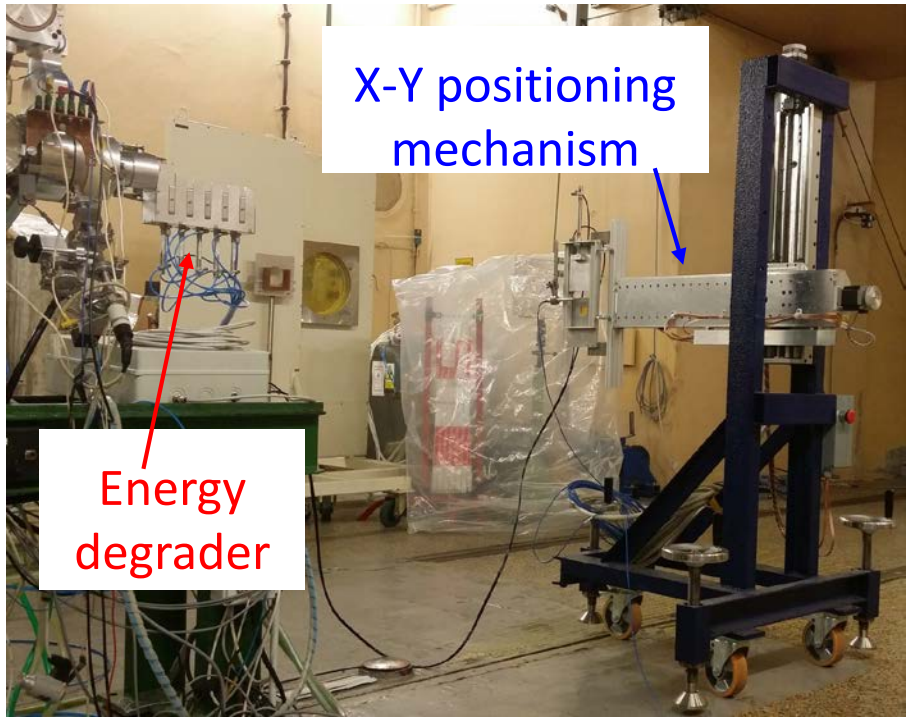


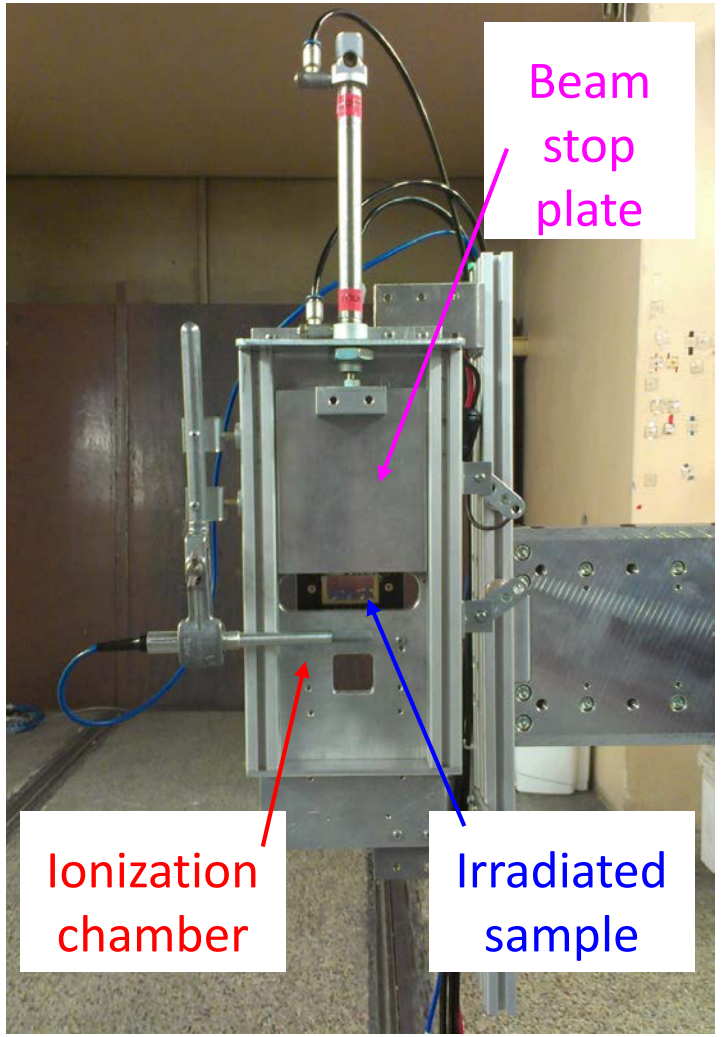
Time structure of the beam

Setup for irradiation



- Energy degrader plates (0.5 - 2 mm Al)
- Beam stop plates (8 mm Al)
- Shielding (8 mm Al)
- Ionization chamber
- Irradiated sample
- Shielded part of target
- X-Y positioning mechanism
- Beam pipe and its exit window
- Proton beam





- On-line monitoring of instantaneous flux, accumulated dose and fluence
- Remotely controlled energy degrader plates and beam stops
- Irradiation of silicon sensors, FPGAs, cables, scintillators, …

F. Křížek et al. - "Irradiation setup at the U-120M cyclotron facility", Nucl. Instr. Meth. Phys. Res. A 894 (2018) 87–95

EIC Phenomenology at CTU in Prague I.

- More than 50% of physics studied is related to EIC physics
- We participate in Yellow Report Physics Working Groups:
  - Inclusive Reactions
  - Exclusive Reactions
- We participate in YR Workshops
  - Presentation at 1st EIC YR Workshop, Inclusive Physics WG, M. Krelina
- We delivered numerical grids for MC Event generation for the Inclusive Physics WG

EIC Phenomenology at CTU in Prague II.

- Precise study of vector mesons production
  - EIC and its precise measurement of *ep* collisions could help identify $q\bar{q}$ potential, reveal D-Wave contribution or spin rotation effects
  - **M. Krelina, J. Nemchik**, R. Pasechnik, **J. Cepila**; Eur.Phys.J.C 79 (2019) 2, 154; 1812.03001 [hep-ph]
  - **J. Cepila, J. Nemchik, M. Krelina**, R. Pasechnik; Eur.Phys.J.C 79 (2019) 6, 495;: 1901.02664 [hep-ph]
  - **M. Krelina, J. Nemchik**, R. Pasechnik; Eur.Phys.J.C 80 (2020) 2, 9; 1909.12770 [hep-ph]
- Gluon saturation study
  - EIC will allow study the subnucleonic degrees of freedom representing regions of high-gluon density, so-called hot spots, in *ep* as well as in *eA*
  - **J. Cepila, J. G. Contreras**, J. D. Tapia Takaki; Phys.Lett.B 766 (2017) 186-191; 1608.07559 [hep-ph]
  - **J. Cepila, J. G. Contreras, M. Krelina**; Nucl.Phys.B 934 (2018) 330-340; 1804.05508 [hep-ph]
  - **D. Bendova, J. Cepila, J. G. Contreras**; Phys.Rev.D 99 (2019) 3, 034025; 1811.06479 [hep-ph]
  - **M. Krelina**, V. P. Goncalves, **J. Cepila**; Nucl.Phys.A 989 (2019) 187-200; 1905.06759 [hep-ph]

EIC Phenomenology at CTU in Prague III.

- Study of nuclear shadowing dynamics
  - EIC collisions energy will be enough high to study gluon shadowing, but too low to utilize long coherence length limit; therefore correction on finite coherence length should be applied
  - **Michal Krelina, Jan Nemchik;** Eur.Phys.J.Plus 135 (2020) 6, 444; 2003.04156 [hep-ph], https://zenodo.org/record/3470138
  - Numerical grids for structure functions for generation MC Event for the Inclusive group were delivered for various targets (p,d,He,Ca,Au,Pb,U); parametrisations KN20 at https://jeffersonlab.github.io/txgrids/_build/html/grids.html
- Investigation of Balitsky-Kovchegov equation
  - We developed and applied the impact parameter dependent Balitsky-Kovchegov equation whose effects could be studied in details at EIC
  - **J. Cepila, J. G. Contreras, M. Matas**; Phys.Rev.D 99 (2019) 5, 051502; 1812.02548 [hep-ph]
  - **D. Bendova, J. Cepila, J. G. Contreras, M. Matas**; Phys.Rev.D 100 (2019) 5, 054015; 1907.12123 [hep-ph]
- And other papers are on the way…

Summary

- Significant interest exists in EIC project
- Several groups already involved in EIC preparation
- Potential to contribute to detector R&D development and construction
- Well established phenomenology program

- Currently we are in process of formulation EoI of Czech institutions