Nuclear Fragmentation Measurements with NA61/SHINE
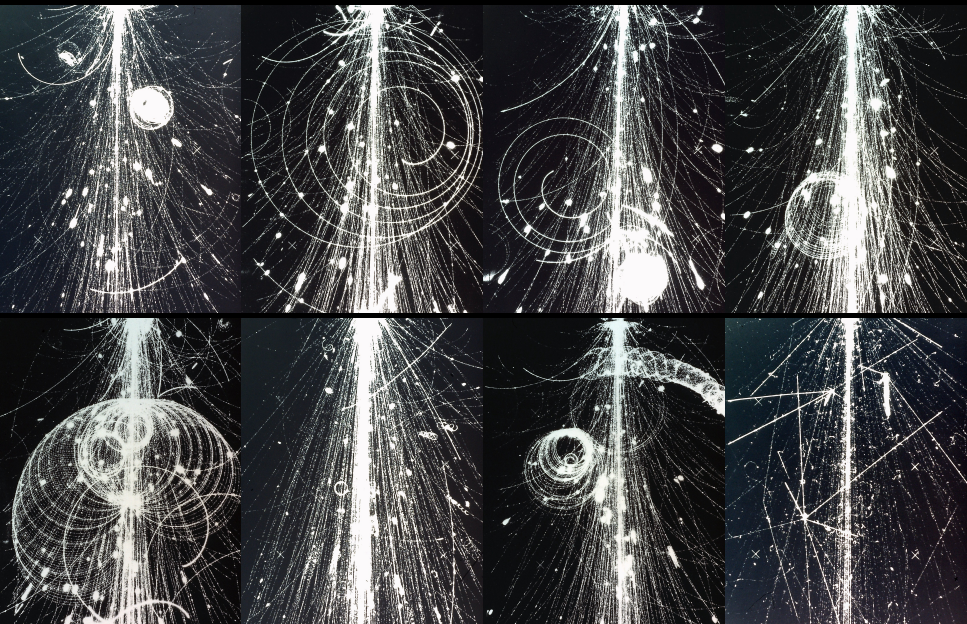## Results and Prospects

M. Unger (KIT) for the NA61/SHINE Collaboration

NA35 3.2 TeV O+Pb interactions

Cosmic-Ray Related Measurements with NA61/SHINE

- Particle Production in Air Showers
  - p+C Interactions
    (31, 60, 90 120 GeV/c)
  - π+C Interactions
    (30, 60, 158, 350 GeV/c)
- Galactic Cosmic Rays
  - $\bar{p}$, d and $\bar{d}$ Production
    (p+p at 20, 31, 40, 80, 158, 400 GeV/c)
  - Nuclear Fragmentation NEW!
    (C+C, C+CH$_2$ at 13.5 AGeV/c)
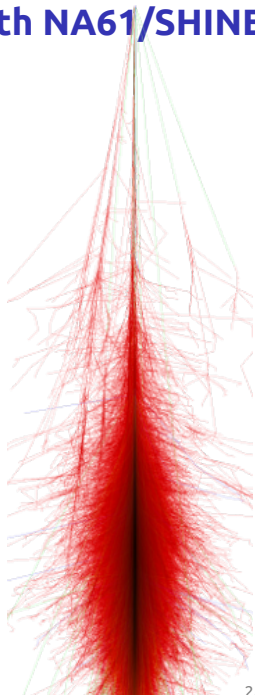
Addendum to the NA61/SHINE Proposal SPSC-P-330

Feasibility Study for the Measurement of Nuclear Fragmentation Cross Sections with NA61/SHINE at the CERN SPS

The NA61/SHINE Collaboration

Oct 2017

Current status and desired accuracy of the isotopic production cross sections relevant to astrophysics of cosmic rays I. Li, Be, B, C, N

Yoann Génolini
Service de Physique Théorique, Université Libre de Bruxelles, Belgium

David Maurin
LPSC, Université Grenoble-Alpes, CNRS/IN2P3, France

Igor V. Moskalenko
HEPL and KIPAC, Stanford University, USA

Michael Unger
IKP, Karlsruhe Institute of Technology, Germany

Mar 2018

Addendum to the NA61/SHINE Proposal SPSC-P-330

Study of Hadron-Nucleus and Nucleus-Nucleus Collisions at the CERN SPS
Early Post-LS2 Measurements and Future Plans
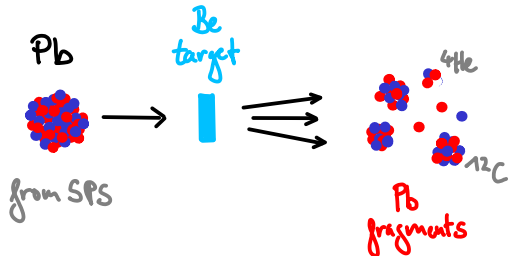
The NA61/SHINE Collaboration and the CERN team

Mar 2018
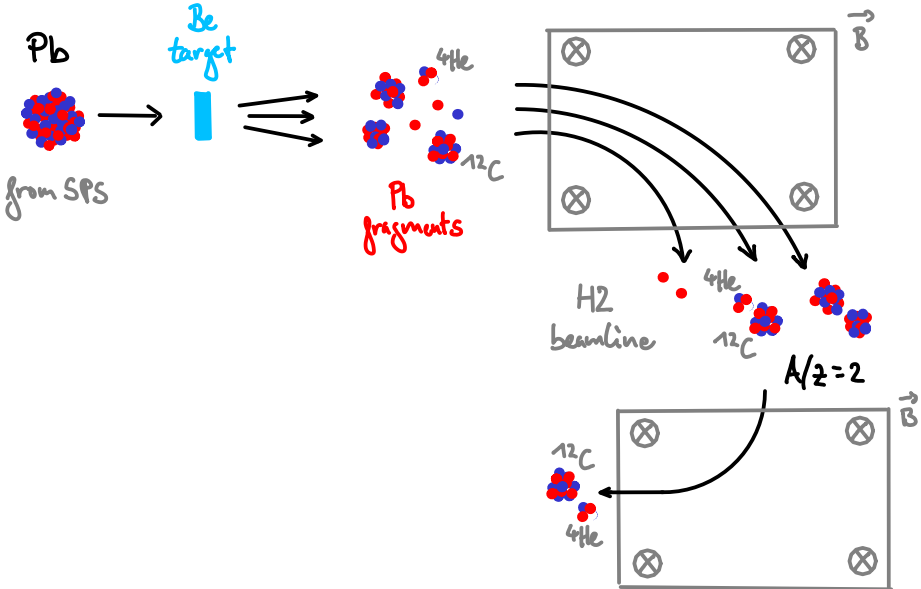
Dec 2018

PROCEEDINGS OF SCIENCE

New Results from the Cosmic-Ray Program of the NA61/SHINE facility at the CERN SPS

Aug 2019

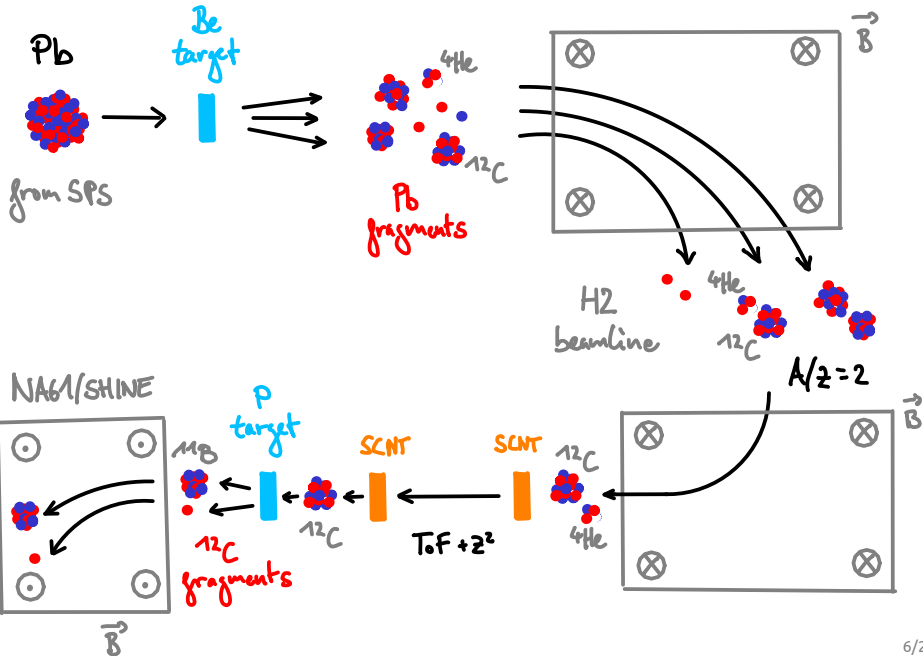# Nuclear Fragmentation with SPS and NA61/SHINE

Nuclear Fragmentation with SPS and NA61/SHINE

Nuclear Fragmentation with SPS and NA61/SHINE

Pb — from SPS

Be target

Pb fragments

⁴He

¹²C

$\vec{B}$

H2 beamline

$A/z = 2$

⁴He

¹²C

NA61/SHINE

$\vec{B}$

¹²B

P target

¹²C fragments

SCNT

SCNT

ToF + z^2

¹²C

⁴He

$\vec{B}$

The Super Proton Synchrotron (SPS) at CERN

LHC

SPS

Maximum Beam Momentum: $Z \times$ 450 GeV/c, accelerates p, p̄, O, S, Ar, Pb,

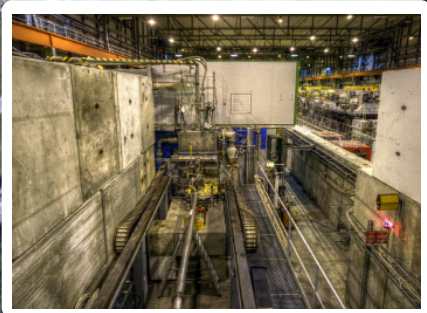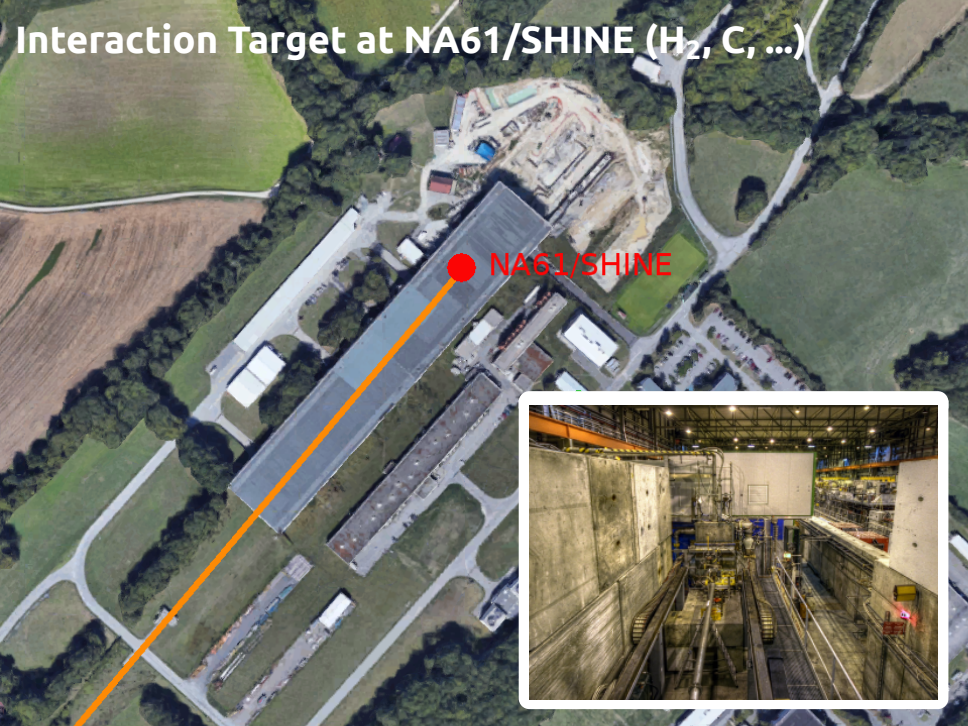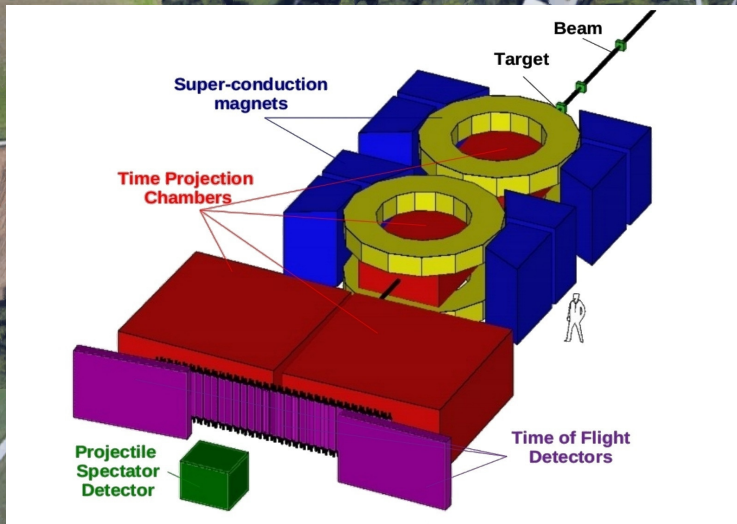# H2 Beam Line: Primary Beam, fragments, $\pi^{\pm}$, $K^{\pm}$...

H2

A **precise** (2% dp/p acceptance), robust, flexible magnetic spectrometer

EHN1 Building

NA61

~8m EARTH

~2-2.8m

~10m

Target

muon halo

TT20

SPS

I. Efthymiopoulos - CERN - EDMS No: 1165938
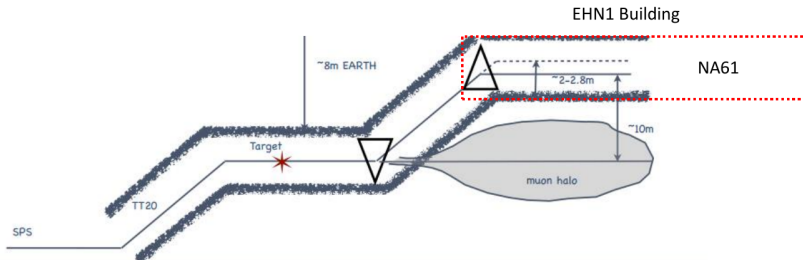
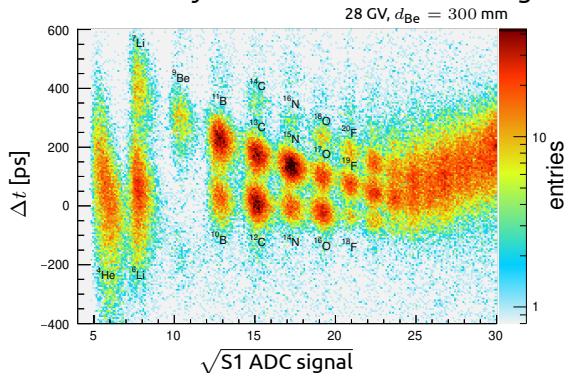# Interaction Target at NA61/SHINE (H₂, C, …)

NA61/SHINE

Particle Production Measurement at NA61/SHINE

- large acceptance $\approx 50\%$ at $p_T \leq 2.5\,\text{GeV/c}$
- momentum resolution: $\sigma(p)/p^2 \approx 10^{-4}\,(\text{GeV/c})^{-1}$
- tracking efficiency: $> 95\%$, pid with dE/dx and ToF
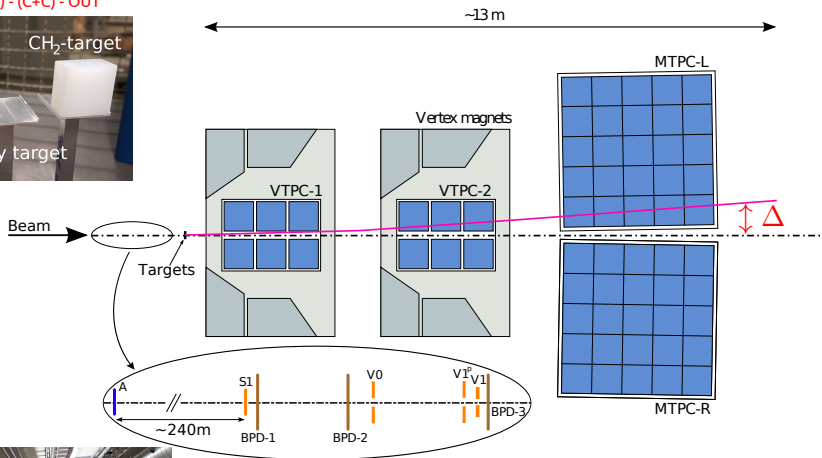
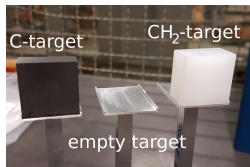# 2018 Pilot Run on Nuclear Fragmentation

composition of secondary ion beam measured during data taking:

- primary Pb beam on Be target, rigidity selection in H2 beam line
- special H2 beamline optics (simulation and operation by N.Charitonidis)
- three days of data taking at 27 GV
- 1.1×10^6 beam trigger on $Z^2 = 36$
- offline selection: 3.6×10^5 ^{12}C beam particles
- 20k ($^{12}C+CH_2$) and 17k ($^{12}C+{}^{12}C$) interactions

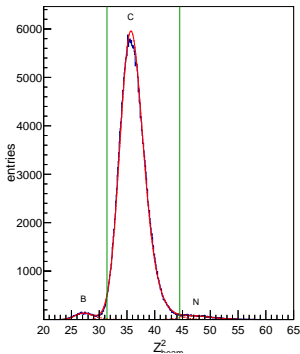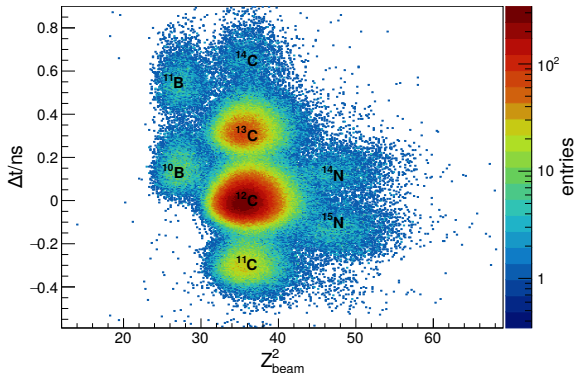# 2018 Pilot Run on Nuclear Fragmentation

"C+p = (C+CH₂) - (C+C) - OUT"

C-target   CH₂-target

empty target

Beam

Targets

~13 m

MTPC-L

Vertex magnets

VTPC-1   VTPC-2

Δ

MTPC-R

~240m

A   S1   V0   V1'V1

BPD-1   BPD-2   BPD-3

$$\text{ToF(A to S1)} + \text{d}E/\text{d}x\text{(S1)} \rightarrow (A, Z^2)_{\text{beam}}$$
$$\Delta + \text{d}E/\text{d}x\text{(MTPC)} \rightarrow (A, Z^2)_{\text{fragment}}$$
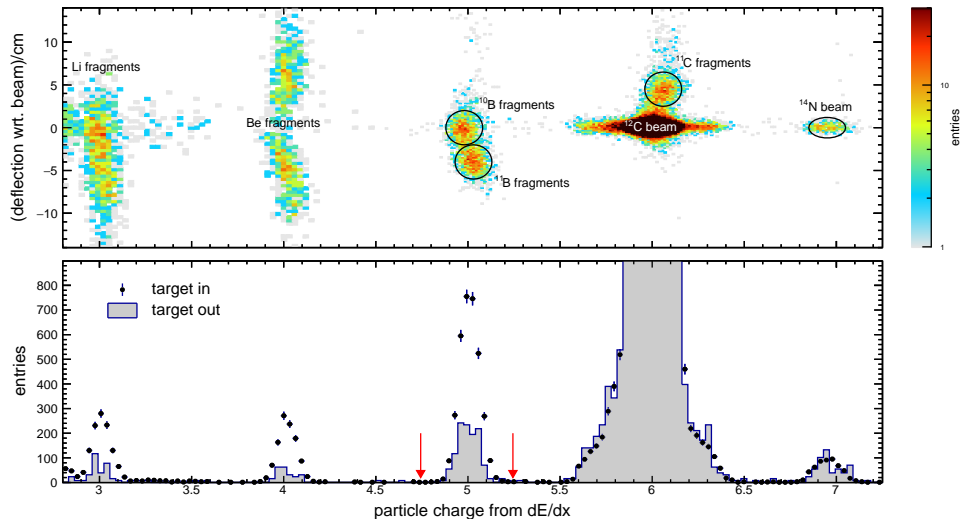
^{12}C Beam Selection

triggered beam composition:

offline beam selection:
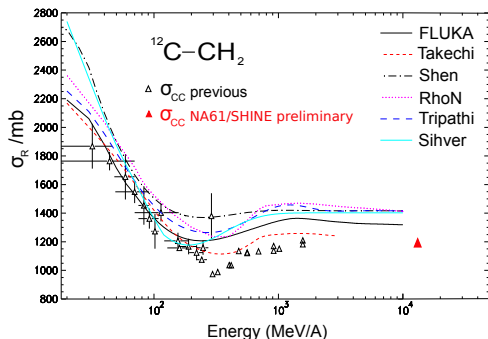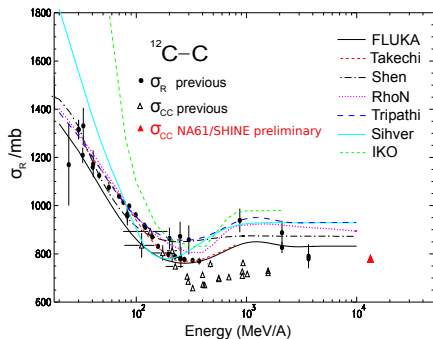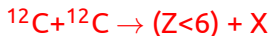
- ^{12}C purity: 99.2%
- B contamination: <0.1%
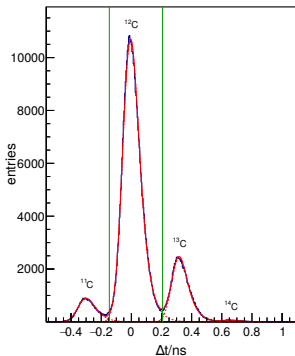
Identification of Isotopes Produced in Target (MTPC)
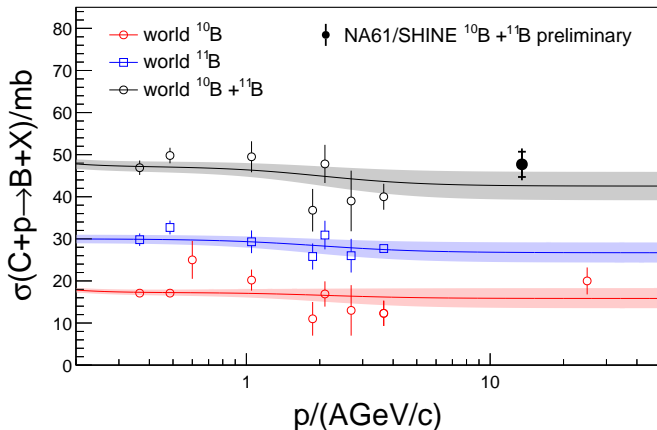

B-selection indicated by red arrows

Charge-Changing C+C & C+CH₂ Cross Section (preliminary)

$^{12}C+^{12}C \rightarrow (Z<6) + X$

$^{12}C+CH_2 \rightarrow (Z<6) + X$

adapted from L. Shiver et al, Adv. Space Research **49** (2012) 812

F. Sutter, Masters Thesis KIT 2019
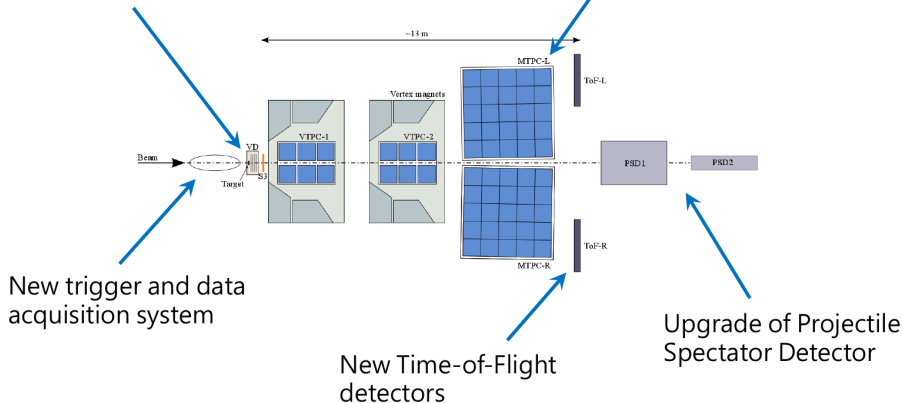
Direct ^{10}B + ^{11}B Production (preliminary)

$$\sigma(^{12}C + p \rightarrow {}^{10}B + X) + \sigma(^{12}C + p \rightarrow {}^{11}B + X) =$$
$$47.7 \pm 3.0 \text{ (stat.)} \pm 2.3 \text{ (syst.) mb}$$

Plans For Run3

Replacement of the TPC
read-out electronics
to increase data rate to 1 kHz

Construction of Vertex Detector (VD)
for D^0, $\overline{D^0}$ decay reconstruction

New trigger and data
acquisition system

New Time-of-Flight
detectors

Upgrade of Projectile
Spectator Detector

Plans For Run3

Beam request for 24 days of secondary light ion beam at 13 A GeV/c
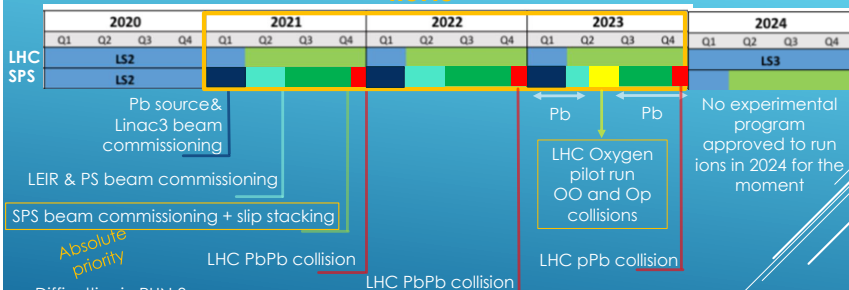
Reyes Fernandez, "Ion beams in 2021-2024", open session, NA61 Collab Meeting September 2019

Plans For Run3

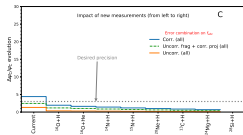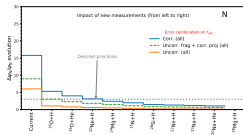| reaction	N_{inter}	A/Z
^{16}O + H	250k	2
^{12}C + H	150k	2
^{16}O + He	100k	2
^{14}N + H	40k	2
^{10}B + H	5k	2
^{11}B + H	5k	2
^{12}C + He	5k	2
^{13}C + H	5k	11/5
^{15}N + H	5k	13/6
^{20}Ne + H	5k	15/7
^{24}Mg + H	5k	2
^{28}Si + H	5k	2
^{7}Li + H	5k	7/3
$\sum = 0.6$M		

Li

Be

B

C

N

Genolini+2018
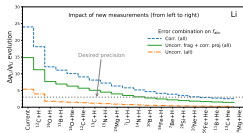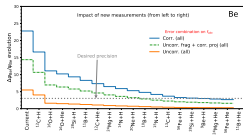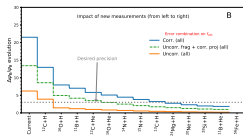
New Collaborators Welcome!!

- upgrade of detector
- planning of data taking
- optimization of trigger
- targets
- data analysis