Si-MWPC tracking and momentum reconstruction for SRC-2022 experiment

Timur Atovullaev

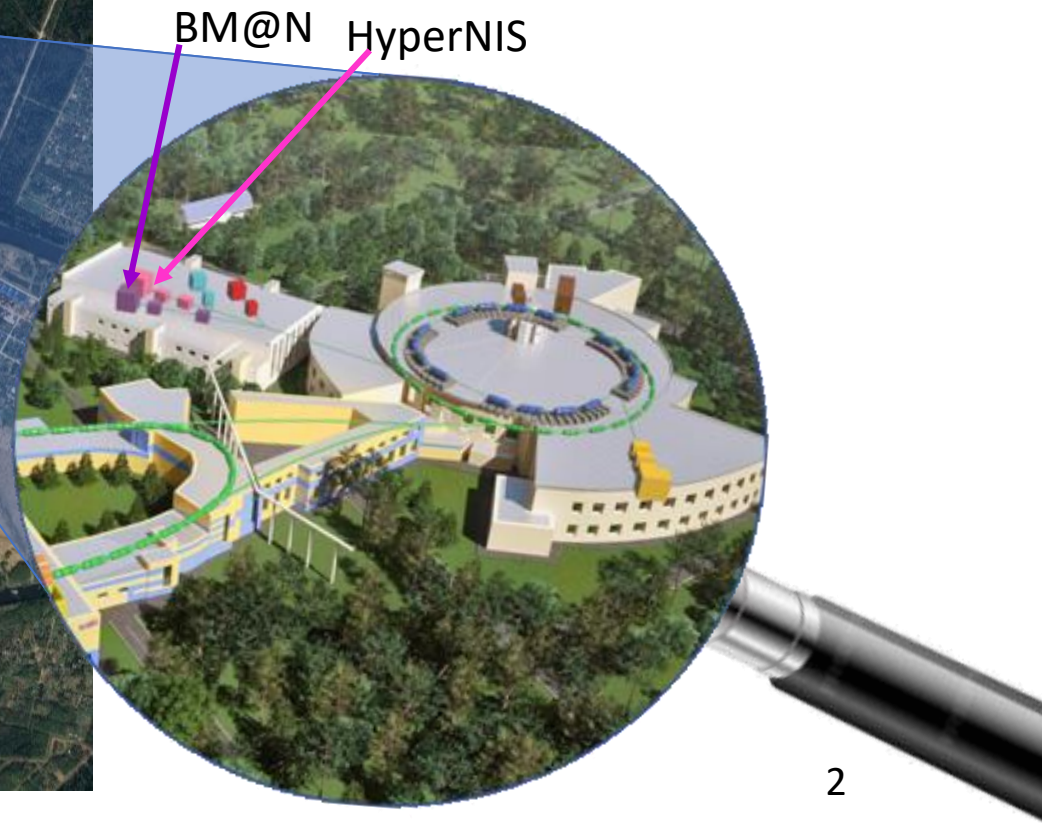
27th October 2025
The 29th International Scientific Conference of Young Scientists and Specialists (AYSS-2025)

Where?

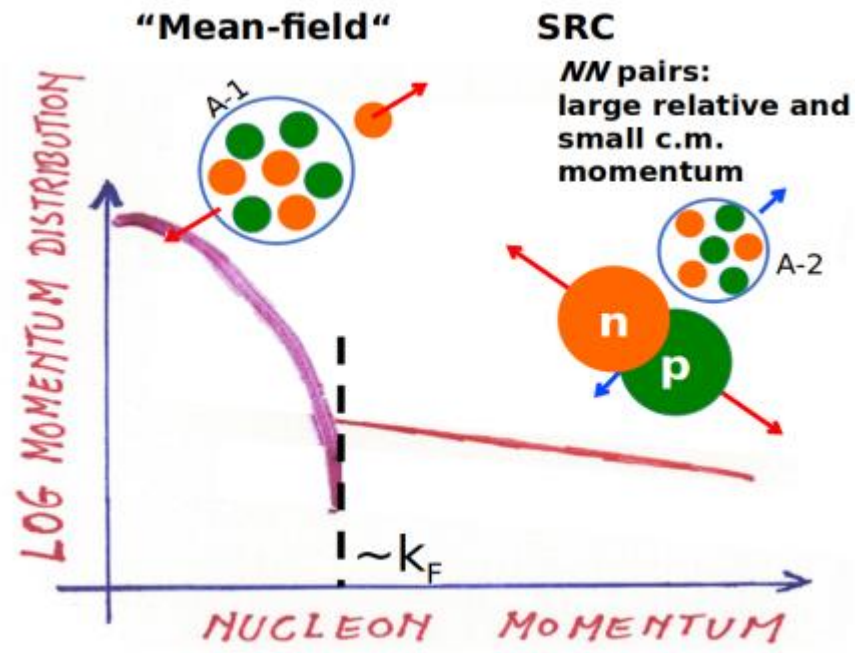
2018 – 1st SRC experiment at BM@N

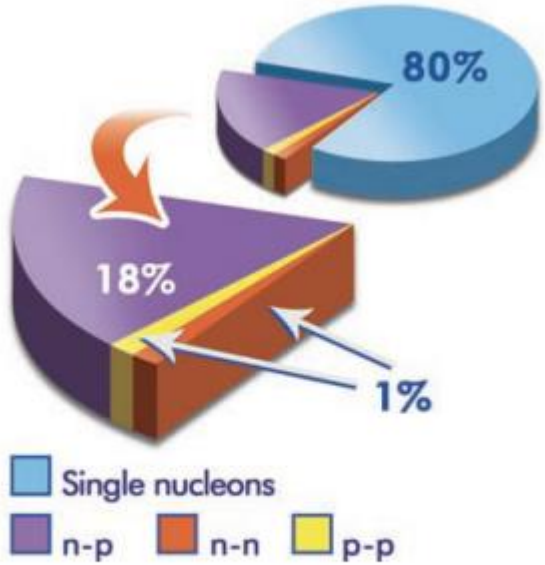
2022 – 2nd SRC experiment at BM@N

The next experiments are planned at HyperNIS



What?





SRC: n-p dominance

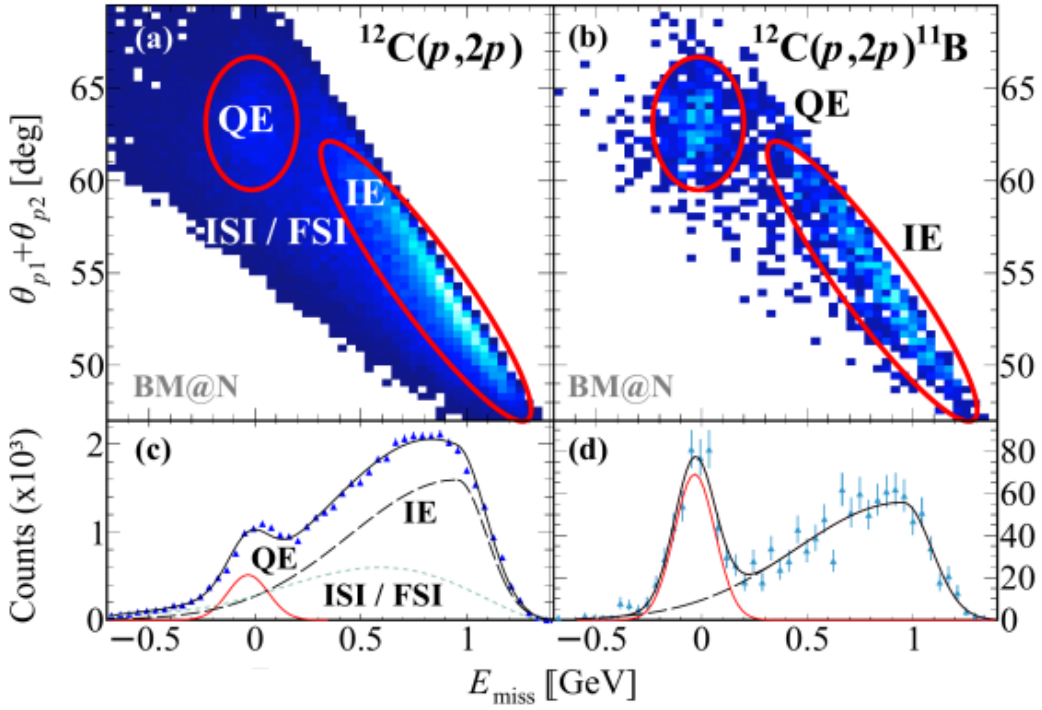
A. Tang et al., Phys. Rev. Letters (2003)
E. Piasetzky et al., Phys. Rev. Letters (2006)
R. Shneor et al., Phys. Rev. Letters (2007)
R. Subedi et al., Science 320, 1476 (2008)

MF: $^{12}C(p,2p)^{11}B$

SRC: $^{12}C(p,2p)^{10}B,^{10}Be$

Feeling sad and lonely? Become a nucleon! After all, 80% of nucleons are free and looking for their pair!

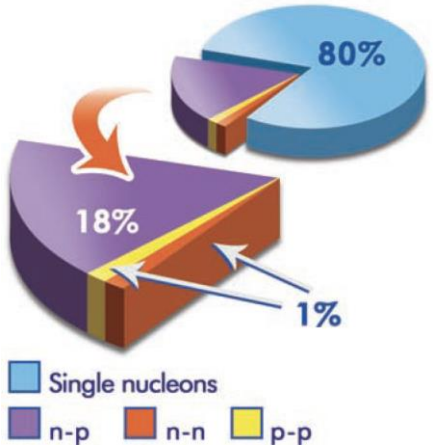
Main results of 2018 experiment



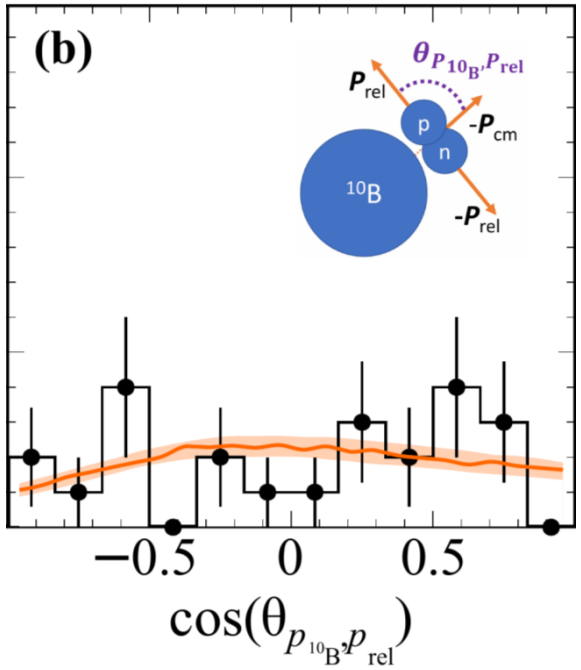
Fragment tagging suppress rescattering
(Initial/Final state interactions)
Select quasi-elastic scattering

23 np SRC pairs

2 pp SRC pairs



Factorization of nuclear many-body wave function
Applied in Generalized Contact Formalism



M. Patsyuk et al. Nature Physics 17, 693 (2021)

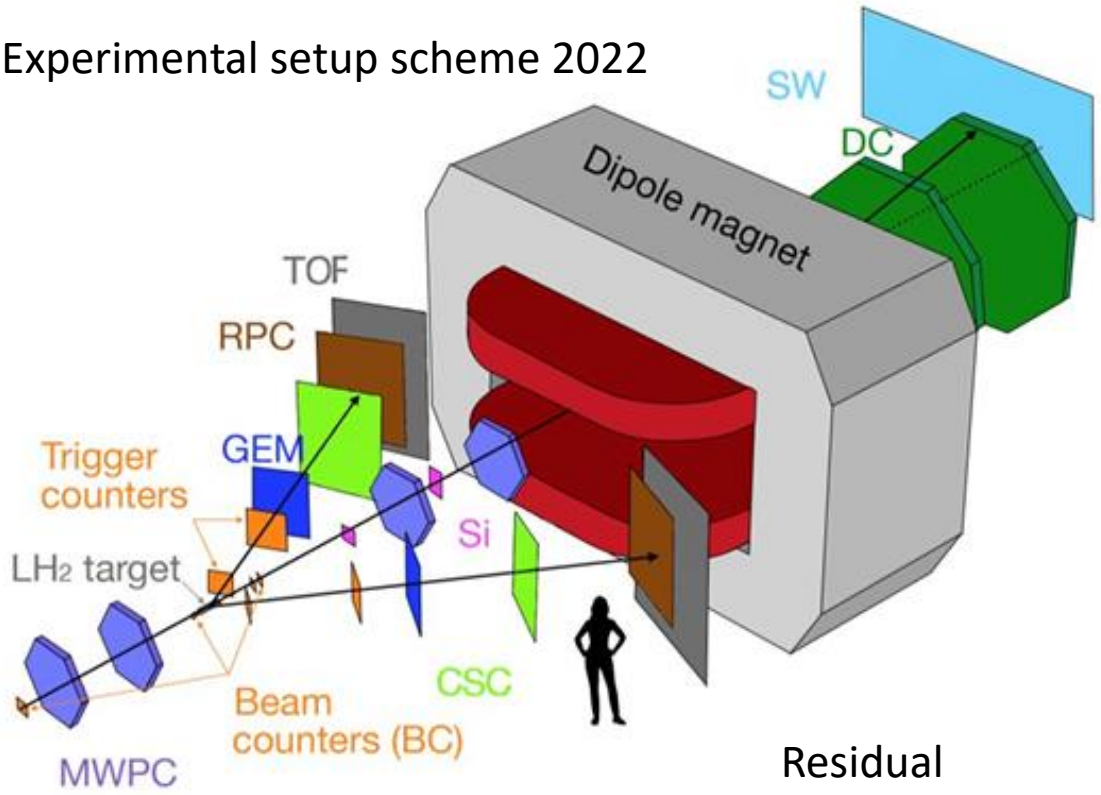
How?

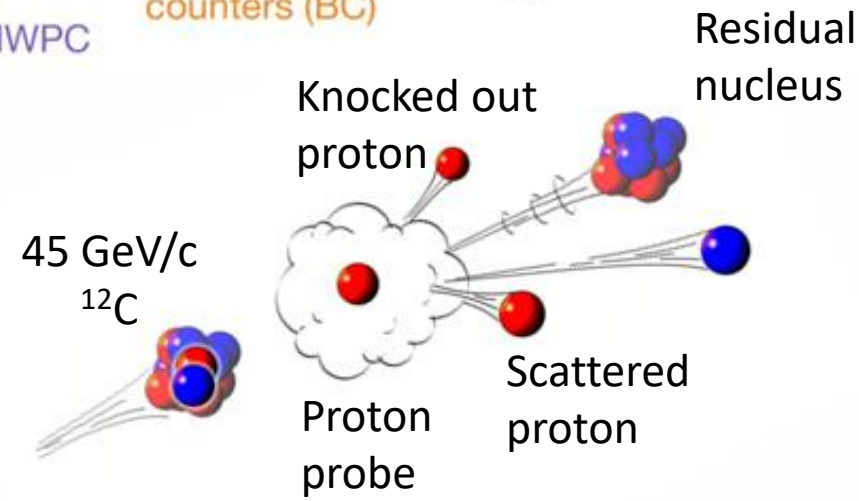
45 GeV/c **^{12}C beam** momentum
(3.7 GeV/c/nucleon)

Inverse kinematics:
- ✓unstable nuclei
- ✓pmiss, pn
- ✓p probe:
  - ✓larger cross-section
  - ✓(compared to e-scattering)
- ✓fragment ID + pA-2

Main goal: reactions cross section measurements and studying fragment properties

Experimental setup scheme 2022





Breaking news: Atoms have started studying humans for the first time. It turns out that 99% of people can't pass through walls, but 1% can — by breaking them down.

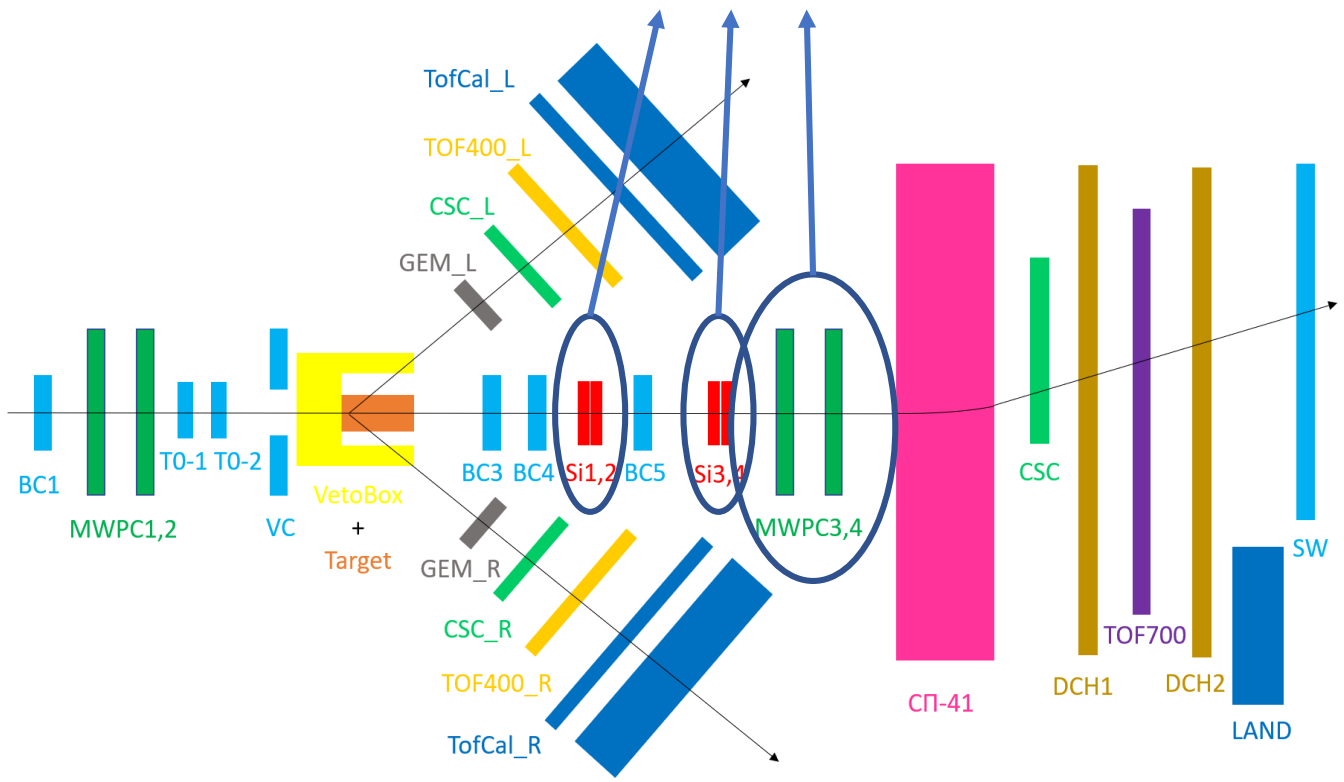
Upstream tracks

Input:
- Si digits (clustered points in local coordinate system)
- MWPC3, 4 track segments (tracks combined in the chamber itself)

alignment ↓ tracking

Output:
- UpStream Tracks (X, Y, Z, Tx, Ty)
- Coordinate resolution at target center ~1mm
- Angular resolution at target center ~0.6mrad
- Efficiency 83%

Detectors used for tracking: Si1-4, MWPC3,4



- Which track do you keep singing all the time?
- Si-Si MWPC Si

Momentum reconstruction with MDF

Step 1:

Simulation

Input:

Wide beam + wide momentum

Unreacted nuclei

Track before magnet

Track after magnet

Known momentum

Output:

P/q (X_0, Y_0, Z_0, Tx_0, Ty_0, X_1, Y_1, Z_1, Tx_1, Ty_1)

$Tx_{\text{before magnet}}$ (X_0, Y_0, Z_0, Ty_0, X_1, Y_1, Z_1, Tx_1, Ty_1)

Step 2:

Momentum reconstruction

Input:

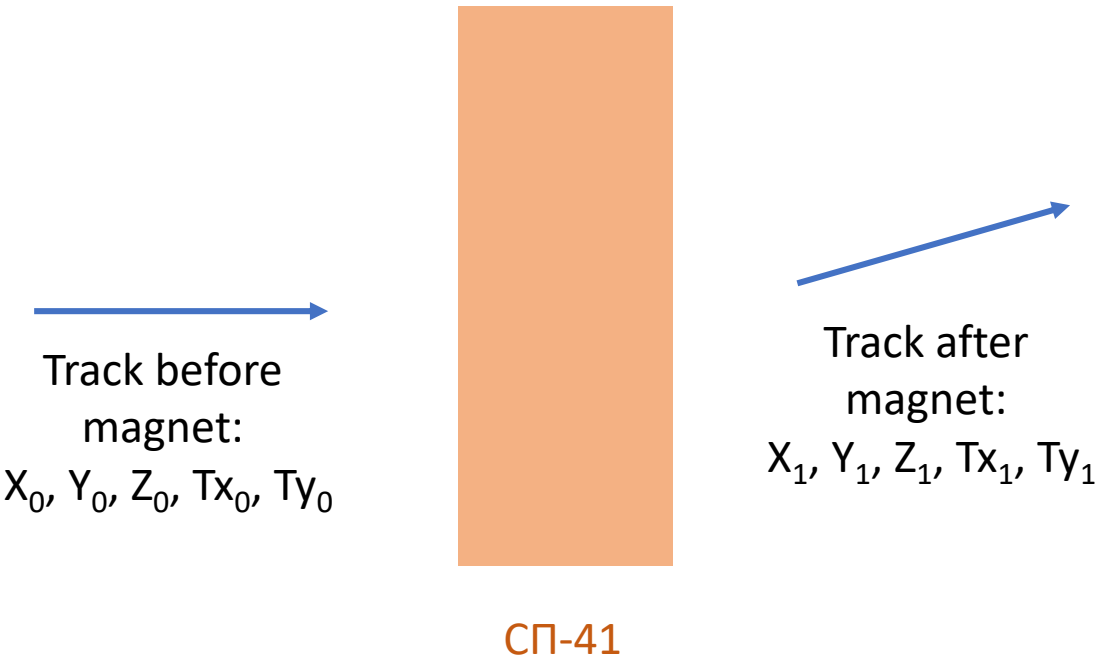
Track before magnet

Track after magnet

Matching conditions (ΔTx, ΔTy)

Output:

P/q

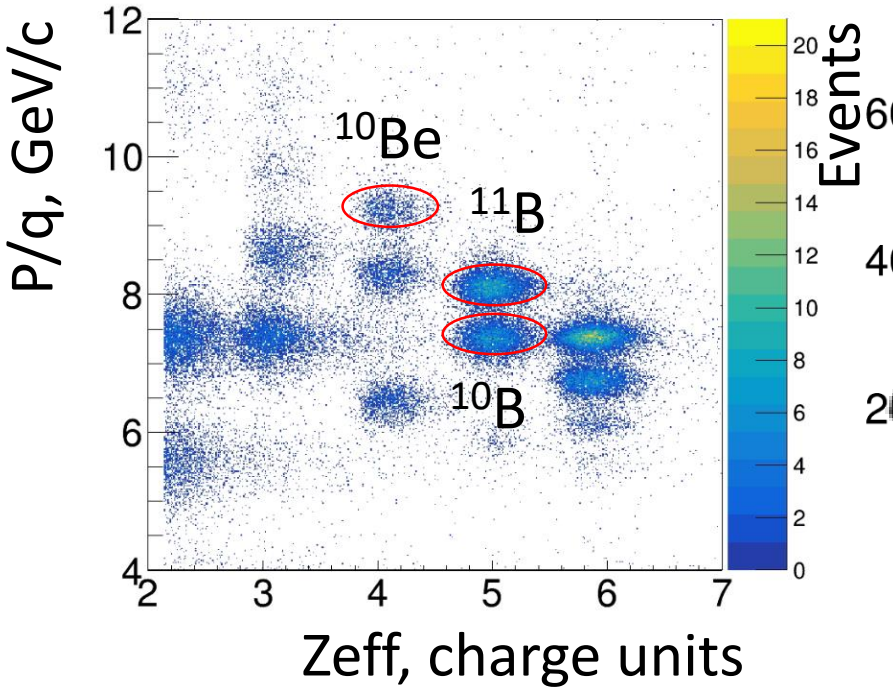


— What's in the black box?
— A cat.
— And what state is it in?
— Hopefully not in the ground!

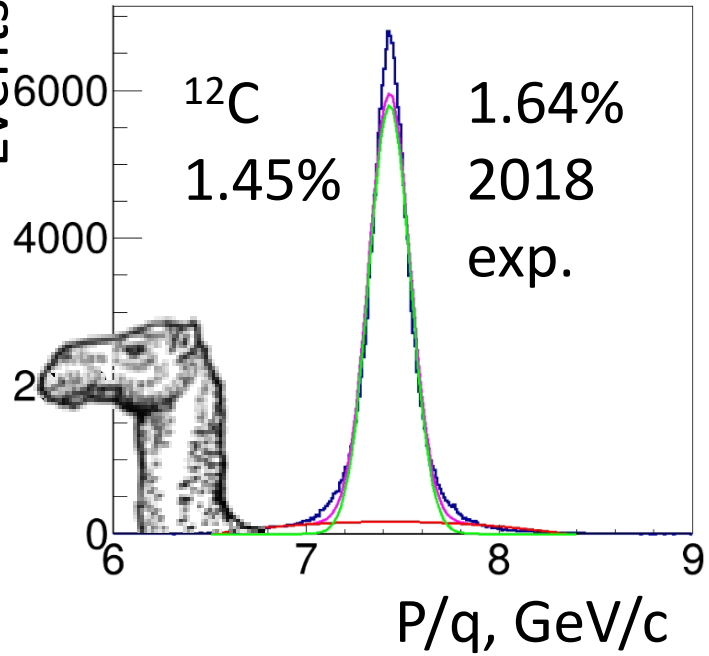
Heavy-fragment identification

MF: $^{12}C(p,2p)\ ^{11}B$

SRC: $^{12}C(p,2p)\ ^{10}B,^{10}Be$

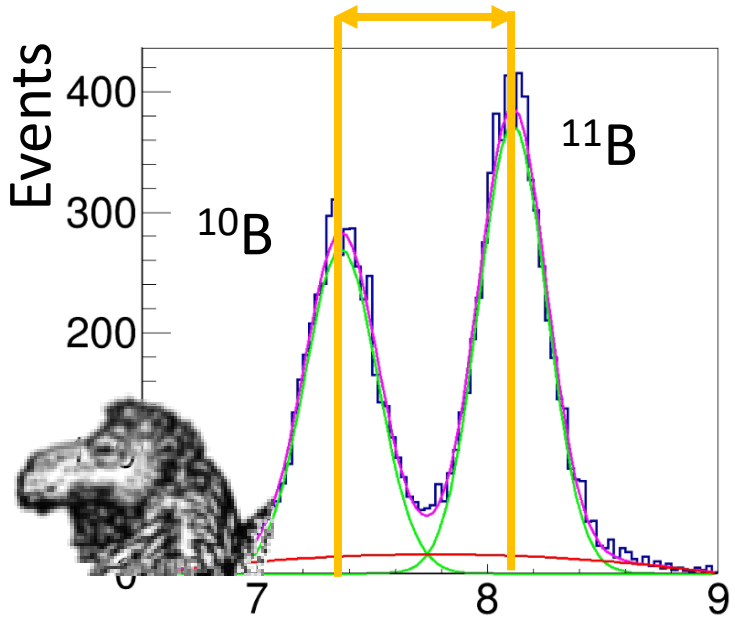


Fragment identification



Beam momentum resolution

4.9 σ



Boron isotopes separation

Conclusion and summary

- Tracking before magnet
- Fragment momentum reconstruction

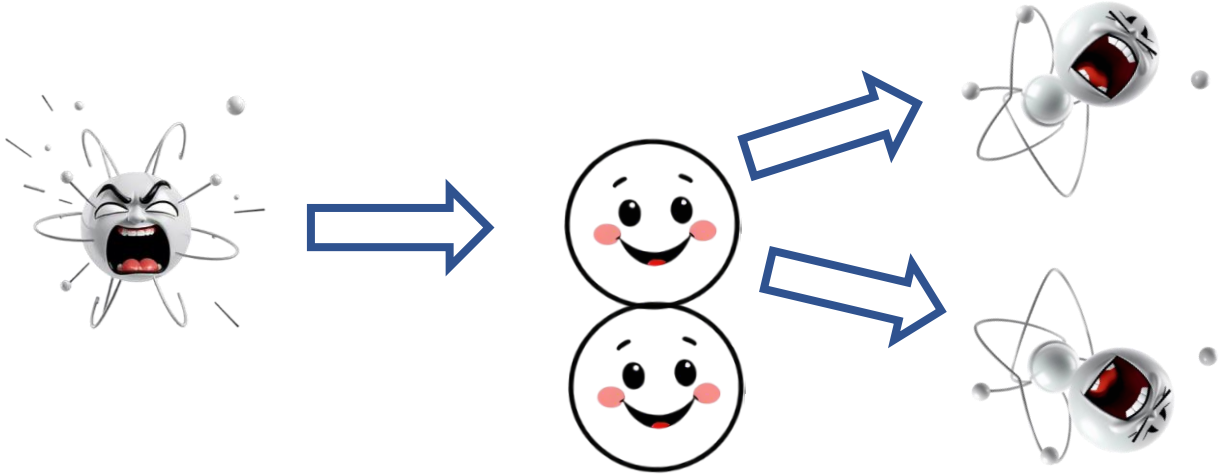
Current analysis status:

Nucleon momentum before interaction = Fragment momentum +
+ Protons momentum in arms – Target momentum

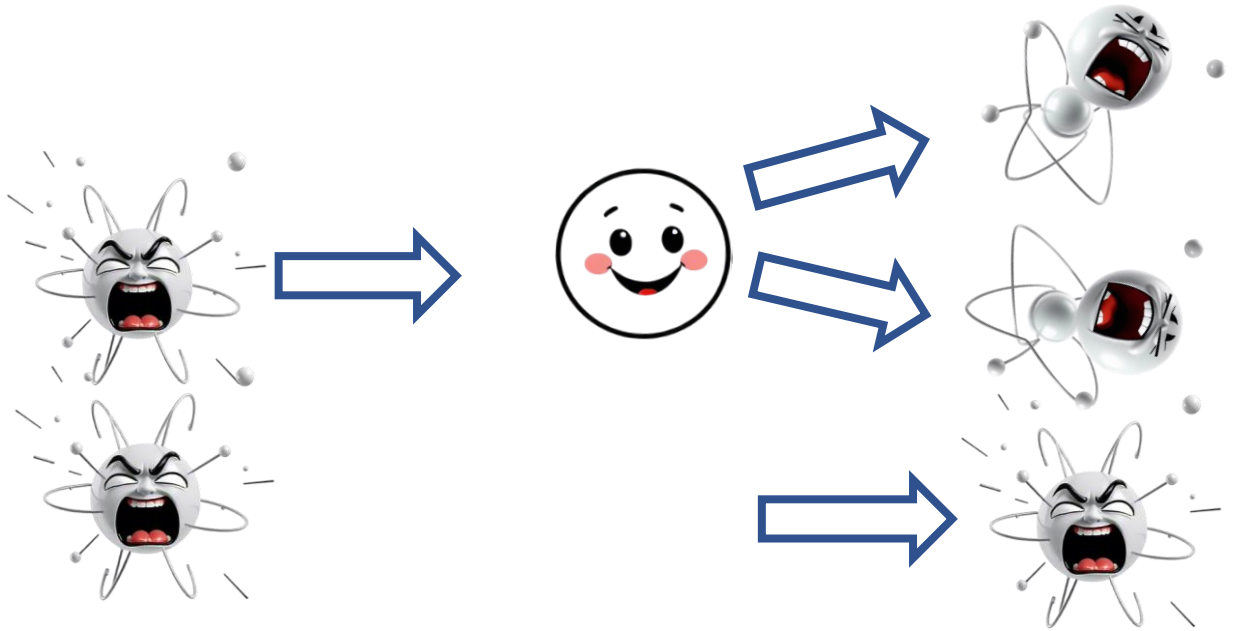
The cat escaped from the box, adding some text to my presentation; apparently, it was in an excited state

Thank you for attention!

SRC in direct kinematics



SRC in inverse kinematics



BackUp

Case	X tracks				Y tracks			
1	Si2	Si4	M3	M4	Si1	Si3	M3	M4
2	Si2	Si4	M3		Si1	Si3	M3	
3	Si2	Si4		M4	Si1	Si3		M4
4	Si2		M3	M4	Si1		M3	M4
5		Si4	M3	M4		Si3	M3	M4
6	Si2	Si4			Si1	Si3		
7	Si2		M3		Si1		M3	
8	Si2			M4	Si1			M4
9		Si4	M3			Si3	M3	
10		Si4		M4		Si3		M4
11			M3	M4			M3	M4
12	Si2	Si4	M3	M4	Si1	Si3	M3	M4
13	Si2	Si4	M3	M4	Si1	Si3	M3	M4
14	Si2	Si4	M3	M4	Si1	Si3	M3	M4
15	Si2	Si4	M3	M4	Si1	Si3	M3	M4

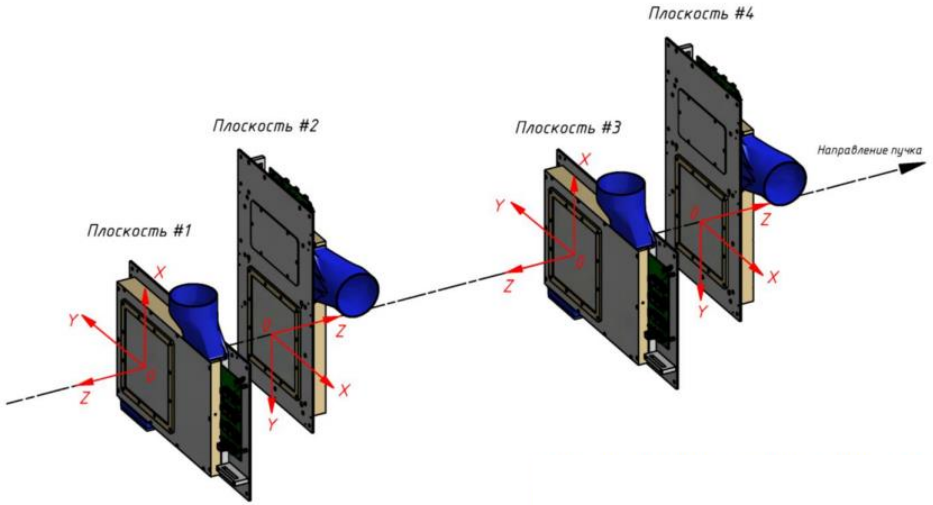
Cases 12-15:
If case 1 but no tracks satisfying the conditions for the vertex and chi2

Loop over combinations with 3 point, choosing best chi2 track

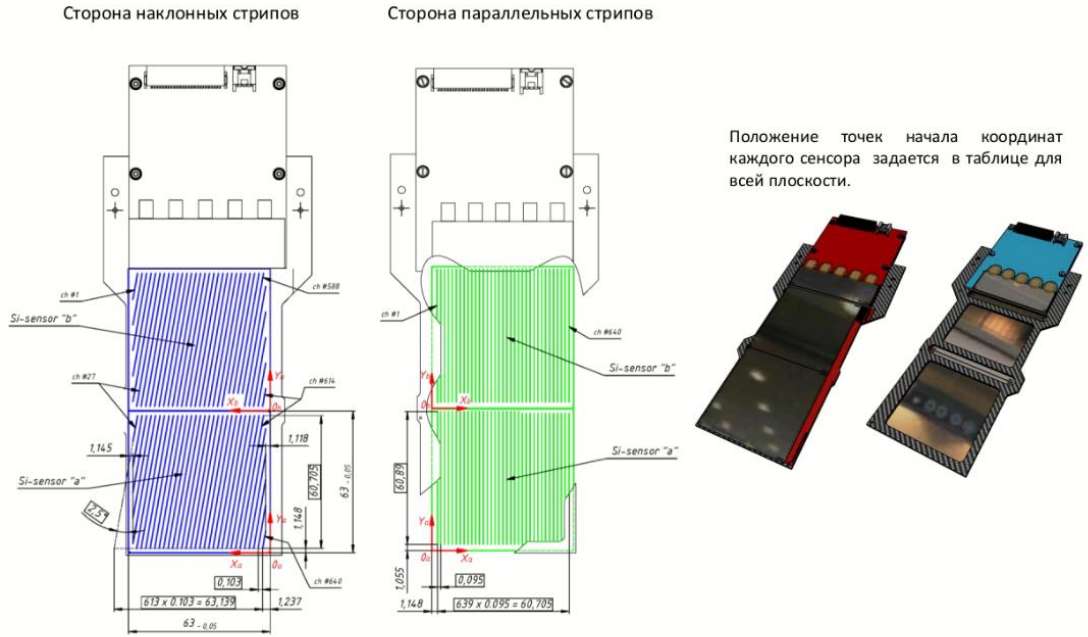
It helps to reduce fake hits influence

Геометрическое выравнивание кремниевых детекторов.

Ориентация 4-х плоскостей в сеансе SRC-2021



Положение стрипов в Si-сенсорах модуля (SRC-2021).



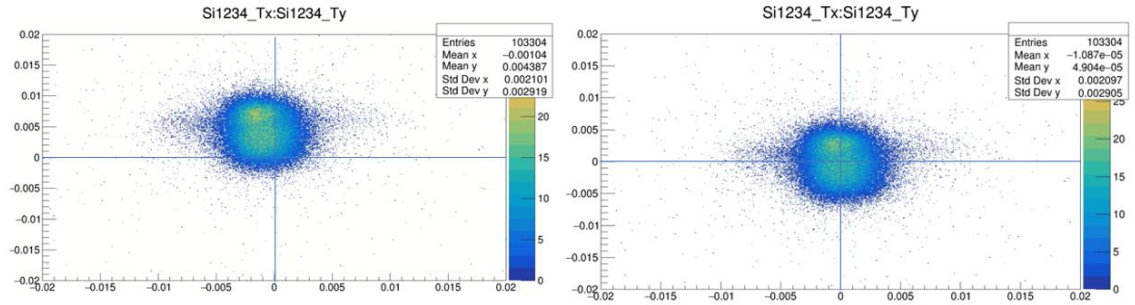
Для каждой станции восстанавливаются X и Y координаты, образующие хиты.

Процедура выравнивания. Часть 1

1) Выбираем события, в которых в каждой станции Si ровно один хит.

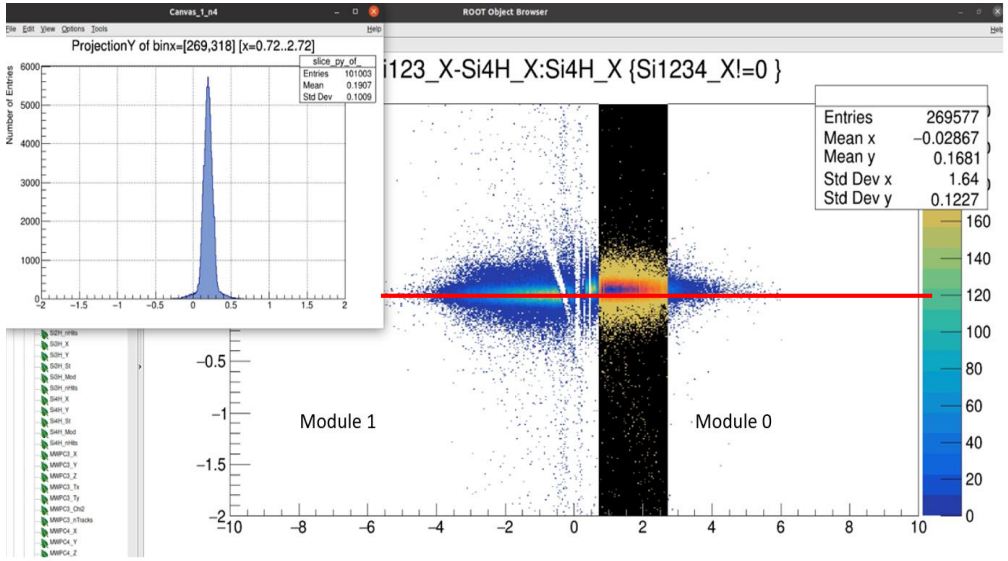
2) Составляем различные комбинации треков: Si1234, Si123, Si124, Si134, Si234.

3) Выравниваем углы треков Si1234, двигая 3 и 4 станции.



4) Выравниваем отдельные модули каждой станции.

5) Шаги 3 и 4 повторяются до тех пор, пока среднее значение углов не будет меньше 1 мрад, а разница координат трека и хита для каждого модуля каждой станции не станет меньше 0.1 мм.



Процедура выравнивания. Часть 2

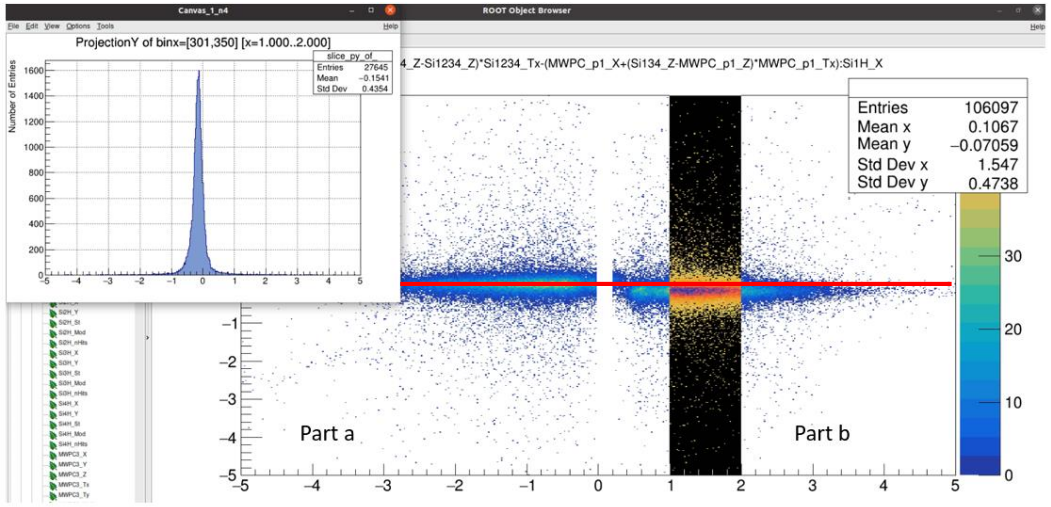
1) Выбираем события, в которых в каждой станции Si ровно один хит, в MWPC3 и MWPC4 – один трек.

2) Составляем комбинации треков: Si1234M34, Si1M4, M34.

3) По разнице углов Si1M4 и M34 выравниваем детекторы Si1-4 относительно MWPC.

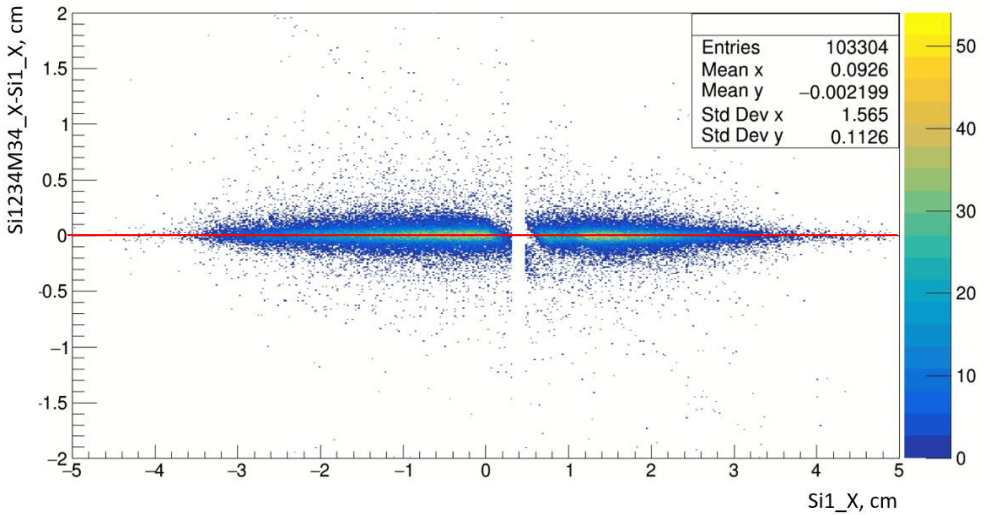
4) По разнице координат треков Si1234 и M34 довыравниваем отдельные части кремниевых детекторов.

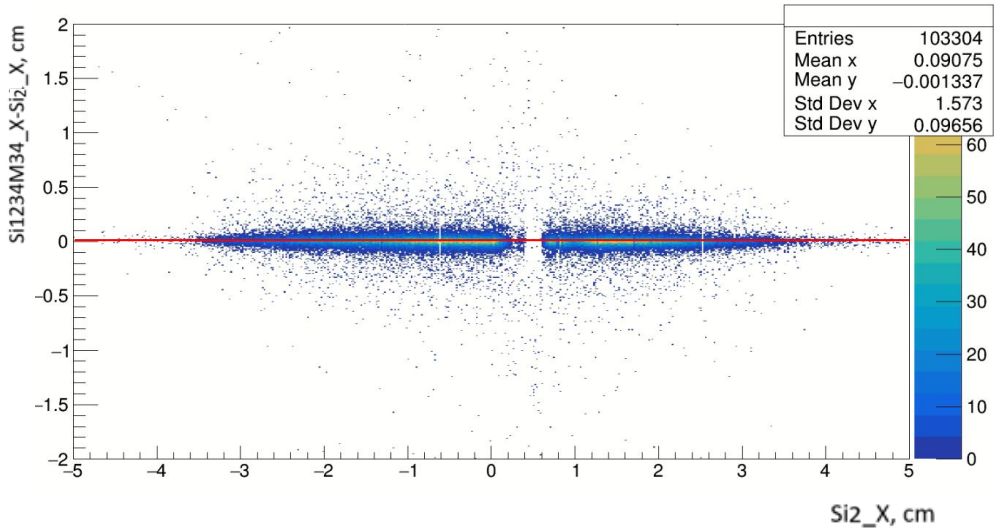
5) Проверяем углы и координаты треков Si1234M34.

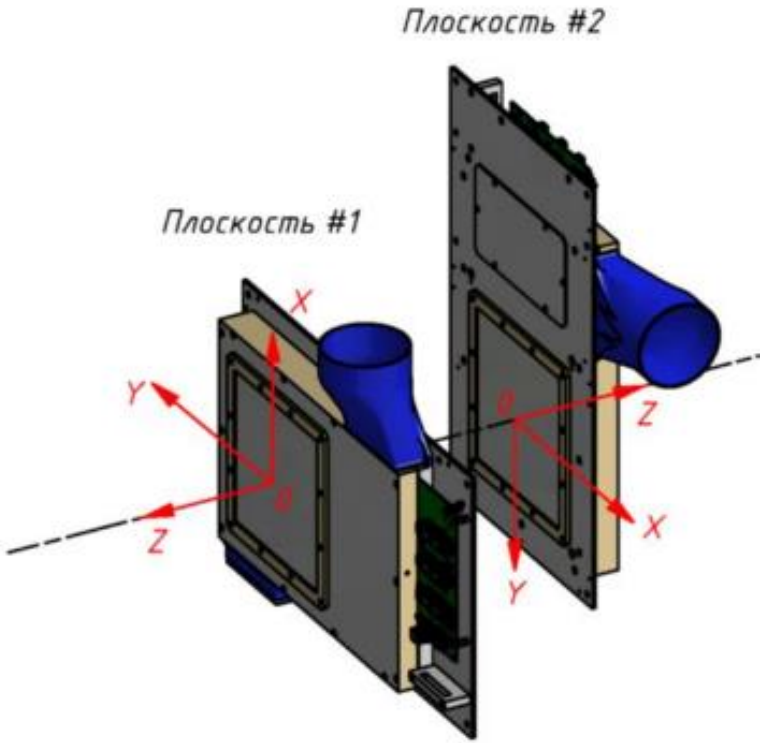


Здесь Si1234M34 – трек, включающий в себя хиты Si1, Si2, Si3, Si4 и треки MWPC3 и MWPC4; Si1M4 – трек, включающий в себя хит Si1 и трек MWPC4; M34 – общий трек MWPC3 и MWPC4

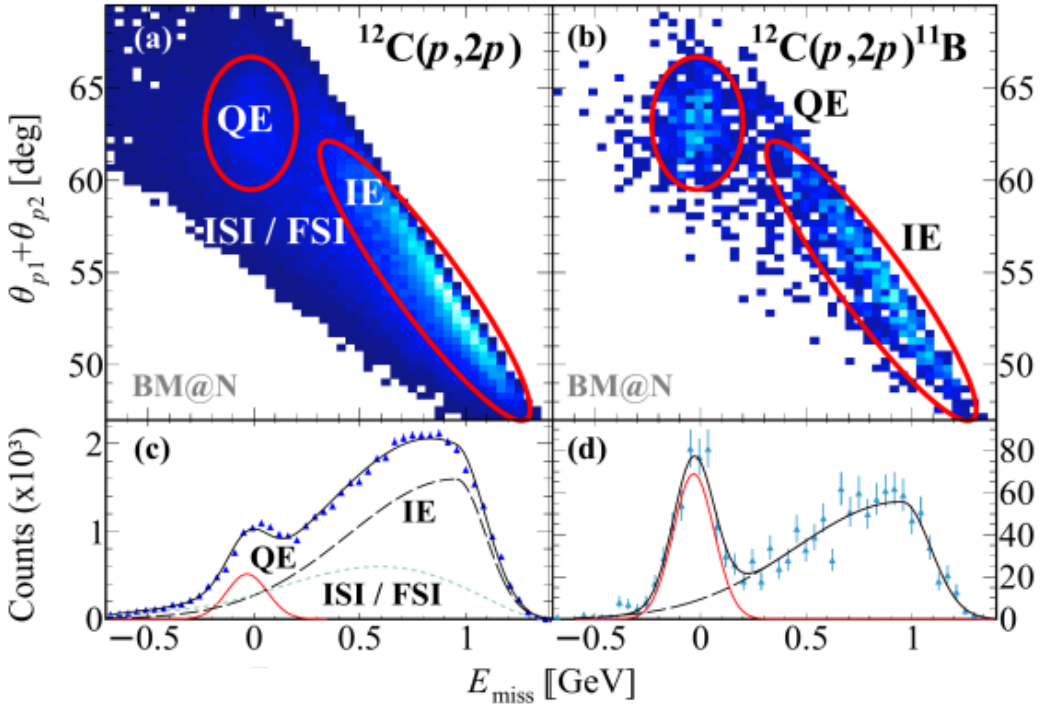
Графики после выравнивания

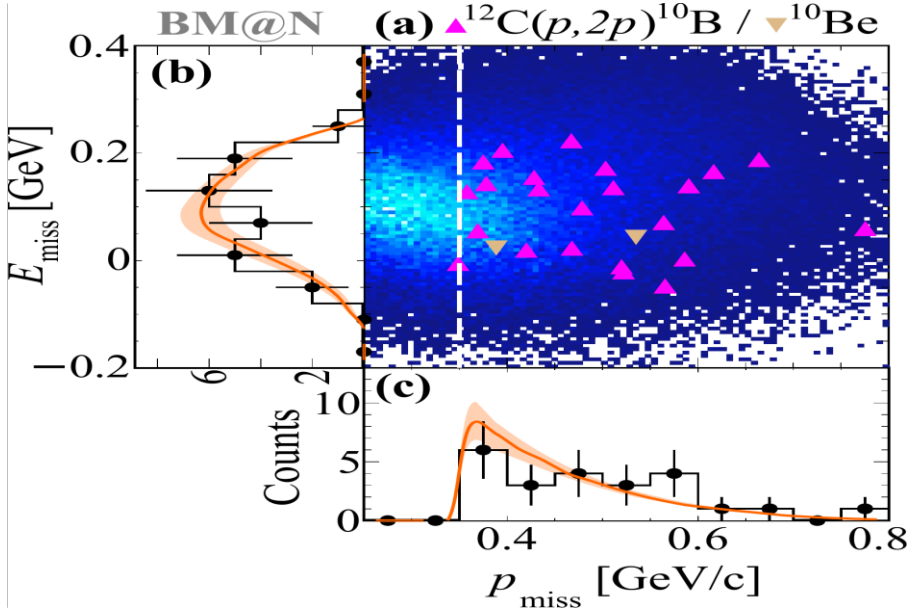






Main results of 2018 experiment

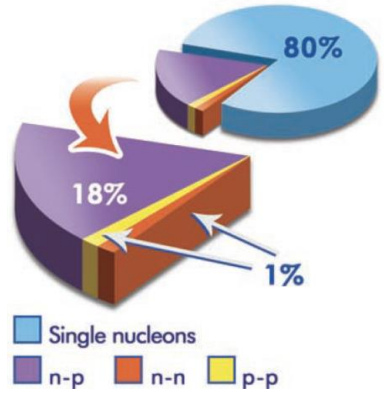




Fragment tagging suppress rescattering
(Initial/Final state interactions)
Select quasi-elastic scattering

23 np SRC pairs

2 pp SRC pairs



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An important result of 2018 experiment: Factorization

Factorization of nuclear many-body wave function
Applied in Generalized Contact Formalism

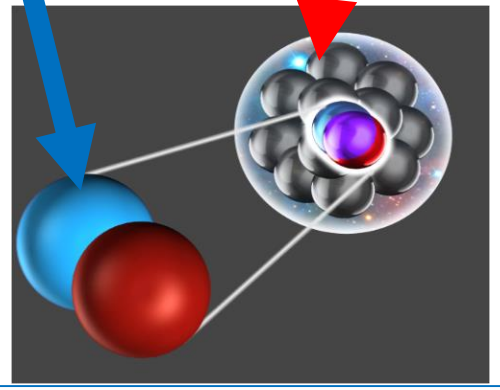
$$\Psi \xrightarrow{r_{ij\to 0}} \sum_{\alpha} \varphi_{ij}^{\alpha}(\boldsymbol{r}_{ij}) A_{ij}^{\alpha}(\boldsymbol{R}_{ij}, \{\boldsymbol{r}_k\}_{k\neq i,j})$$

~ A-2 system

Channels $\alpha = \pi_2 S_2 j_2 m_2$

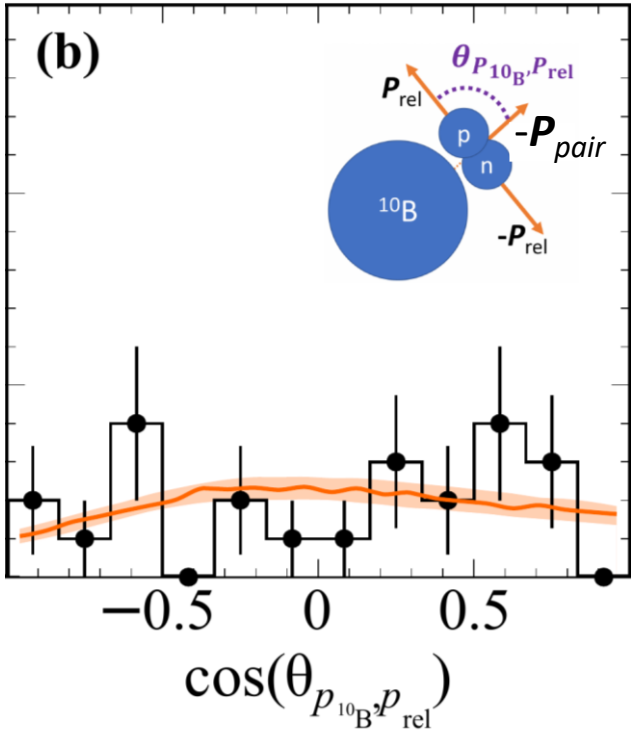
SRC pair "universal" function

The pair kind $ij \in \{pp, nn, pn\}$



Scale separation

$$\boldsymbol{p_{Rel} > p_{pair}}$$



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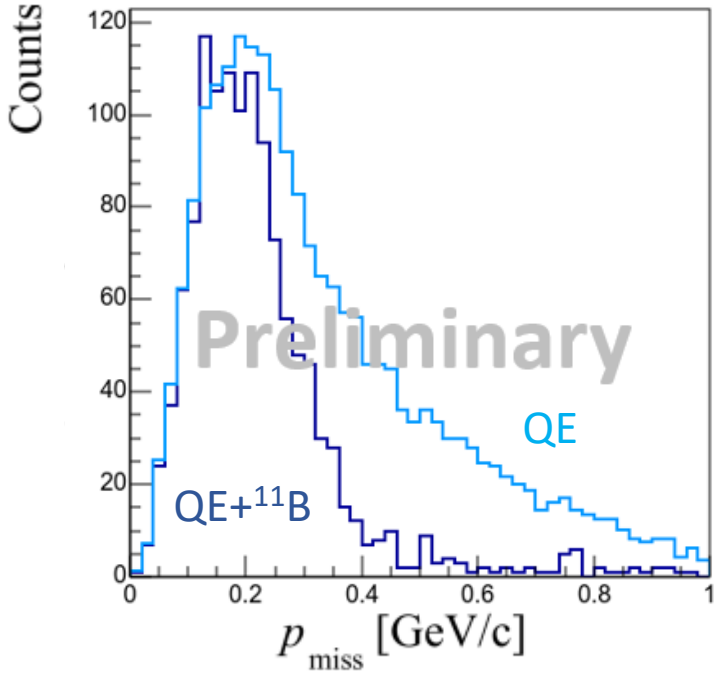
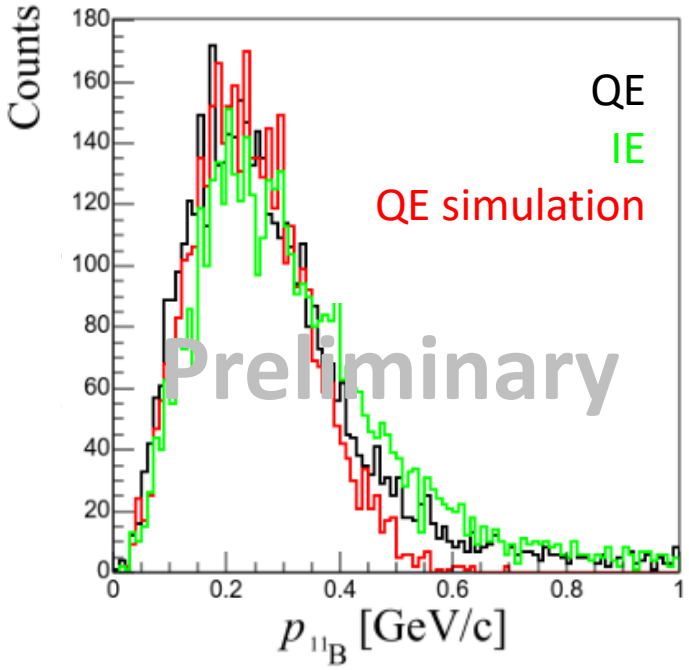
Accessing nucleon momentum distribution

Initial proton momentum

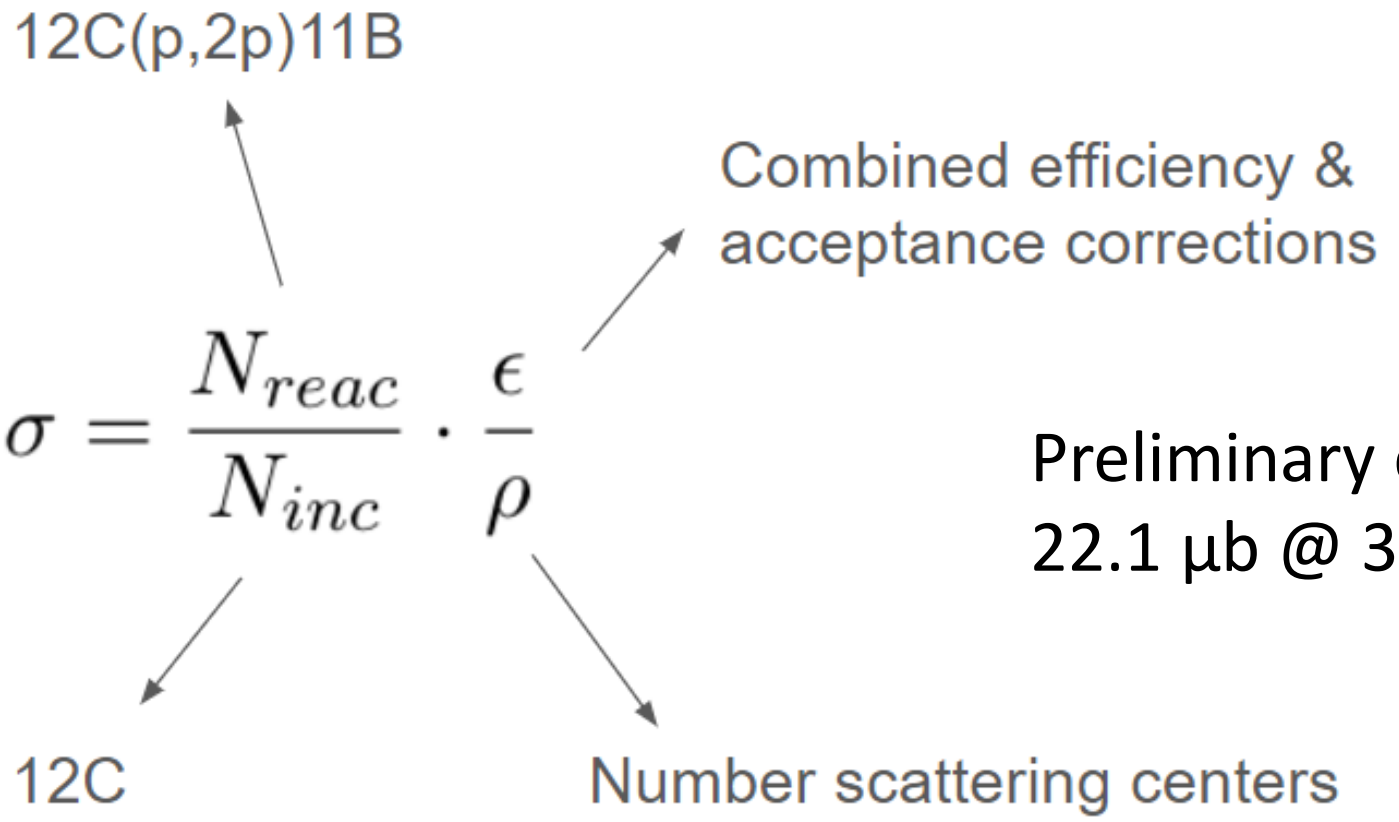


Fragment recoil momentum



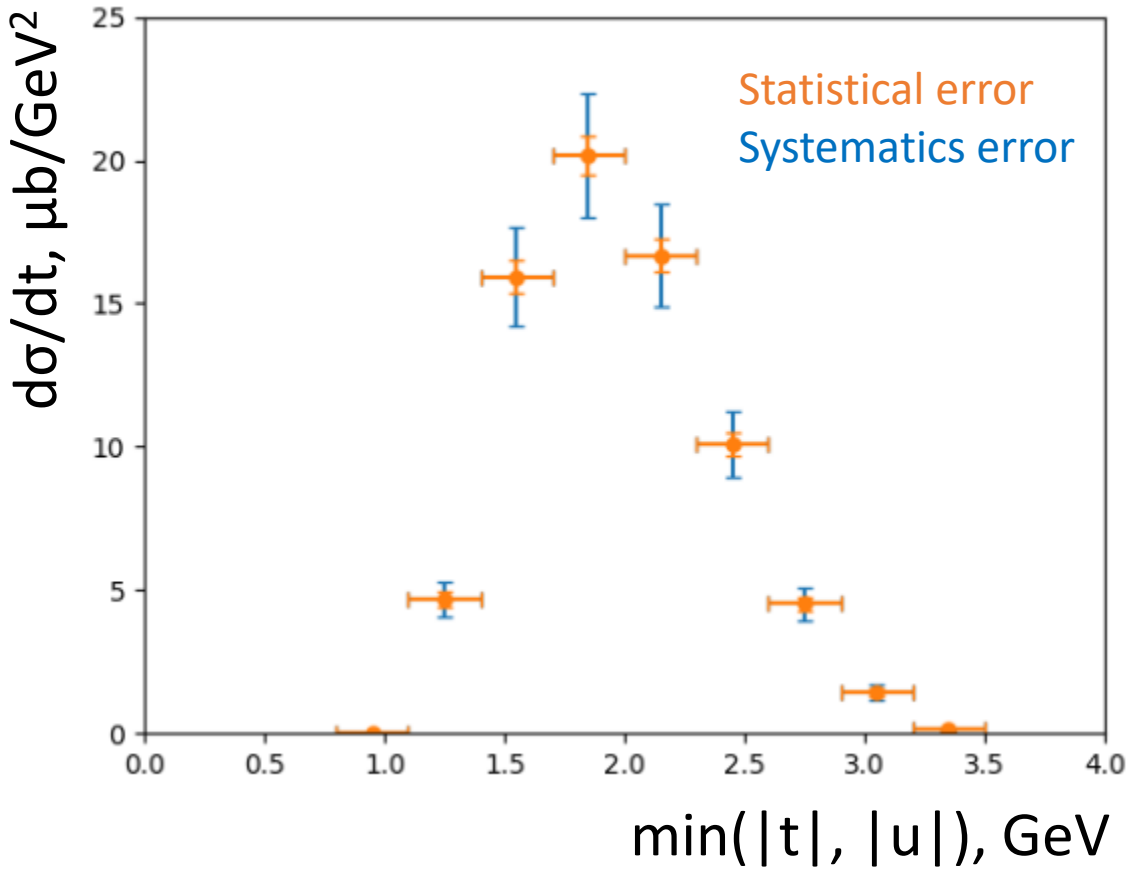
→ single step nucleon knockout process.
Transparent part of reaction

Cross section calculation



Preliminary cross section:
22.1 µb @ 3.75 GeV/c/nucleon

Preliminary QE cross section



This data is to be compared with calculations of A. Larionov (See talk at this conference)

JINR pilot experiment in 2018

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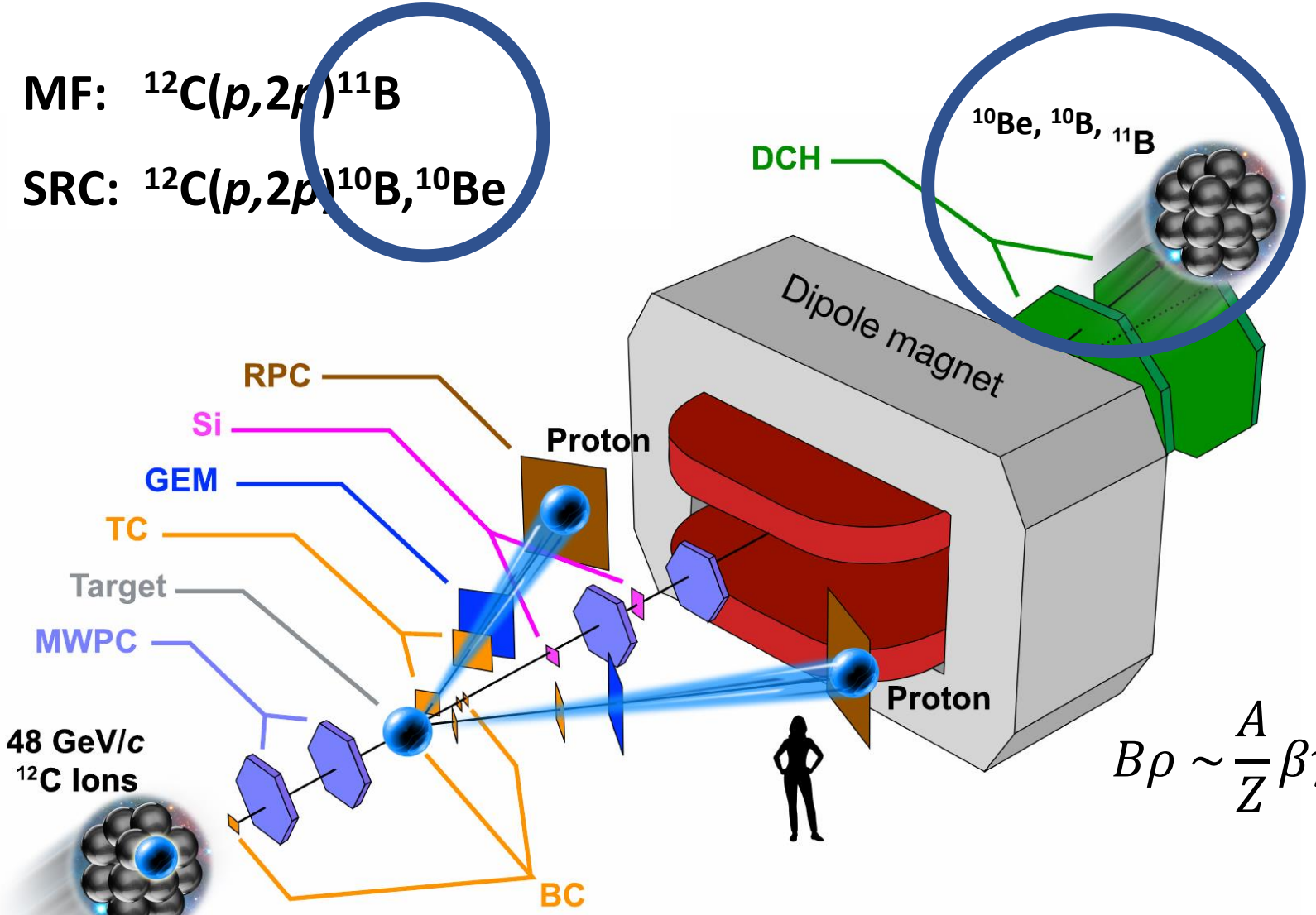
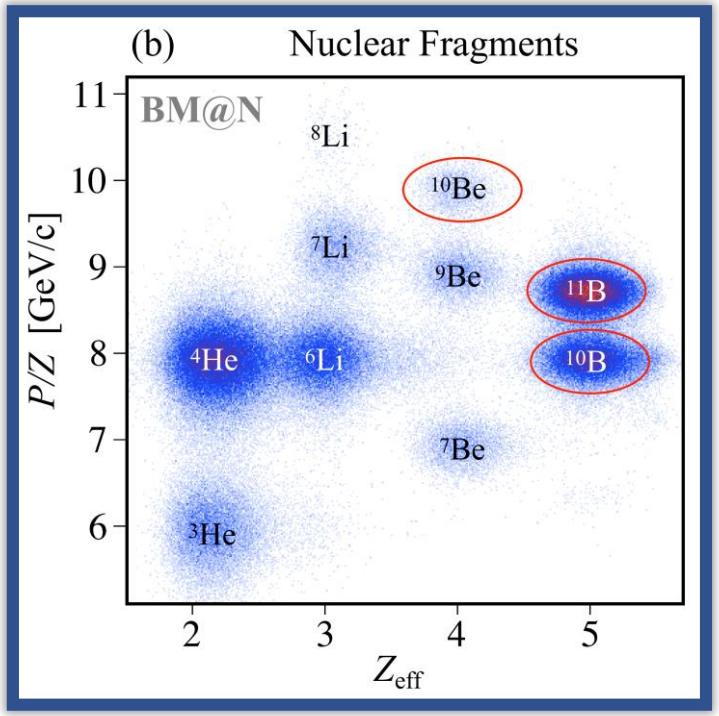
SRC: $^{12}C(p,2p)^{10}B, ^{10}Be$



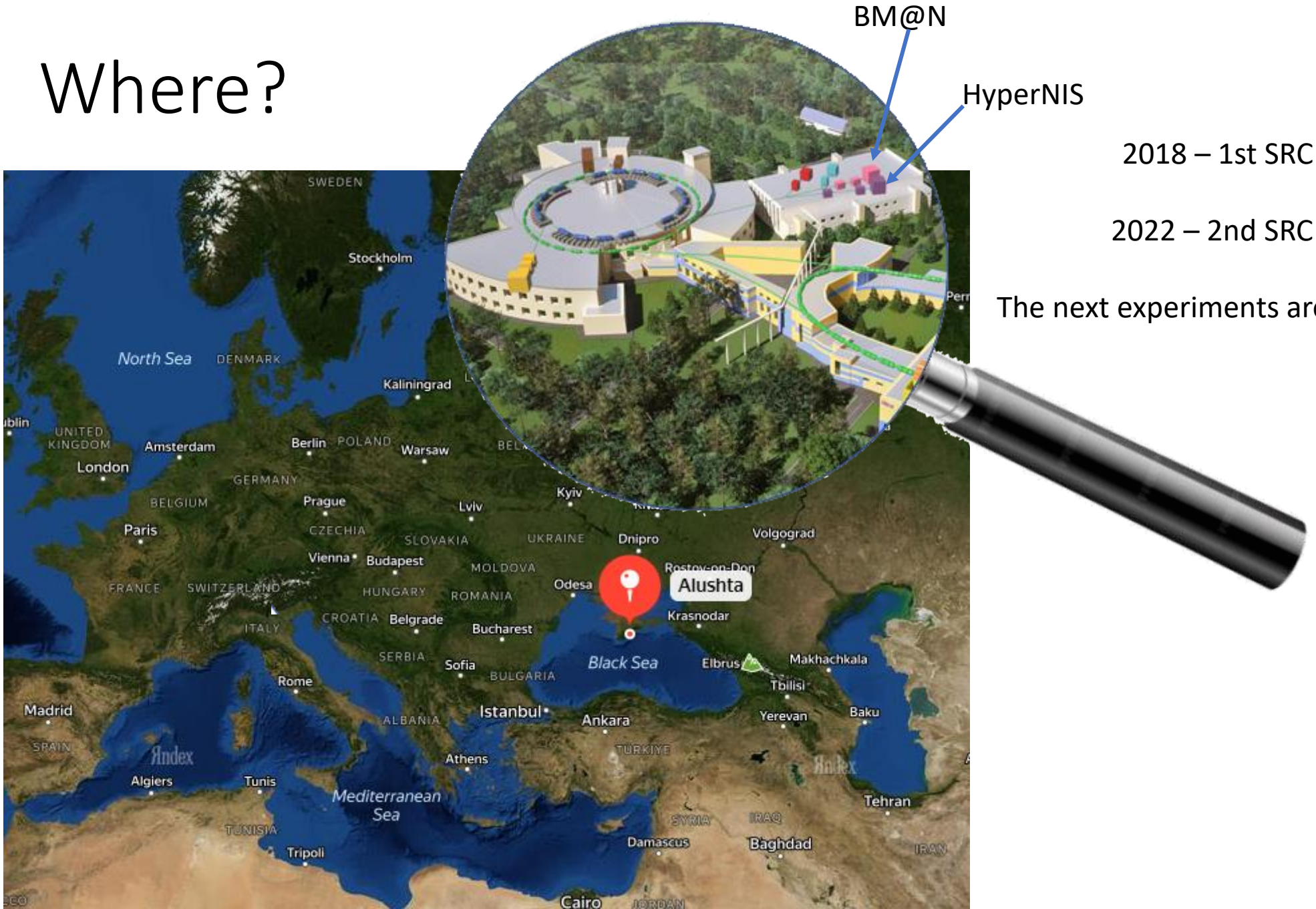


$$B\rho \sim \frac{A}{Z}\beta\gamma$$

Inverse kinematics:

- ✓unstable nuclei
- ✓pmiss, pn
- ✓p probe:
  - ✓larger cross-section
  - ✓(compared to e-scattering)
- ✓fragment ID + pA-2

Where?



2018 – 1st SRC experiment at BM@N

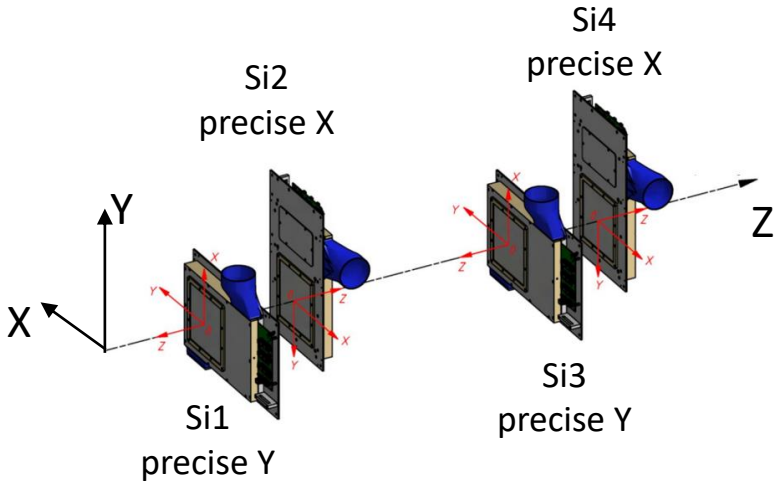
2022 – 2nd SRC experiment at BM@N

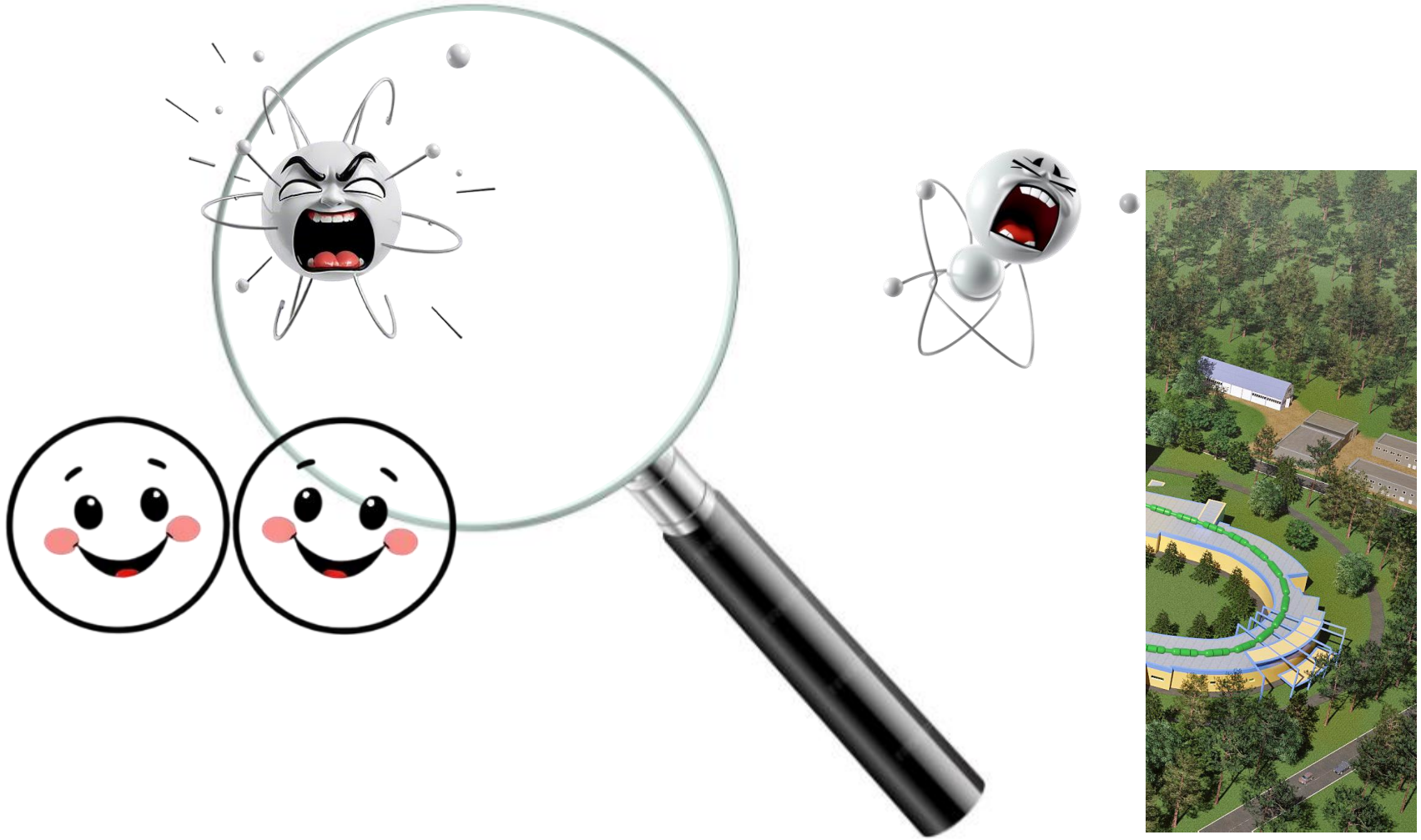
The next experiments are planned at HyperNIS

Alignment

Si detectors:
- 2 pairs of detectors, Si1, Si2, Si3, Si4
- Each detectors consist of 2 modules
- Each module consist of 2 direct strips plane and inclined strips plane

Alignment for each plane, each module






Nica