Super Thin Metal Microstrip Detectors as Fixed Targets at LHC

V. Pugatch [1,2]

[1] Institute for Nuclear Research NASU, (KINR)

(KINR HEP Department @ LIA IDEATE)

[2] EMMI (GSI)

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Fixed Targets at LHC (operational and proposed).

- Physics Motivation
- Technical Realization

Gaseous Targets:

- SMOG (operational at LHCb)

Solid Targets:

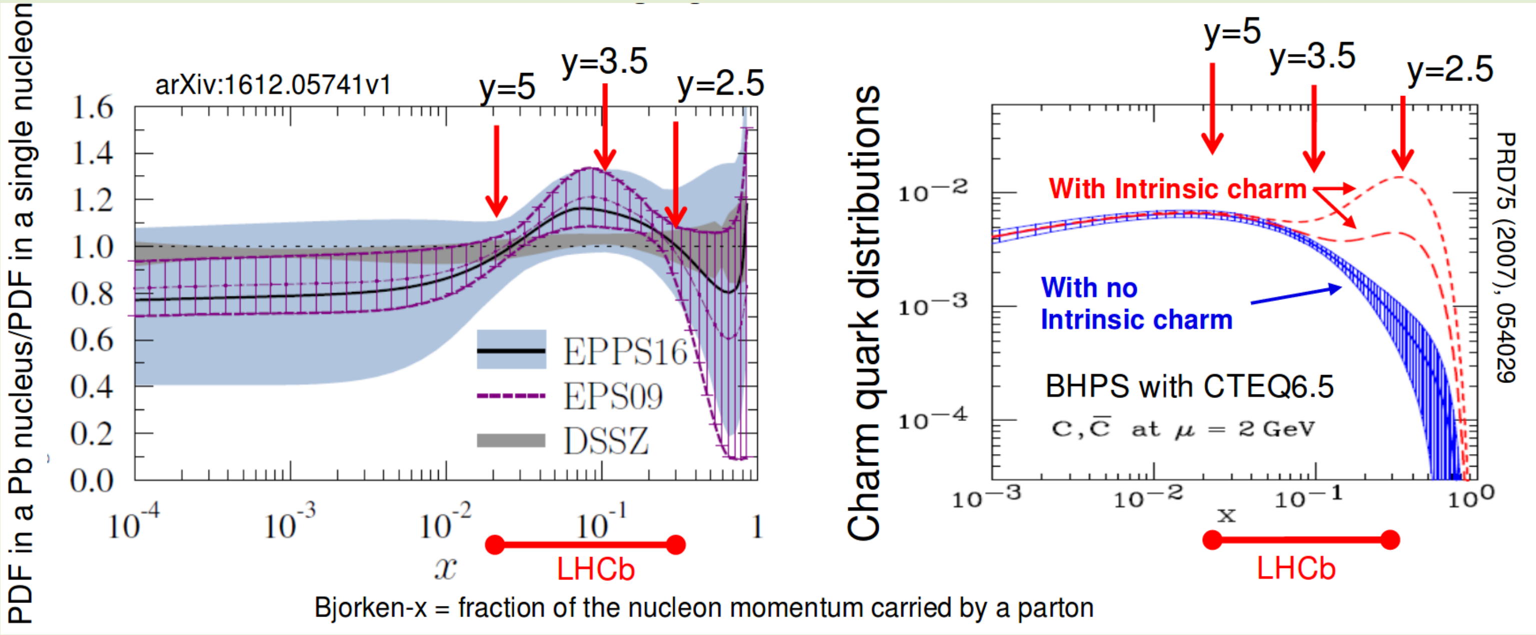
- AFTER (proposal)
- Bending Crystal (tests ongoing since many years)
- **Multi-target setup in a halo of the LHC beam (Proposal)**
  > Microstrip Metal Detectors-Targets (Current presentation)

Fixed-target heavy ion physics at LHCb

Motivation to perform fixed-target heavy ion physics at LHCb:

Access to intrinsic charm content

Access to nPDF in anti-shadowing region in the nucleon

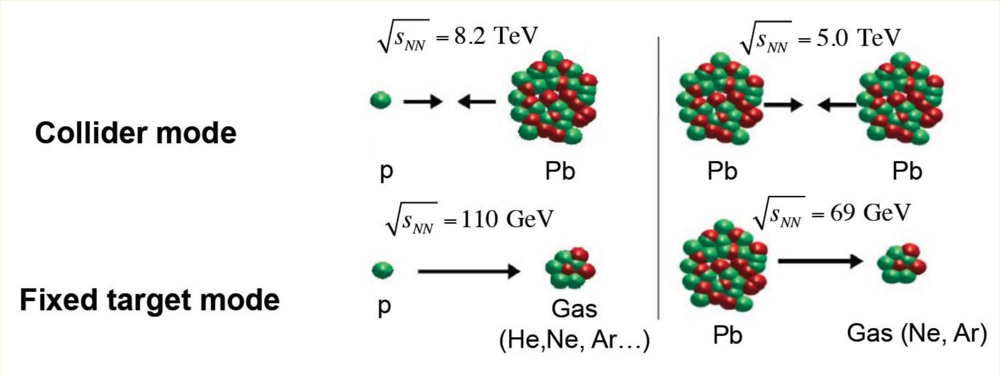


Forward measurement of hidden and open charm production (J/ψ,D $_0$ …) down to low p_T

Large rapidity coverage at large Bjorken-x

Heavy ion collisions studied by the LHCb detector

- **Physics Motivation**



On the way to QGP signatures:

- **Study collisions at various center-of-mass energies**
- **Explore different beam-target systems**
- **Compare results with pp collisions**

Nuclear modification factors

$$R_{p\mathrm{Pb}}(y^*, p_{\mathrm{T}}, \sqrt{s_{\mathrm{NN}}}) \equiv \frac{1}{A}\frac{\mathrm{d}\sigma_{p\mathrm{Pb}}(y^*, p_{\mathrm{T}}, \sqrt{s_{\mathrm{NN}}})/(\mathrm{d}y^*\mathrm{d}p_{\mathrm{T}})}{\mathrm{d}\sigma_{pp}(y^*, p_{\mathrm{T}}, \sqrt{s_{\mathrm{NN}}})/(\mathrm{d}y^*\mathrm{d}p_{\mathrm{T}})}$$

Comparison of p-pB and p-p data for prompt and non-prompt hadron production:

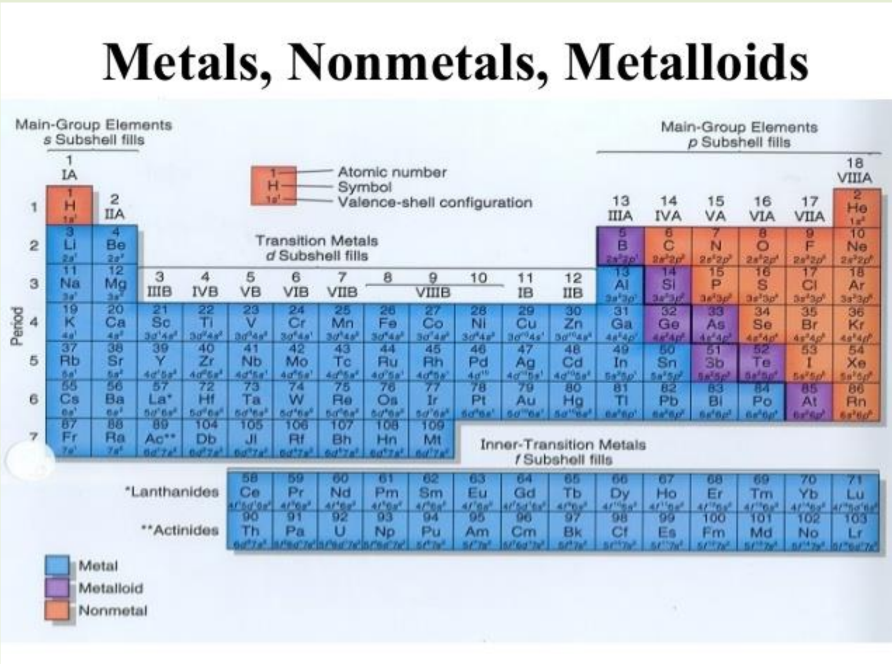
- **Expectation: production of J/ψ from B -mesons is less affected than prompt J/ψ**

- energy loss and shadowing

(J/ψ data agree with “energy loss + NLO shadowing”)

Extending range of nuclei and energies for heavy ions collisions at LHC

(proposal for Multi-Target setup in a halo of LHC beam)



Nucleus-nucleus collisions studied in HEP:

p-p ; p – Pb; p –Au; p – Ne; p – He; d – Au; Pb – Pb; …

Large, yet limited range for knowledge about an impact of the initial state on nucleus-nucleus collisions

Immense variety of metal targets-nuclei (BLUE color in the table):

^{6,7}Li (1^+, $3/2^-$); ^{9}Be ($3/2^-$); ^{12,13}C ($1/2^-$, 0^+); ^{27}Al ($5/2^+$); $^{46-50}$Ti (0^+ - $7/2^-$); ^{56}Fe (0^+); ^{63,65}Cu ($3/2^-$); $^{116, 117, 118, 119, 120}$Sn($0^+$) … up to ^{252}Cf

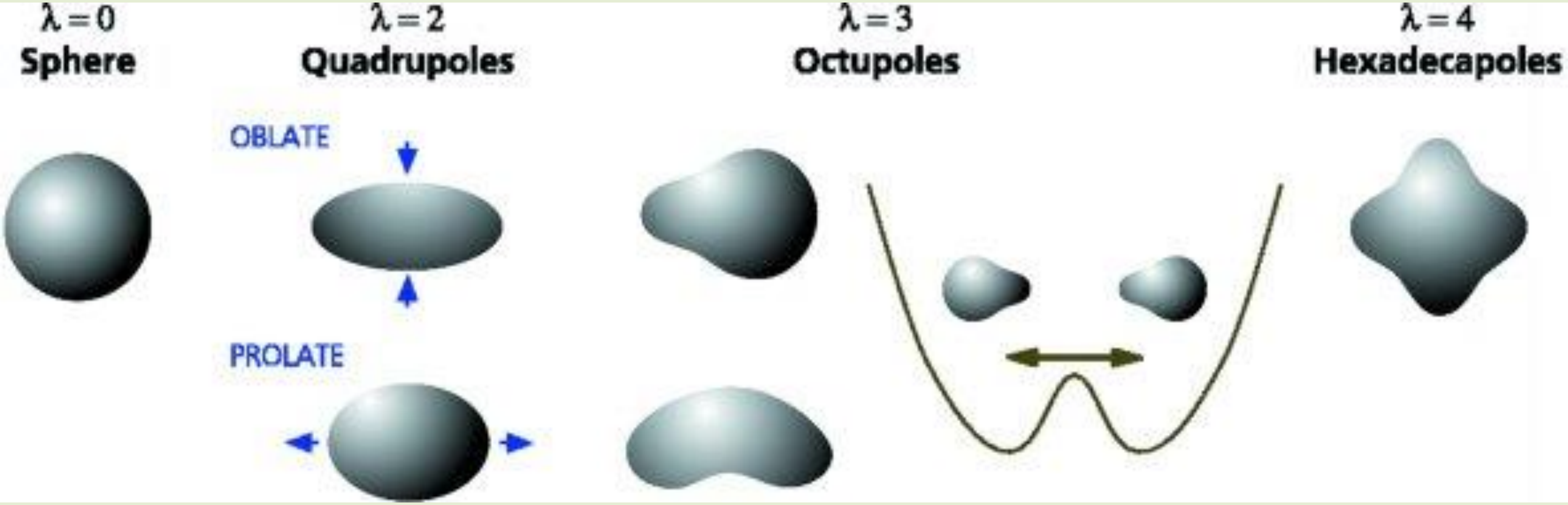
Different ground state properties:

- **Isotopes**
- **Spin and parity**
- **Deformation**
- **Closed shells (magic nuclei)**
- **Neutron skin**
- **…**

Different fixed targets behave differently …

[Bullet Time | City Gallery Wellington]

Extension of the range of nuclei for studies of Nuclear Modification Factor (NMF) in relativistic nucleus-nucleus collisions (fixed target mode)



https://web-docs.gsi.de/~wolle/TELEKOLLEG/KERN/index-s.html

- **Nuclei in ground state have different shape (deformation parameter β), angular momentum, …**
- **Nuclei with closed p-, n-shells (double-magic) are spherical**
- **Nuclear matter density distribution is not uniform**
- **Neutron-rich nuclei have large radius**
- **Neutron excess may create neutron nuclei in collisions ?**

Motivation for Metal Targets in a Halo of the LHC Beam

- **LHCb success in the Ion Physics and Fixed (Gas) Target studies**
- **Fixed Metal Targets: New domains of colliding nuclei and energies at LHC (~ 80 - 110 GeV, nucleon/nucleon cms)**
- **Immense variety of colliding nuclei: enrichment of LHC physics tasks**
  - ➢ **QGP signatures (Nuclear Modification Factors)**
    - **possible dependence on ground state properties of colliding nuclei**
  - ➢ **Nuclear (and possibly atomic) dependence of the quarkonia production**
    - **p_T broadening**
    - **Crystall lattice effects**
- **Multi-target setup: Physics data from N interaction points**
  - – **(N metal targets in LHC beam, simultaneously.**

Transformation of the approach: From the halo to the core of the beam.

- After 'prohibiting' discussions with some of the LHC experts: 'No way for the target to get out of the collimator shadow.' – The only allowed object on the beam way – COLLIMATOR.' – principle of safety against superconducting magnets quenching, radiation damage of physics detector etc.,
- OK! Yet there is another 'object' – being primary – the second colliding beam !
- This is now my approach – make fixed target setup in a beam in a such way that it generates fluxes/fluences of interaction products of the same order of magnitude as it comes out of IP for colliding mode. NEVER EXCEEDS IT !
- Starting point could be just comparable luminosity (impacts related to much lower energy of products in fixed target mode have to be thouroughly evaluated-

Transformation of the approach: From the halo to the core of the beam.

- Let me point out that it is worthy to search for any opportunity to implement the solid targets at LHC.
- It looks that it may happen (if at all !) in decade/decades from now. As far as I foresee rich physics events to be discovered with such targets, it would be worthwhile to develop step-by-step approach to its technical realization.
- For instance, one could start anywhere in the tunnel (in any collimator system arrangements) to study different options of the solid targets interacting with the LHC beams (or two beams) running simple dedicated detector setup (as it has been made in HERA-B, ~8 years before physics studies) to measure the performance of the test wire target .

Transformation of the approach: From the halo to the core of the beam.

- It is constructive approach to start discussions on safety issues from the point of view of affordable luminosities (from the LHC as well as from the detector side).
- Let us start with Superthin Wire Targets, SWT-option (0.1 - 1 mum thickness). The related SWT-setup would be essentially different from the crystall option (much simpler, much less material and accessories, etc.).
- Let us assume the affordable instantaneous luminosity of 10^28 cm^-2 s^-1 for the Pb(beam)-Ni(target) collisions. Inserting 1 mum thick (50 mum wide) Ni microstrip target into a Pb beam with 500 bunches (10^8 ions in each) at the distance of ~3 beam sigma (effective width of 200 mum) one would be close to the above mentioned luminosity.
- Aa "burning target" regime keeping in mind that target could also enter the beam core and might be melted. I suppose, even in such case the luminosity will not exceed limits for normal operation of detector as well as LHC magnets. After that the next strip of the target will arrive into the operational position in a beam to continue the experiment without interruption.
- This is how it could be started. Depending upon the test studies, one could evolve with the setup for real experiment. I would appreciate evaluation/criticism for developing SWT-project.

Transformation of the approach: From the halo to the core of the beam.

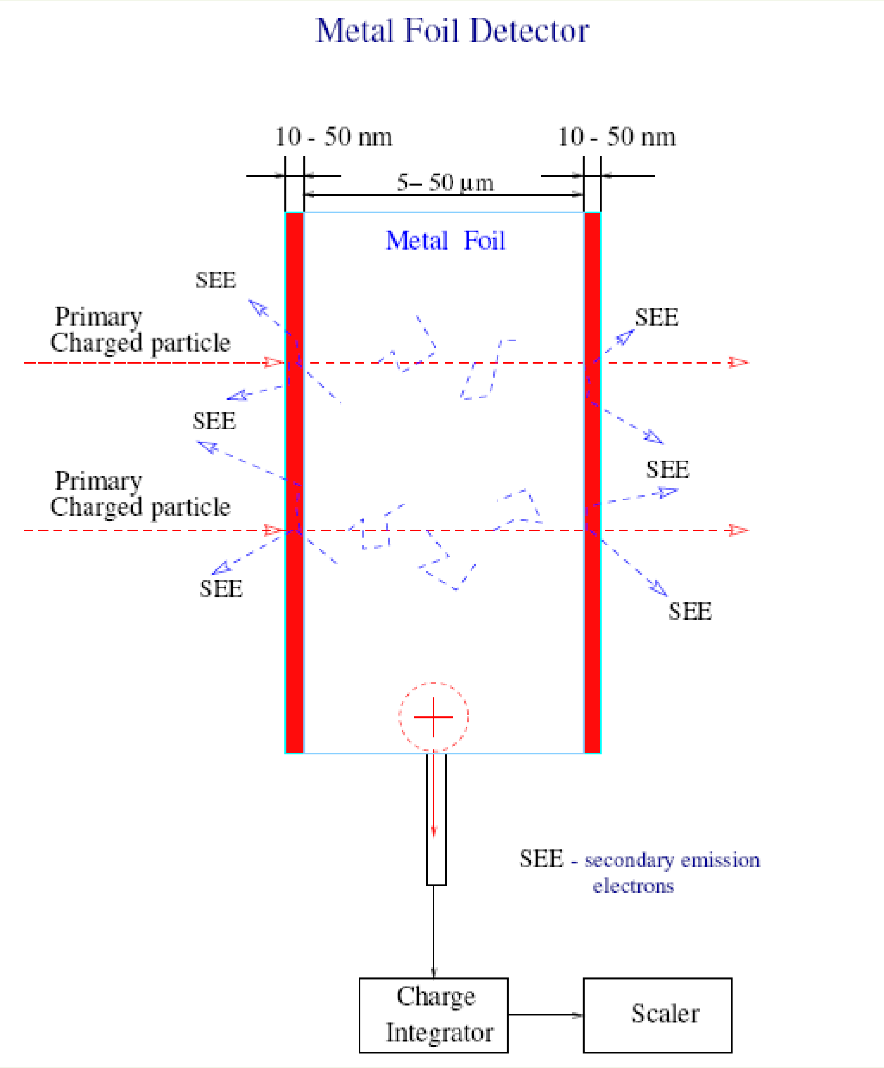
- It is a challenging project.
- I would like to search the way to overcome the challenges.
- From my point of view this is not excluded, at all, even if the target (superthin microstrip one or ... I have some other ideas from my experience with micro-powder targets) is getting status of the primary object for the LHC beam.
- Just one has to work out the safe mode of operation of the complex setup 'beam-target'.
- It was more than one time in the experimental physics - what looked impossible yesterday was solved today. And major sense in this activity is new physics events to discover in such targets.
-

Some basics. MFD Principle of Operation

- **Positive charge appears** in metal foil due to **Secondary Electron Emission** caused by incident charged particles

- Charge is integrated by the **Charge Integrator (ChI).**

- **ChI** converts measured charge into frequency, read out by a scaler.



Luminosity monitoring in metal detector – targets (HERA-B positive experience)

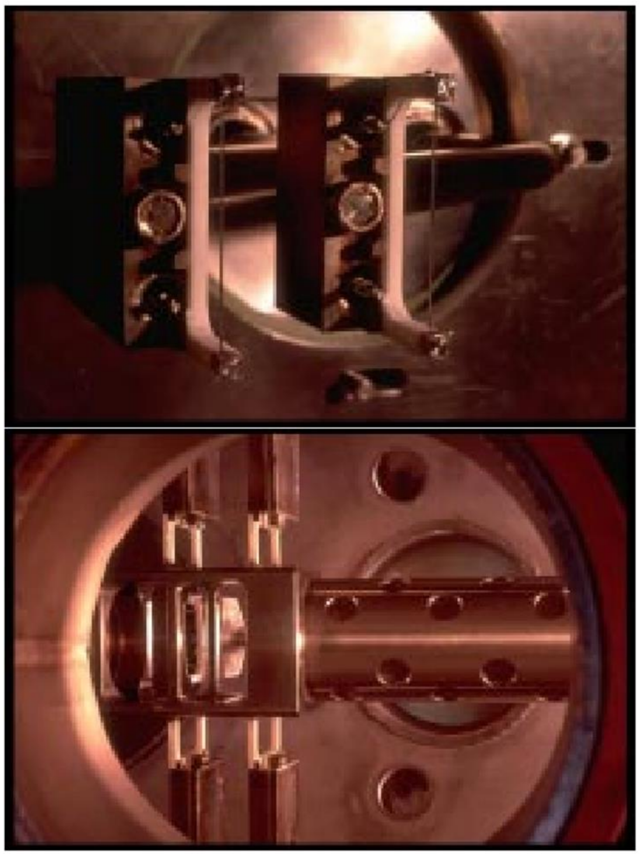
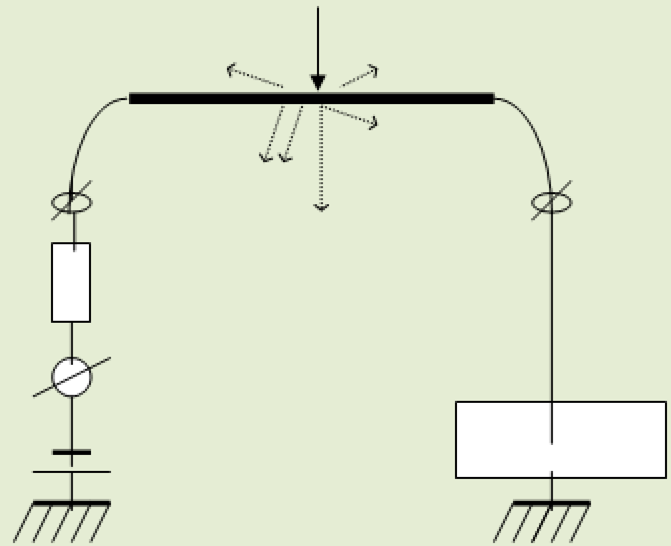


Figure 9: Targets mounted in the VDS vessel.

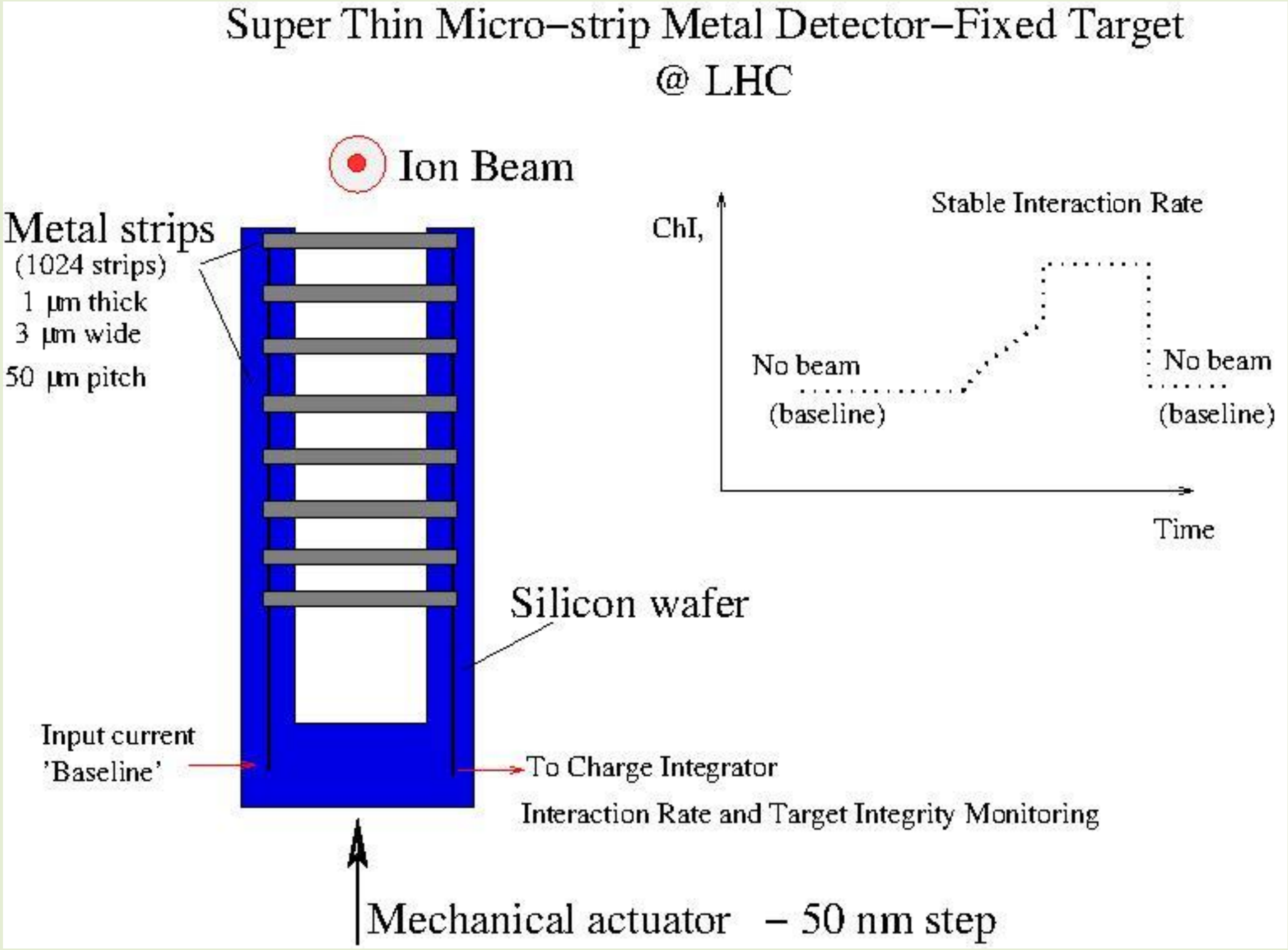


$$L^{i} = \frac{\alpha^{i} N_{BX}^{total}}{\sigma_{inel}^{i}} \lambda$$

λ - Average number of interactions per Bx (filled)

α^{i} *- partial contribution of the i- target*

THE 1ST Sketch of the MMD-target



Summary and Outlook

- **Development of the new approach to metal microstrip detector as a target in LHC beam is launched at KINR in the scope of the LIA IDEATE activity.**
- **We account for its external evaluation (by LAL Colleagues) and proposals for collaboration**

THANKS TO KINR HEPD COLLEAGUES

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- Igor Kostyuk
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- Evgenii Petrenko
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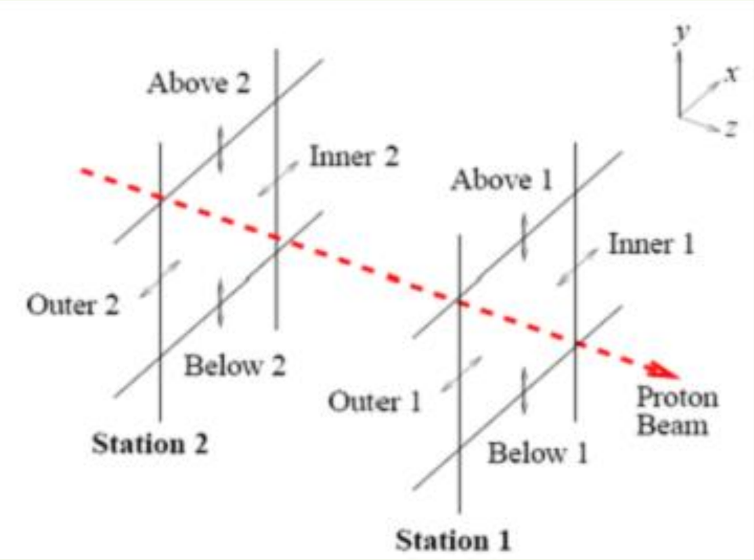
- Dmytro Storozhyk
- Vasyl Dobishuk
- Tetyana Pugatch
- Volodymyr Kyva
- Evgenia Momot
- Hanna Malygina
- Iaroslav Panasenko
- Anton Lymanets
- Victor Iakovenko

Thank you for your attention!

Greetings from Kyiv !

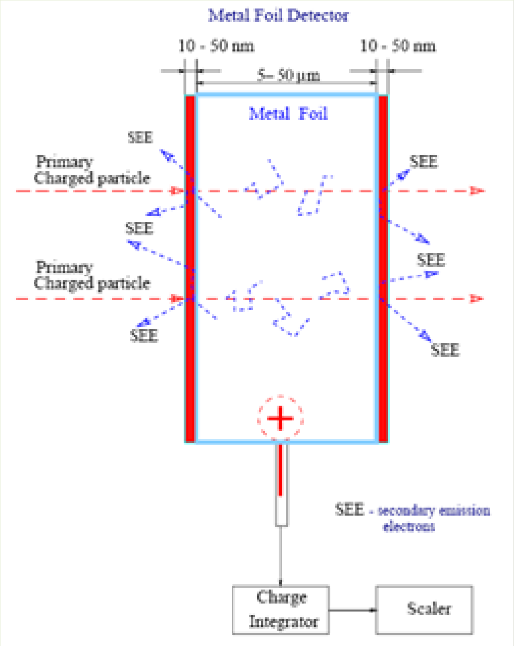
BACKUP SLIDES

Techniques of Multi-Target setup.
HERA-B experience, p-A scattering, p- 920 GeV – 40.6 GeV - cms)



Wire Name	Abbreviation	Material	Geometry
Inner I	I1	Tungsten[a,b]	Circular, Diameter 50 µm
Outer I	O1	Titanium	Circular, Diameter 50 µm
Above I	A1	Aluminum	Ribbon, 50 µm × 500 µm
Below I	B1	Carbon	Ribbon, 100 µm × 500 µm
Inner II	I2	Carbon	Ribbon, 100 µm × 500 µm
Outer II	O2	Carbon[c]	Ribbon, 100 µm × 500 µm
Above II	A2	Palladium	Circular, Diameter 50 µm
Below II	B2	Titanium[b]	Circular, diameter 50 µm

Principle: Metal wire-targets move in/out of the proton beam halo – to provide Interaction rate (luminosity) equally distributed among the targets.

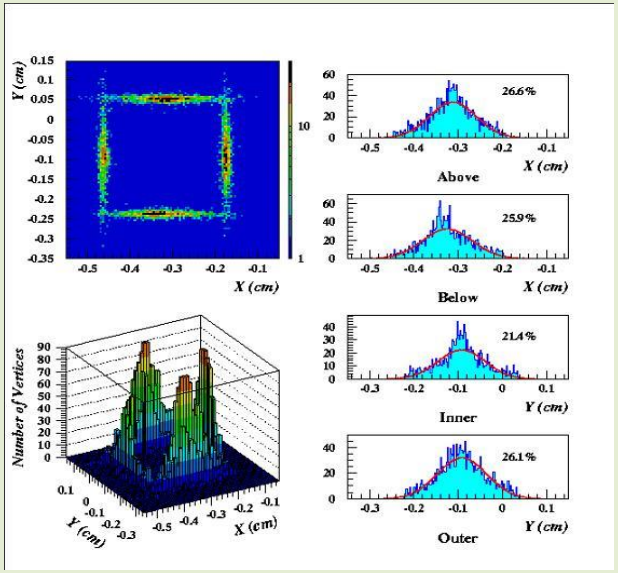


Luminosity Equalization: Target – Metal Detector

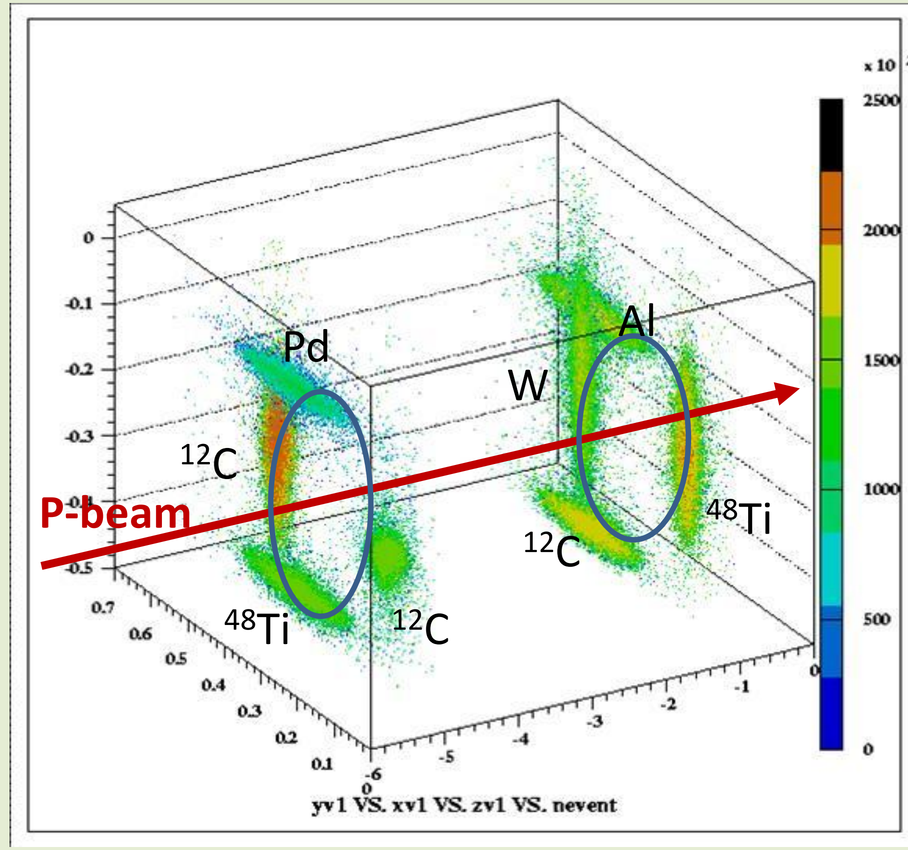
Steering of the target position by the charge generated in it due to SEE initiated by the incident proton beam

Equalization of the luminosities

Charge Integrated in Individual Targets -
data for the steering feedback system at HERA



Wire	Charge Integrators %	Vertices %
Above	26.06 ± 0.08	26.6 ± 0.7
Below	24.26 ± 0.10	25.9 ± 0.7
Inner	23.49 ± 0.06	21.4 ± 0.7
Outer	26.20 ± 0.07	26.1 ± 0.7



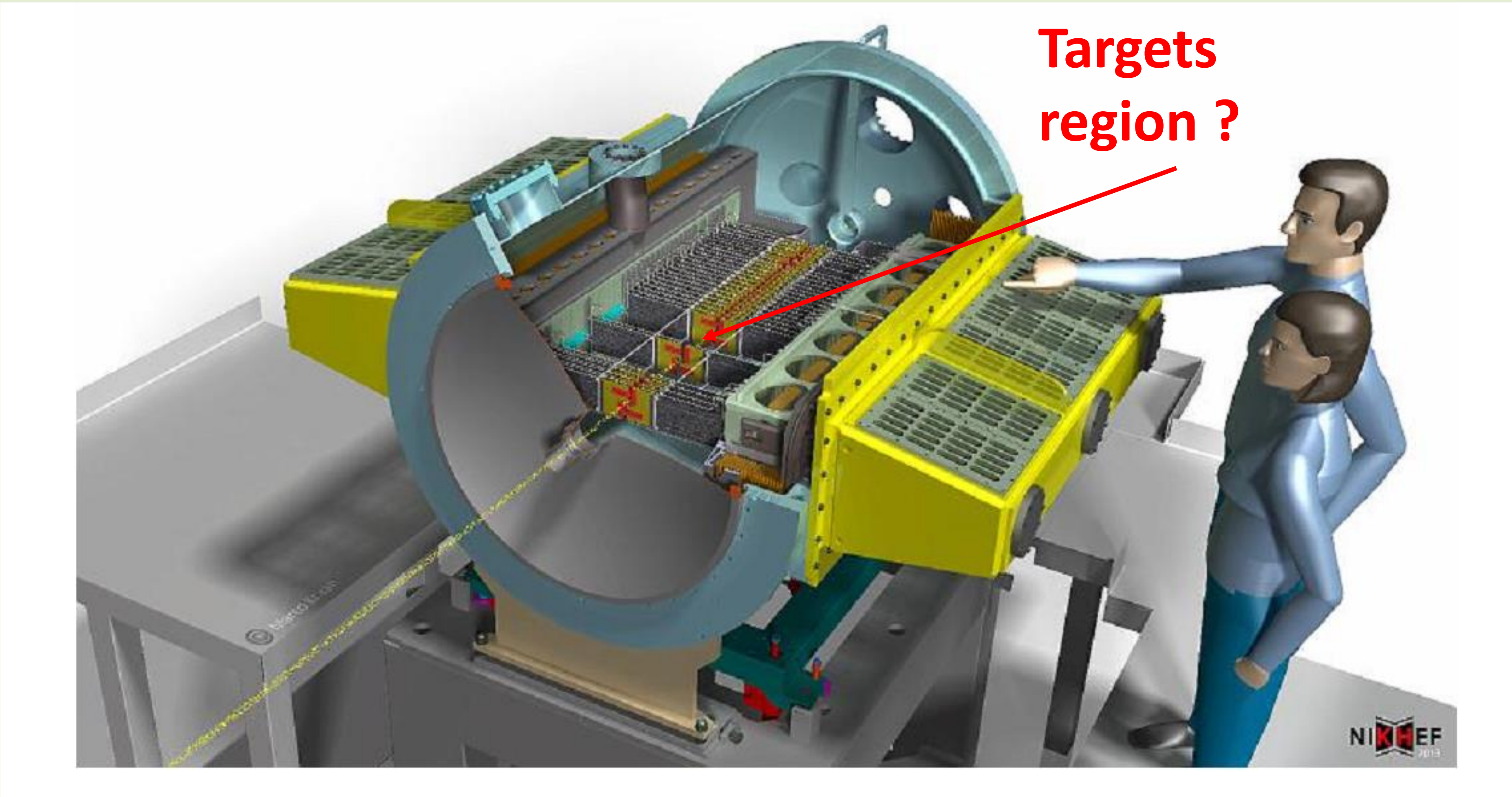
Four targets

Eight targets

Proof of the principle – **Vertices are equally distributed over inserted targets**.
8 targets simultaneously could be handled providing 40 MHz interaction rate

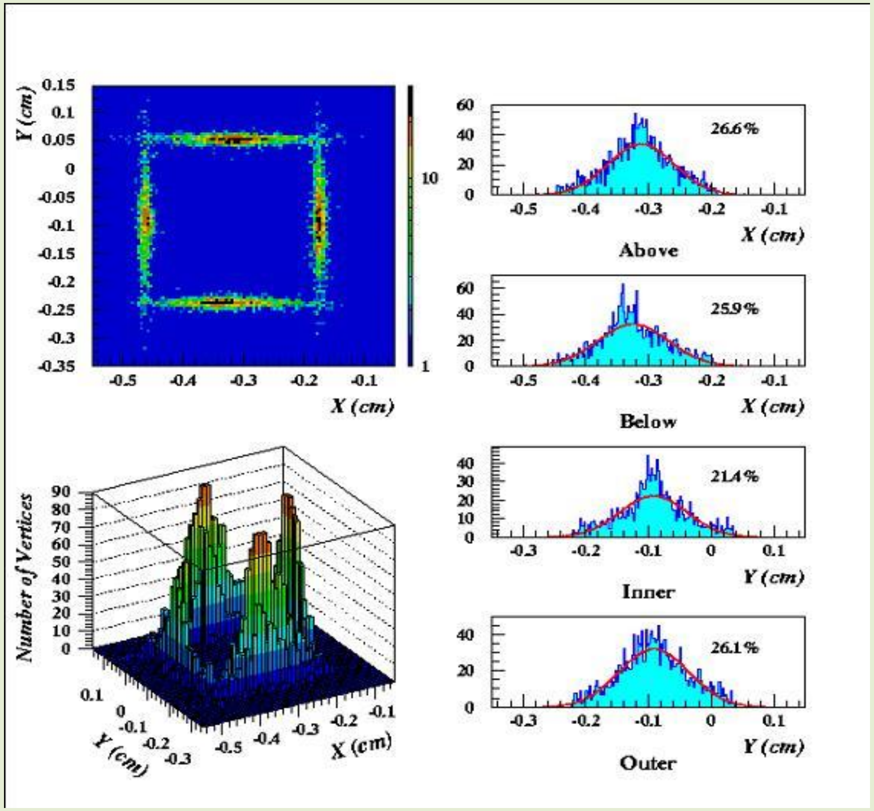
http://dx.doi.org/10.1063/1.1291460

Multi-target setup at LHCb
VELO – VErtex Locator construction after upgrade



Equalization of the luminosities

Charge Integration from Individual Targets -
data for the feedback system at HERA



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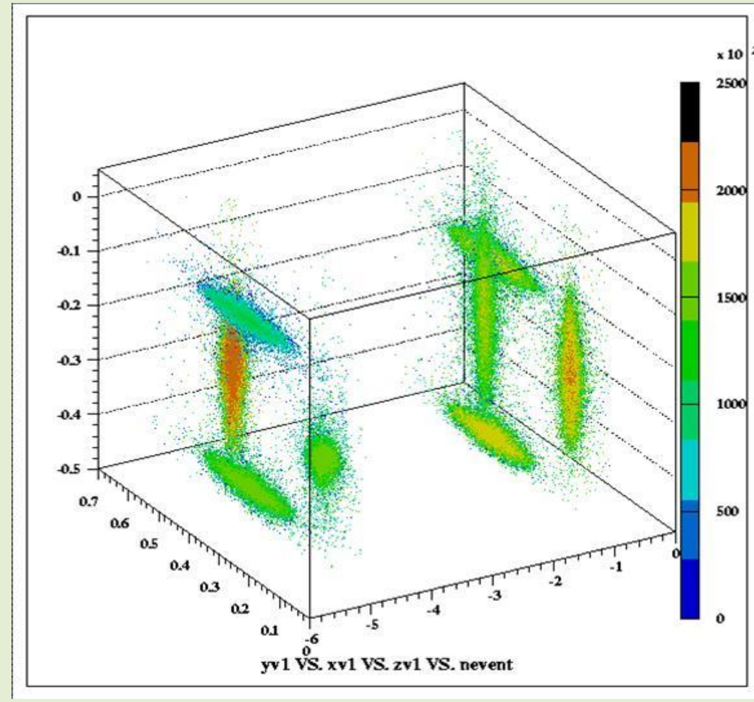

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