The downstream CSC data in the 2022 SRC run

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Outline

1. What is SRC and work motivation

2. 2022 SRC run at BM@N

3. The downstream CSC data - tracking of the forward products

What is SRC - short range correlations

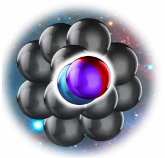
SRC - short range correlations

- nucleons that have relative momenta higher than Fermi level ($k_F \sim$ 250 MeV/c), which are balanced by each other
- temporary ($\sim fs$) strong interactions between nucleons, pairing at distances comparable to their radii (exceptionally close to each other)
- $\sim$80% of kinetic energy of heavy nuclei is within SRC

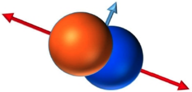
For what SRC

- understanding nuclear structure, nucleon structure, behavior of multiparticle systems, dense drops of nuclear matter (neutron stars), details of the strong interaction

Short-ranged, short-lived, highly correlated pairs of nucleons



High relative and lower center-of-mass momentum



$k_1 > k_F$, $k_2 > k_F$,
$k_1 \simeq k_2$

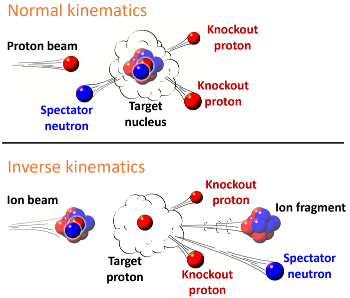
dense configuratios of nucleons

SRC at BM@N 2022 - Physics motivation

Carbon beams on H target

1. Quasi-elastic knockout of nucleons, at maximum momentum and energy transfer
2. interaction with SRC - rare

The dominant SRC pair, pn:



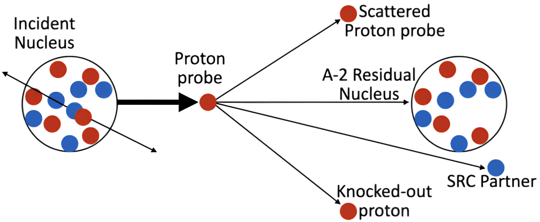
Inverse kinematics:

- available by p-A
- advantage in studying the residual nucleus
- advantage in studying the SRC pair, the "missing" particle

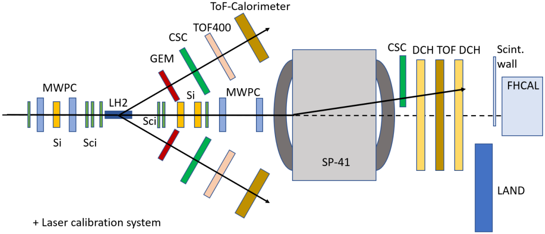
Proton-nuclear interactions:

- larger p-nucleon x-section compared to e^- scattering
- QE p-p scattering has a very strong preference for reacting with high-momentum nuclear protons
- 2018 run $\rightarrow$ Suppress re-scattering (11B)

SRC at BM@N - the experimental technique



Setup



4 Gev/c/u ^{12}C on LH2 target

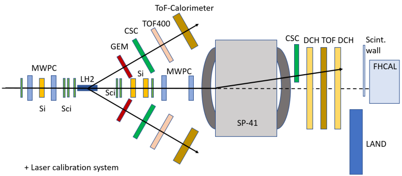
- in the chosen kinematical conditions, the interactions with SRC have an increased probability
- detection of the scattered and knocked-out protons in the TAS (two arm spectrometer)
- detection of the residual nucleus
- **detection of the recoil particle (SRC partner)**

Steps in the CSC data analysis

Input: events with heavy fragments that have:

- 2 reconstructed protons (scattered and knocked-out) in TAS
- reconstructed vertex
- reconstructed tracks - upstream and downstream of the magnet
- identified and reconstructed heavy fragment

Setup



To be done:

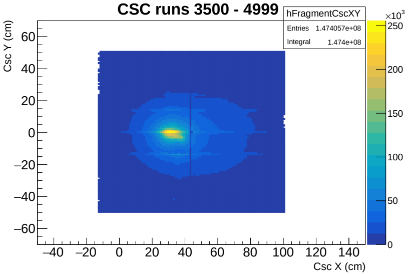
1. identification of the CSC hits **for each event**
2. selection of the proton candidates → SRC "missing"/forward partner
3. analyzing the "missing" protons

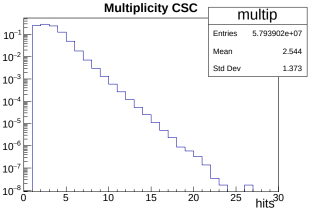
Few tens of SRC p-p events are expected

The downstream CSC

- shifted 43 cm from the beam direction in order to **identify protons** (primary goal) and heavy fragments
- high resolution tracker
- main purpose in this work: looking for the recoil proton from 10 Be reaction (p-p SRC pair)

Occupancy: all registered hits by CSC

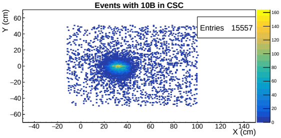


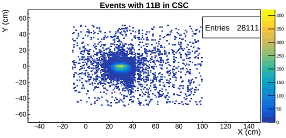


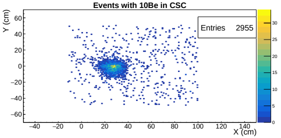
All the registered events (not only the ones selected for the SRC study)

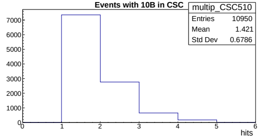
CSC data from the selected events

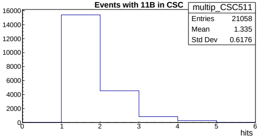
10B | **11B** | **10Be**

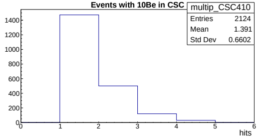










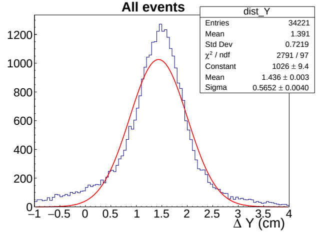


CSC multiplicity		CSC multiplicity	
1	11.17%	>4	0.15%
2	3.6%	>5	0.06%
3	0.74%	>10	0.001%
4	0.22%	>20	0%

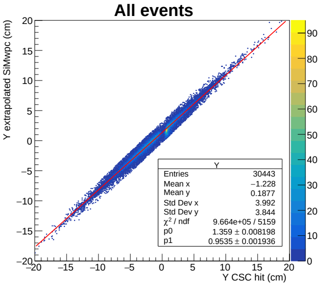
The expected hit position for protons is $\sim$ 60 cm and for the heavy fragments $\sim$ 25-30 cm. The noise is too large to identify protons.

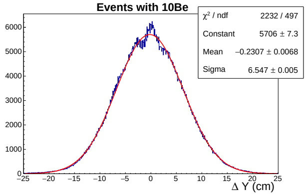
Tracking - assigning CSC hits to the reconstructed tracks

With the tracks **upstream the magnet:**



- shift $\sim$ 1 cm recorded-extrapolated (correlation with the closest hit)
- a clear correlation exists, with $\sigma_{residuals} \simeq 0.56$ cm

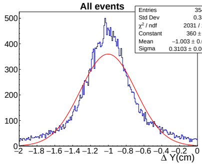


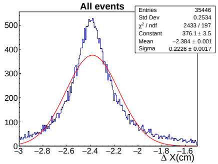


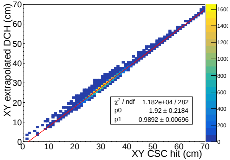
For the mixed events $\sigma_{mixed} > 10 \times \sigma_{residuals}$

Tracking - assigning CSC hits to the reconstructed tracks

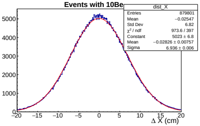
With tracks **downstream the magnet**, from DCH:

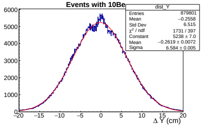






A correlation between hits and extrapolated DCH tracks exists, with $\sigma_{XYresiduals} \simeq 0.24$ cm



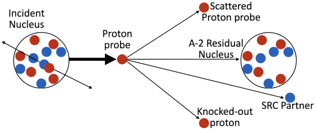


Mixed events with multiplicity = 1

$\sigma_{mixed} \sim 35\ \sigma_{residuals}$

A clear correlation between the CSC hits and the reconstructed upstream and downstream track can be done.

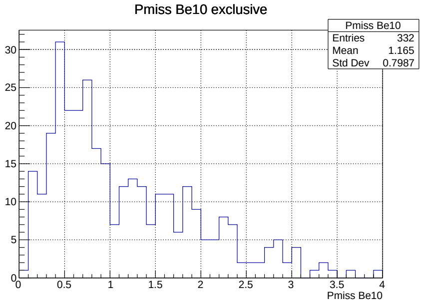
Status of the current work



- the "missing" forward protons are not easy to be identified, due to a high background
- the 2022 data allows to "calculate" the missing protons, from information in TAS and beam

$\rightarrow$ the following approach to identify the proton tracks is proposed:

1. the position of the CSC hit can be predicted
   the momentum of the "missing" proton: $p_{miss\_exclusive} = p_{12C} + p_{tg} - p_1 - p_2 - p_{frag}$
2. confirmation if in CSC there is a hit near the expected proton position



Preliminary results

...to be continued

Наука
сближает народы

Science brings nations together

JINR

Back-up slides ↓

The function for matching 2 trees

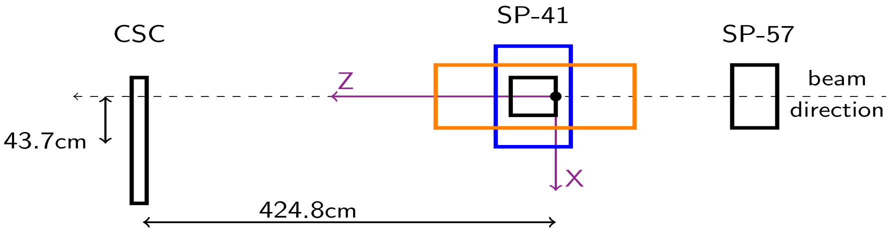
Matching evens in BMN tree with events in CSC (same run number, same event id)
ch_CSC.BuildIndex("RunId","EventId");
auto *cscTreeIndex = ch_CSC.GetEntryNumberWithIndex (RunId, EventId);*

- "Note that this function returns only the entry number, not the data [...] If it finds a pair that matches val, it returns directly the index in the table, otherwise it returns -1. "[1]

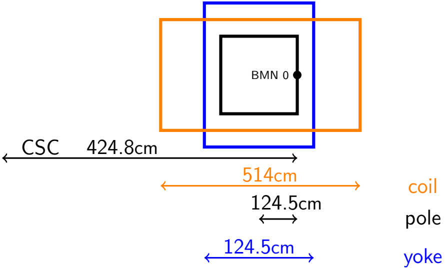
Selection of events: with heavy fragments
beta cut in arms: $0.8 < \text{BetaLeft} \leq 0.98$ $0.8 < \text{BetaRight} \leq 0.98$ —
percentage of accepted synchronized events: 15.89 %
and CSC multiplicity <5 (additional 0.15% events eliminated)

[1] URL: https://root.cern.ch/doc/master/classTTree.html#a1f2ca54aa34f1b64a0bb69ccc0e6c9f8.

Expected hit position in CSC for fragments



$$\theta_{tot} = \frac{Ze}{Ap} \int_0^L B_y \, dz$$



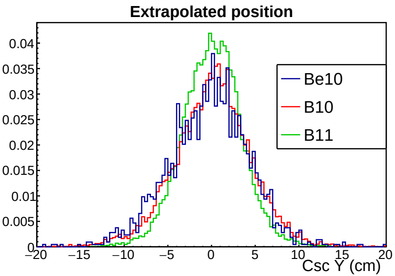
p = 3.7 GeV/c/u

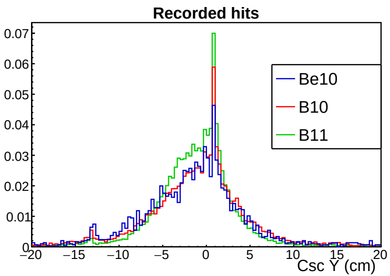
$\int_0^L B_y \, dz = 2.63 Tm$ total field integral $\rightarrow \theta_{tot} = 0.21 \frac{Z}{A}$

fragment	deflection ($^\circ$)	X in CSC
p	12.22	62.14
^{12}C	6.11	31.43
^{10}C	7.33	37.61
$^{10}_{4}Be$	4.9	25.22
$^{10}_{5}B$	6.11	31.43
$^{11}_{5}B$	5.56	28.61

* if the fragment is produced along the beam direction

Y hit position: recorded and extrapolated - all selected events





Y in CSC vs Y in FragSiMwpc: Fitted by Gauss:

track/hit	mean	sigma
Be10 extr	-0.35 $\pm$ 0.1	4.29 $\pm$ 0.07
Be10 recorded	-1.57 $\pm$ 0.1	4.82 $\pm$ 0.1
B10 extr	0.17 $\pm$ 0.04	4.21 $\pm$ 0.03
B10 recorded	-0.96 $\pm$ 0.04	4.61 $\pm$ 0.04
B11 extr	0.05 $\pm$ 0.02	3.3 $\pm$ 0.02
B11 recorded	-1.16 $\pm$ 0.02	3.55 $\pm$ 0.02

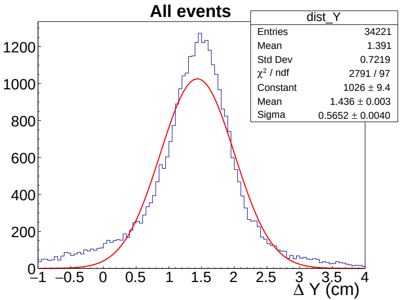
All hits in the selected events:

- smaller σ for bigger A, Z
- the recorded hits spread larger than the extrapolated tracks
- shift $\sim$ 1 cm rec-extr

Residuals on Y - selected tracks

Y in CSC vs Y in FragSiMwpc

Tracks with residuals outside mean $\pm$ 3σ are excluded



The distribution is not a perfect Gaussian - it may be a sum of many, but what the resolution can depend on?

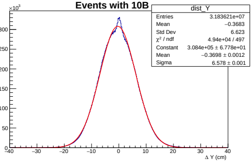
the shift from 0 may be due to the not-perfect perpendicular magnetic field or alignment and in situ detectors position measurement and resolution of fitted tracks, resolution in CSC;

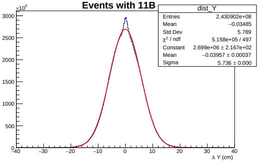
Conclusion: a clear correlation exists, with $\sigma \simeq 0.55$ cm

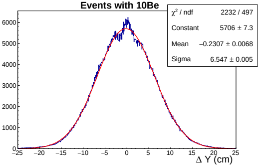
Selected: only events with multiplicity $= 1$

For events inside $\pm 3\sigma$ (according to Simpwc assignement),

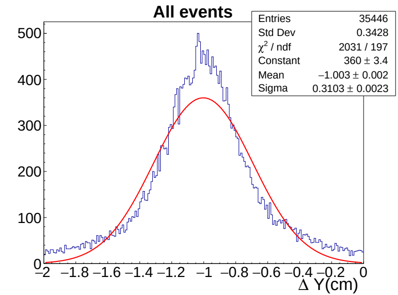
$\sigma = 10 \times \sigma_{residuals}$:

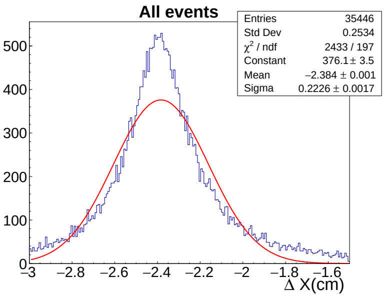


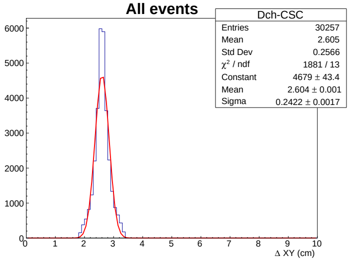




Dch-CSC residuals inside 3 σ

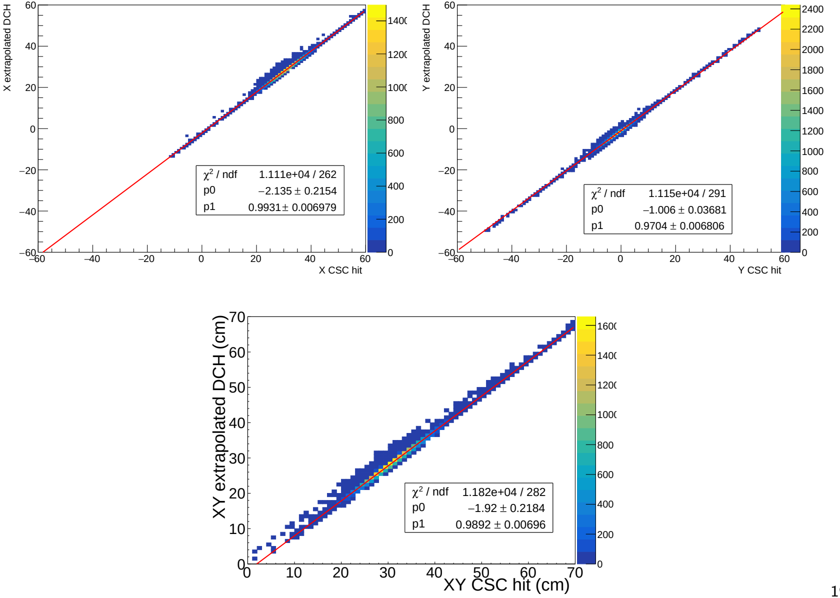






- correspondence by minimum XY (between CSC hit and DCH extrapolation to CSC) inside 3σ
- 14.63 % of tracks are outside 3σ
- a correlation between hits and extrapolated DCH tracks exists, with $\sigma \simeq 0.24$ cm
- shift on both X of 2 cm and Y of 1 cm $--->$ non perfect magnetic field / non perfect in situ alignment ? both upstream and downstream tracks show a shift in Y

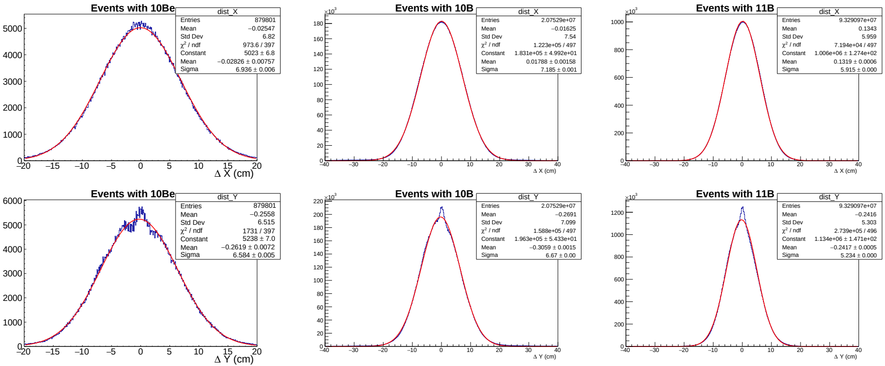
position in CSC vs extrapolated DCH



Mixed events - DCH

events with multiplicity $= 1$, inside 3 σ

$\sigma \sim 35\ \sigma_{residuals}$



Status of the SRC at JINR

2018 run at BM@N: $^{12}C(p,2p)^{11}B$

- the first experiment on SRC in inverse kinematics
- detection of 11B: scattering on a "transparent" carbon nucleus
- 25 events (23 np + 2pp) confirmed the SRC properties known from e^- experiments

Status of the 2022 run 45 GeV/c 12C

- Main goal: reactions cross sections and fragmentation properties for single nucleon knockout and SRC pairs, ground-state proton momentum distributions with fragment tagging (suppress ISI/FSI, rescattering)
- SRC: Improved statistics, detect recoil SRC-pairs n/p ratios, multi-fragment reconstruction, fragment distribution
- *Finish analyzing the full 2022 set of data*

future run - 2026?

- will be in HyperNis area
- will use tensor-polarized deuteron beam for

SRC cut

```
if(VertexZ > -576.2+cut || VertexZ < -576.2-cut) continue;
if(BetaLeft<0.8 || BetaLeft>0.98 || BetaRight<0.8 ||
    BetaRight>0.98) continue;

if(Mdf_Fragment[0]== 511)  continue;

if(pow(VertexX-1,2) + pow(VertexY,2) >= 3*3) continue; //beam

   if(Pmiss<=0.350) continue;

   if(ThetaOpening<=63) continue;

   if(Mdf_Tracks!=1) continue;

   if(Mdf_Fragment[0]==510) {your work}
   if(Mdf_Fragment[0]==410)  {your work}
```