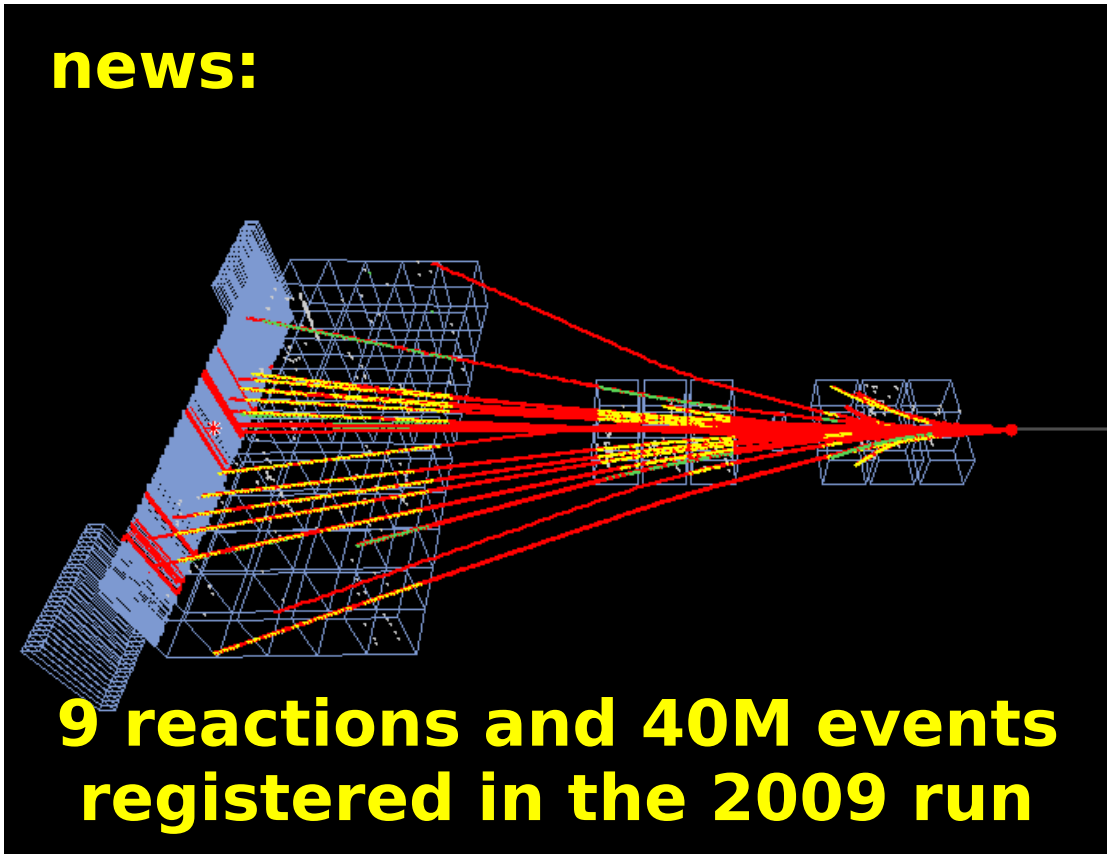
# NA61/SHINE: Status and Data taking with ion beams

**(SHINE – SPS Heavy Ion and Neutrino Experiment)**






*M. Gazdzicki, Frankfurt, Kielce*
*for the NA61 Collaboration*

- Preliminary results from the 2007 pilot run
- 2009 physics run
- data taking schedule with ion beams

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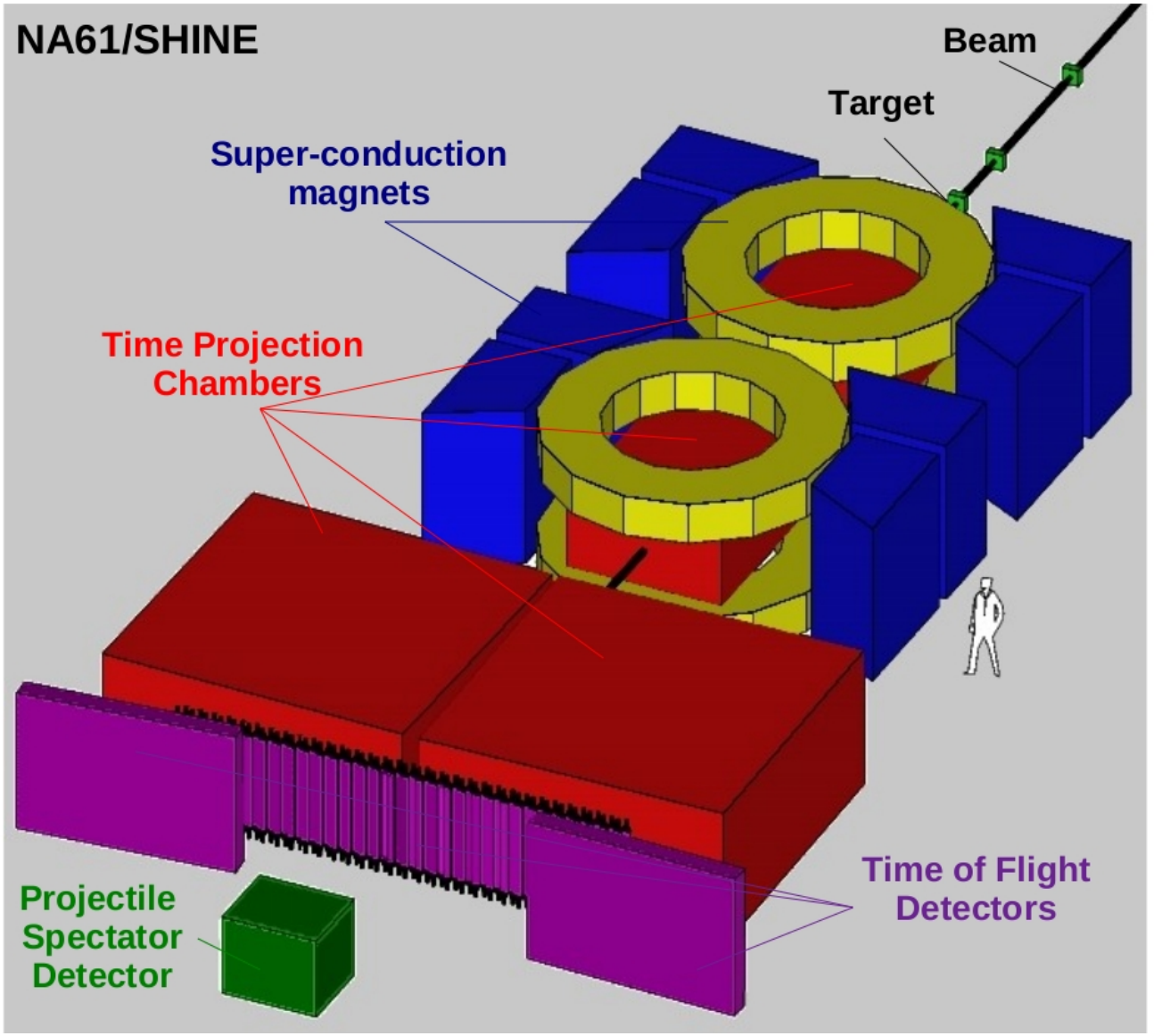
# Detector



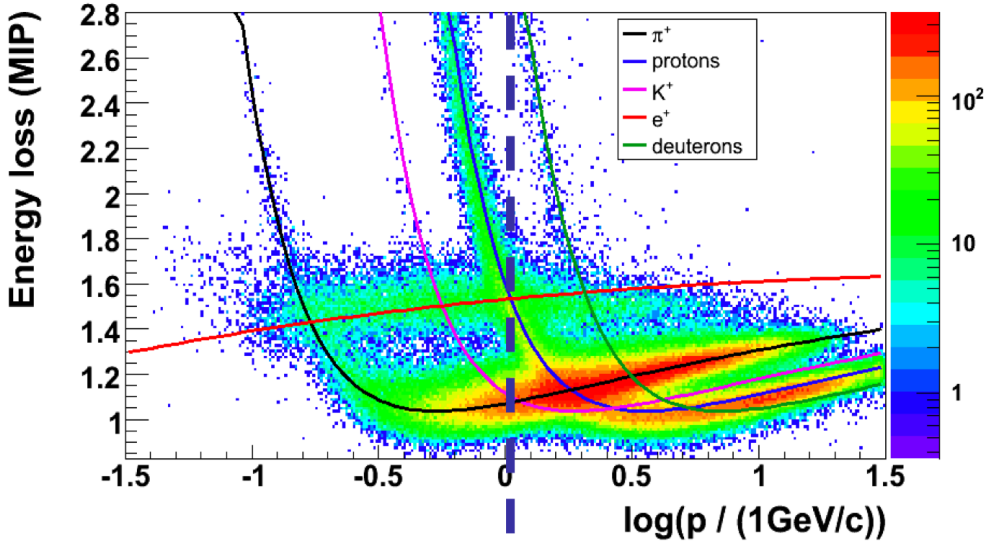

**NA49 facility +**

**TPC read-out (x10)**
**ToF (x2)**
**PSD (x10)**
**Beam pipe (x10)**

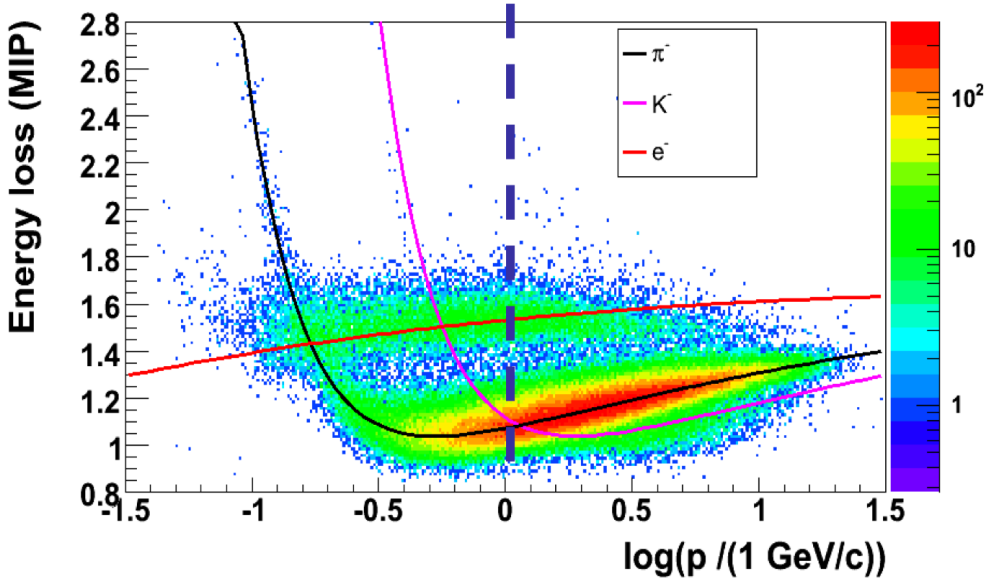
*NA49: Nucl. Instrum. Meth. A430, 210 (1999)*
*NA61 upgrades: CERN-SPSC-2006-034, SPSC-P-330*

# Particle identification: dE/dx and *tof* measurements

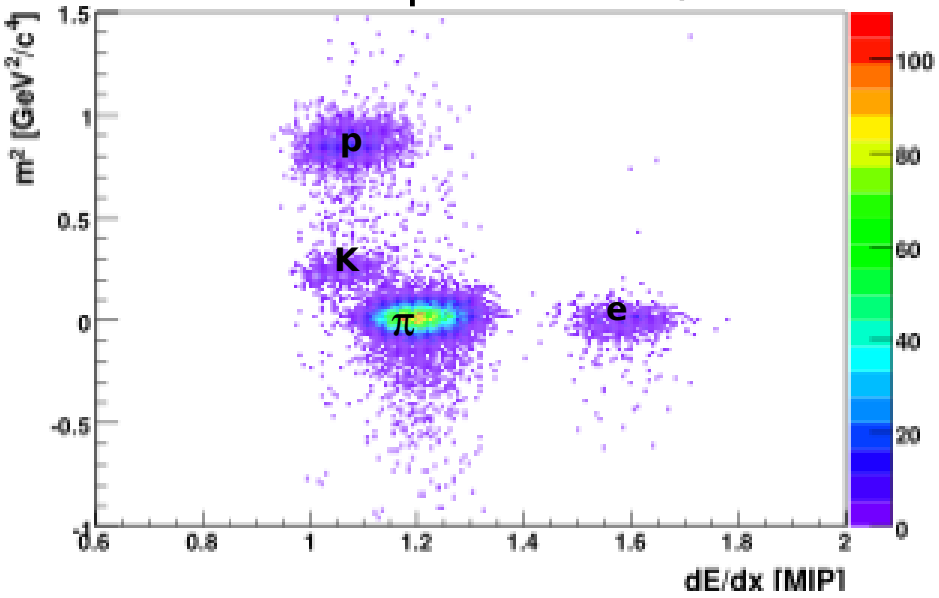
**Positive particles**




**Negative particles**



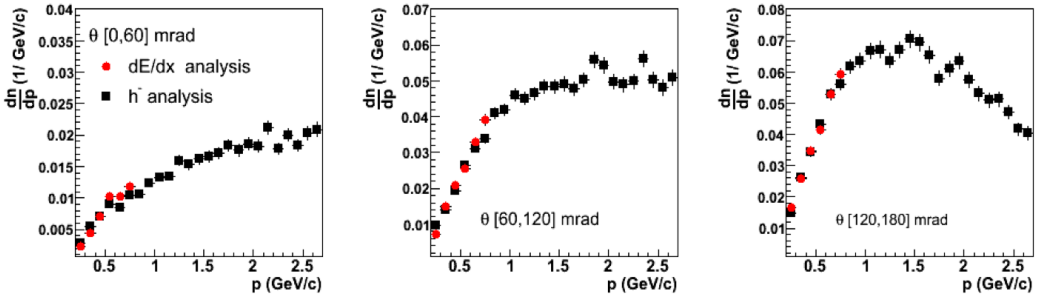

2 < p < 3 GeV/c



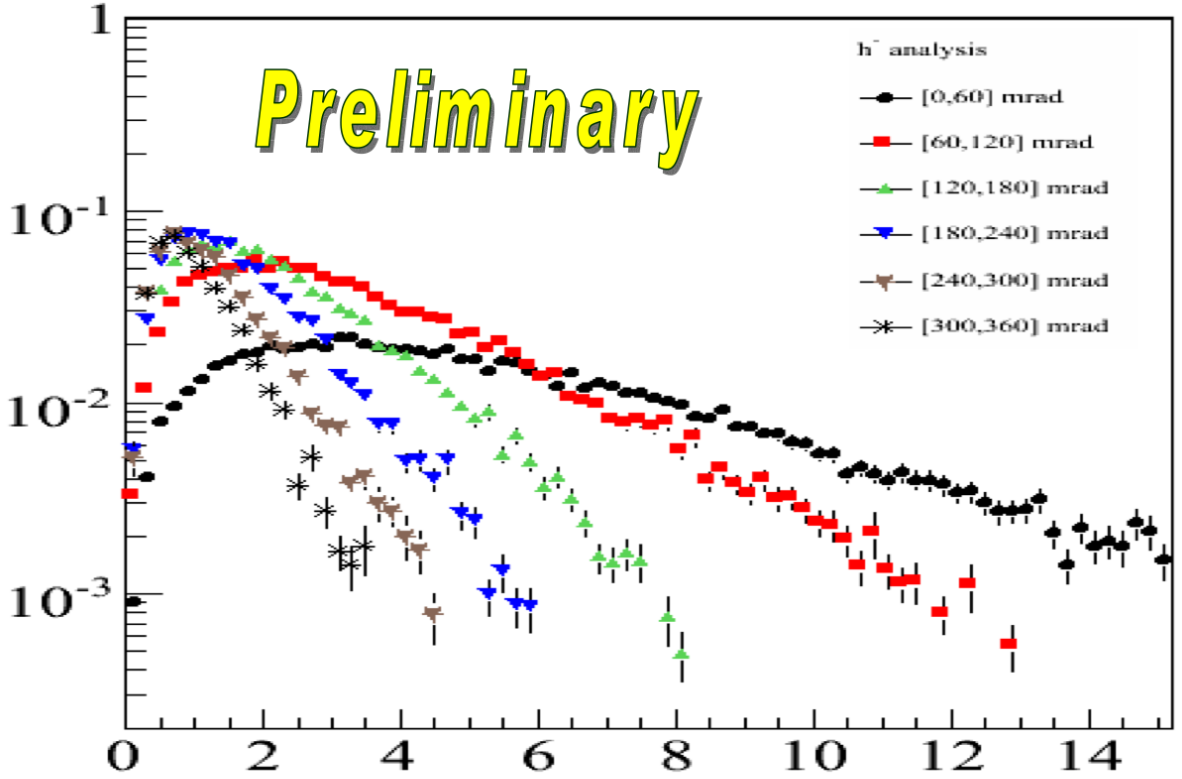

**σ(dE/dx)/<dE/dx> ≃ 4%**

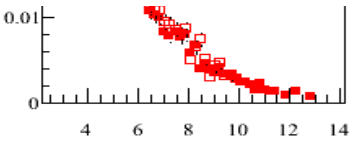
**σ(*tof*) ≃ 60-120 ps**

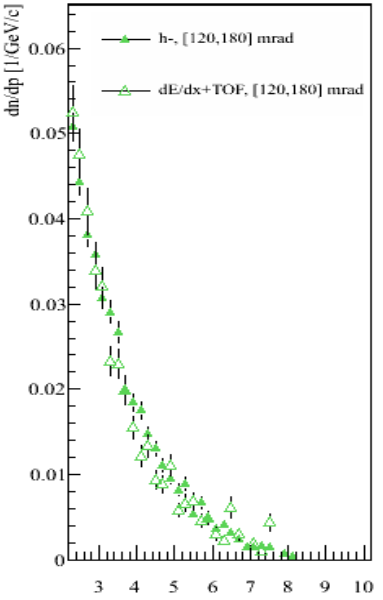
# Preliminary results from the 2007 pilot run




**p+C at 31 GeV/c**



# 2009 physics run

Data taking period:  July 26 – November 16

Aim:  high statistics data for:

- T2K: p+C and p+(T2K RT) at 31 GeV/c
- cosmic-ray: π+C at 158 and 350 GeV/c
- CP, OD:  p+p at 10-158 GeV/c

Registered in 2009:

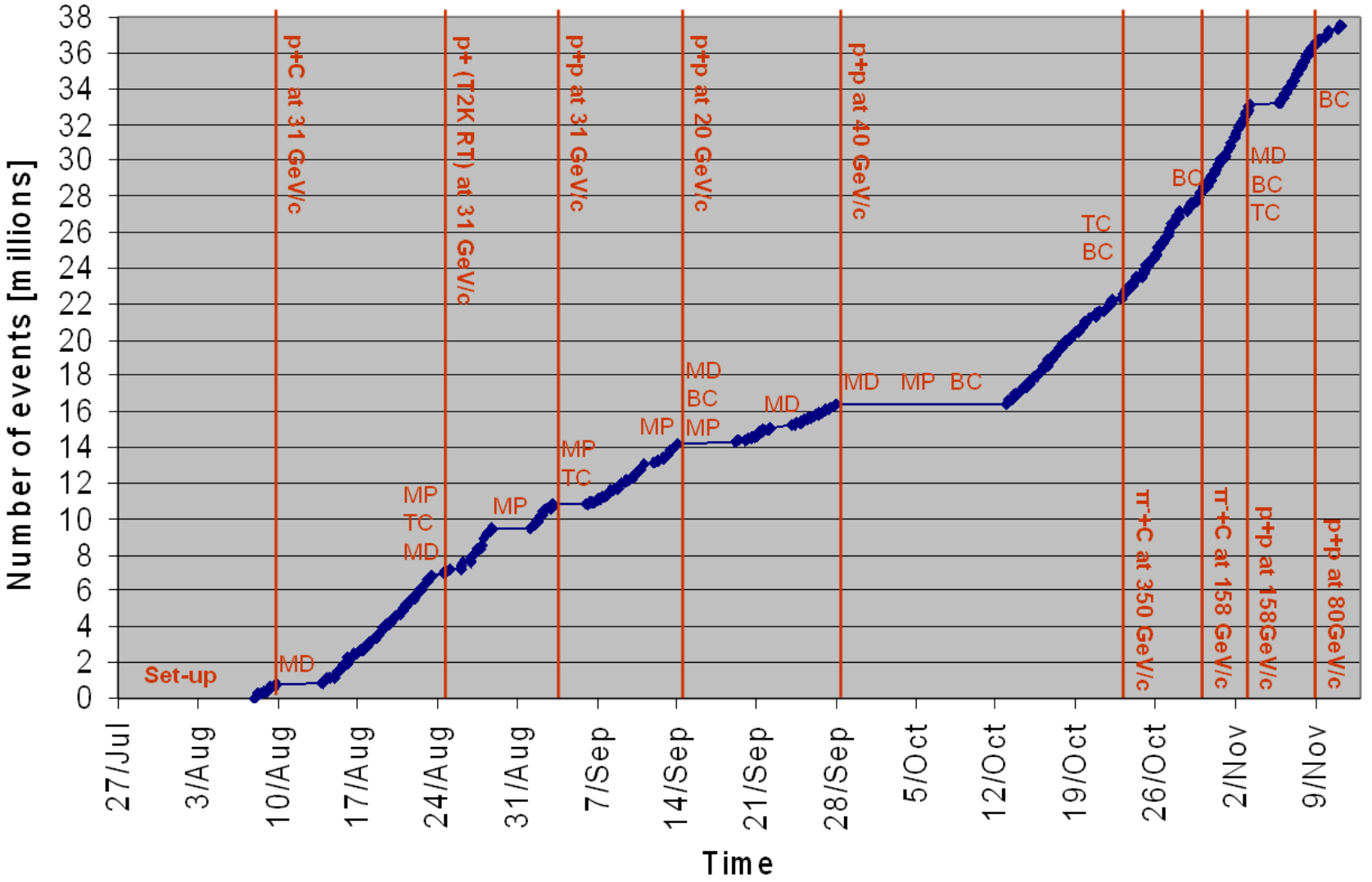
p+C at 31 GeV/c
p+(T2K RT) at 31 GeV/c

pion+C at 158 GeV/c
pion+C at 350 GeV/c

p+p at 20 GeV/c
p+p at 31 GeV/c
p+p at 40 GeV/c
p+p at 80 GeV/c
p+p at 158 GeV/c

*p+p at 10 GeV/c were not registered due to insufficient beam quality*

# 2009 run history

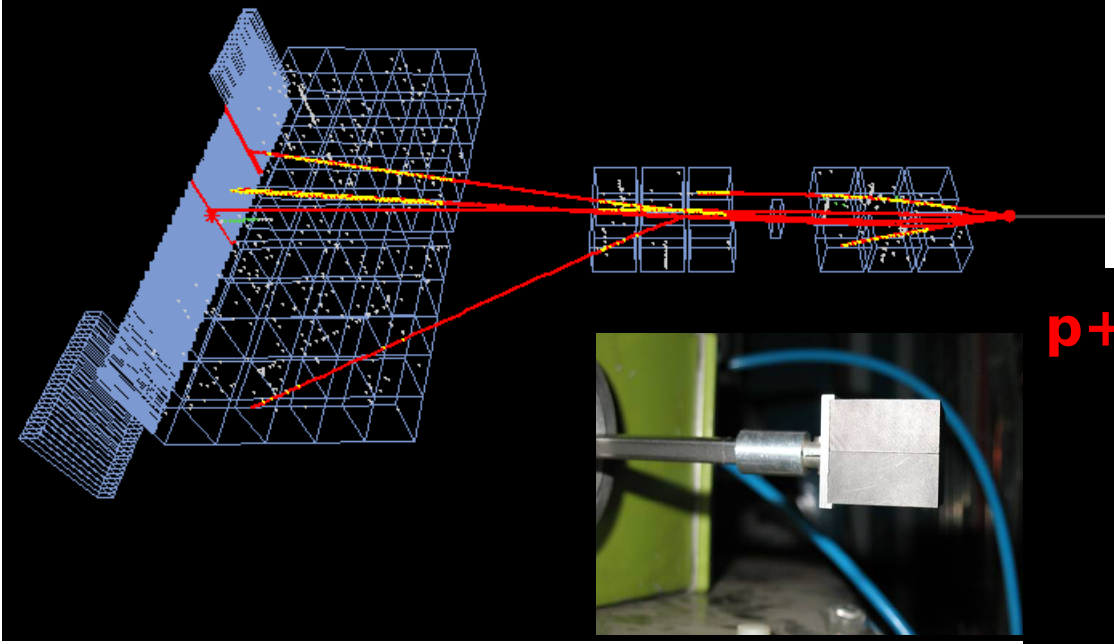



MD – Machine development
MP - Machine problems
TC - Target Change
BC - Beam Change

***Many thanks to CERN machine as well as beam line operation and maintenance teams***

# 2009 run: neutrinos

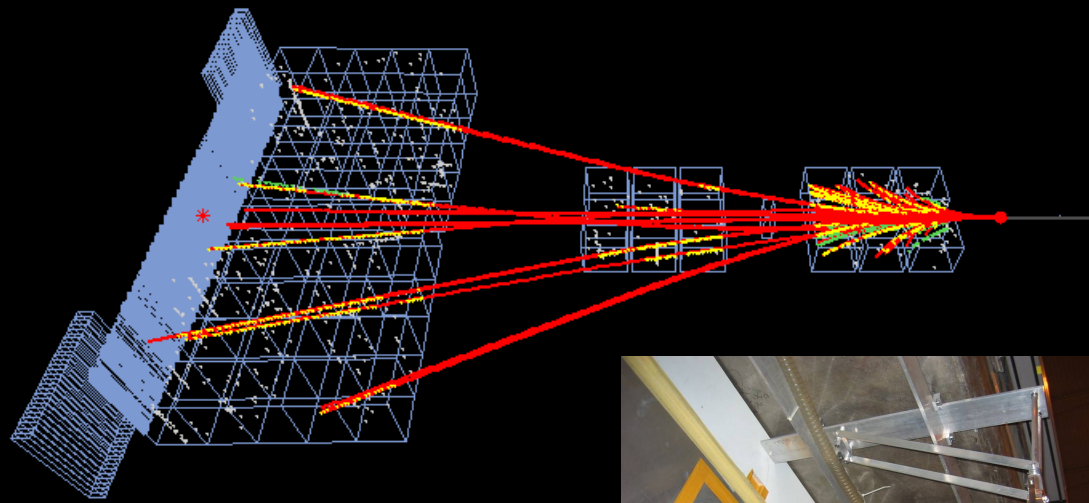
**p+C at 31 GeV/c** **6M events**





**p+(T2K replica target) at 31 GeV/c**

**4M events**



# Measuring neutrino oscillations

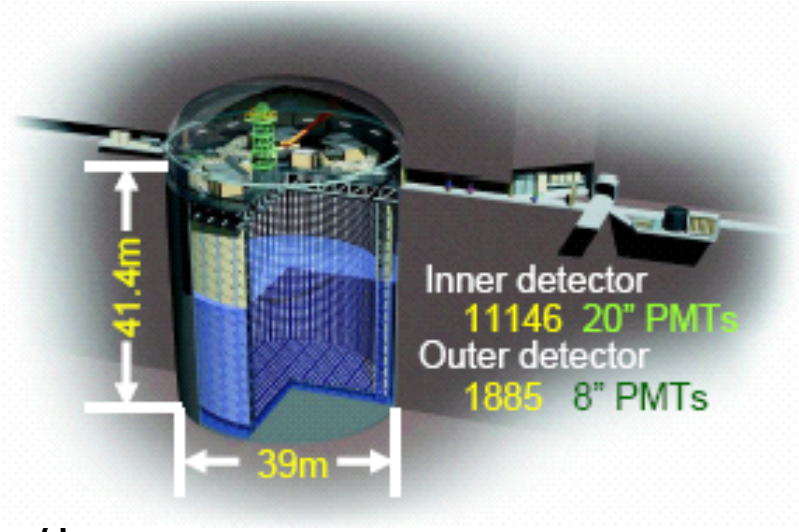
**T2K**

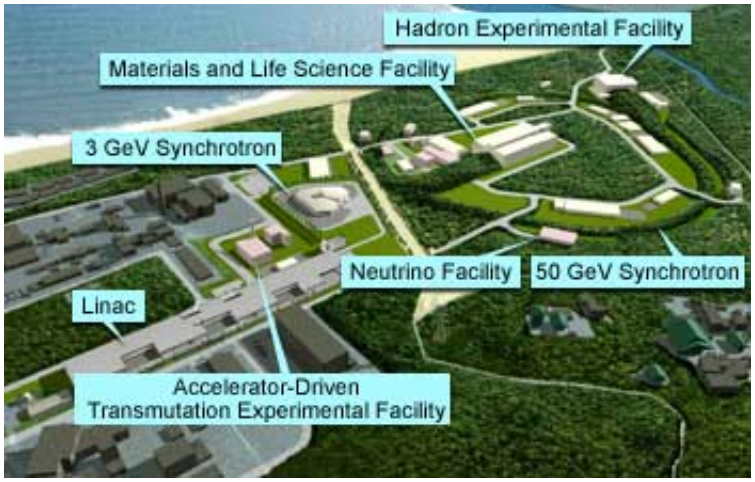
**Measures initial neutrino flux**

**Measures initial neutrino flux**

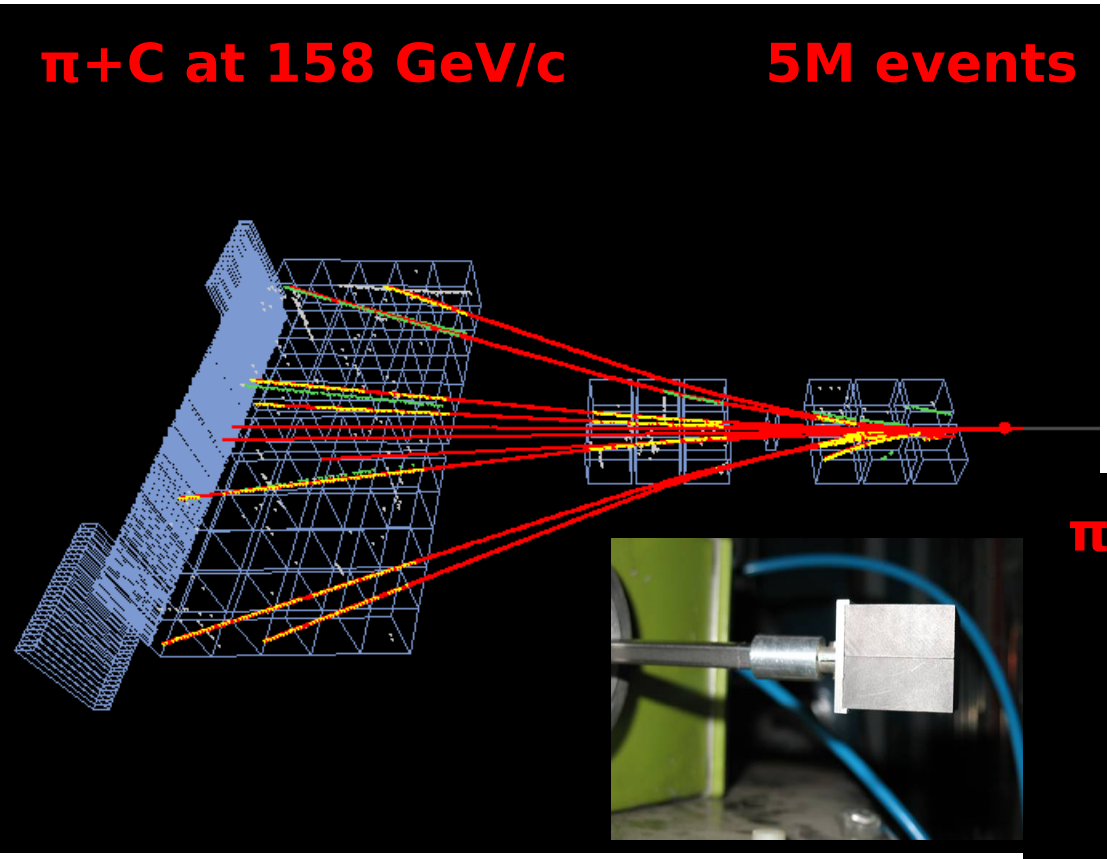


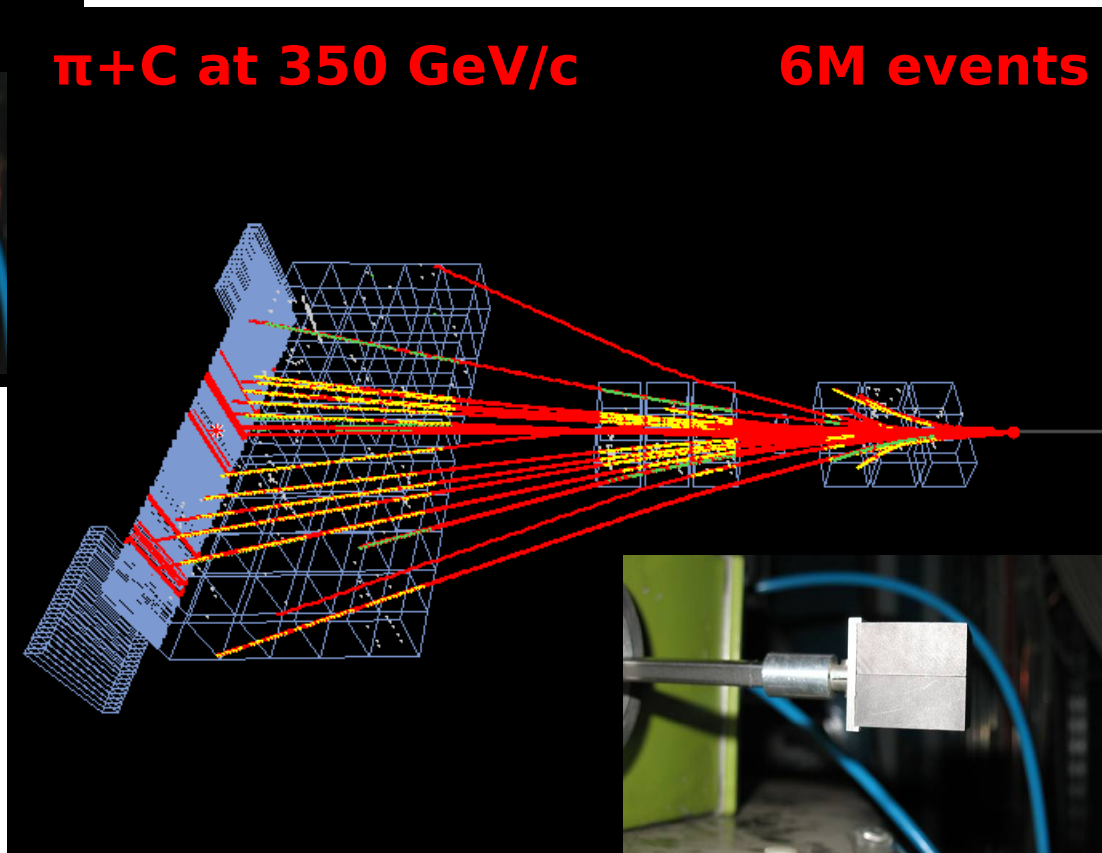




# 2009 run: cosmic-rays



# Measuring cosmic-ray composition

p? | Fe?

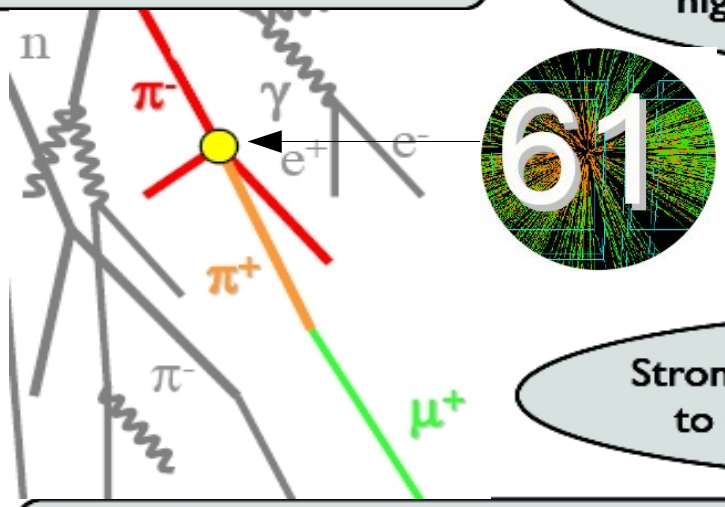
Cosmic ray composition: of central importance for understanding sources, knee, ankle, ...

Modern detector installations: high-statistics/quality data

Indirect measurement (extensive air showers): simulations needed

Strong model dependence: due mainly to simulation of muon production

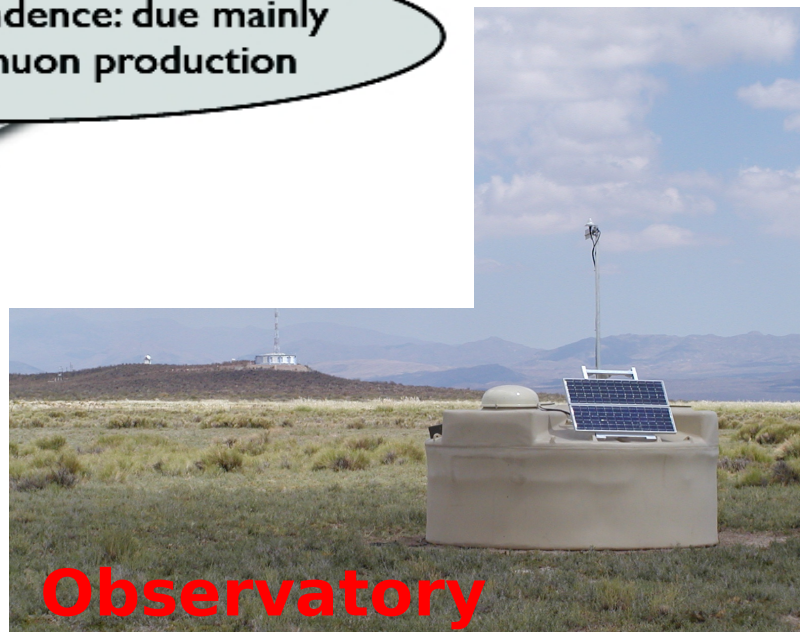
Muon production related to hadronic interactions at fixed-target energies



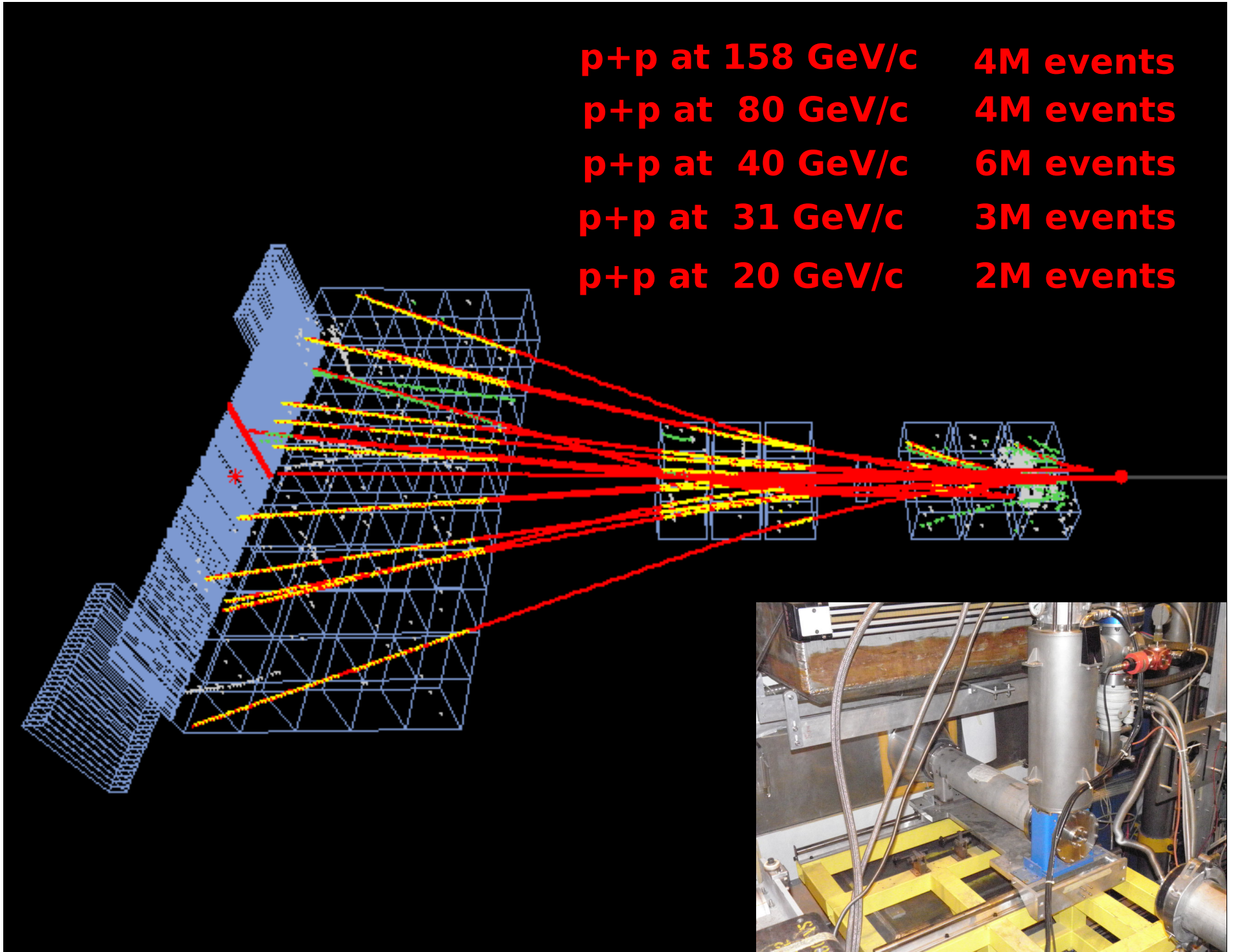




Pierre Auger Observatory

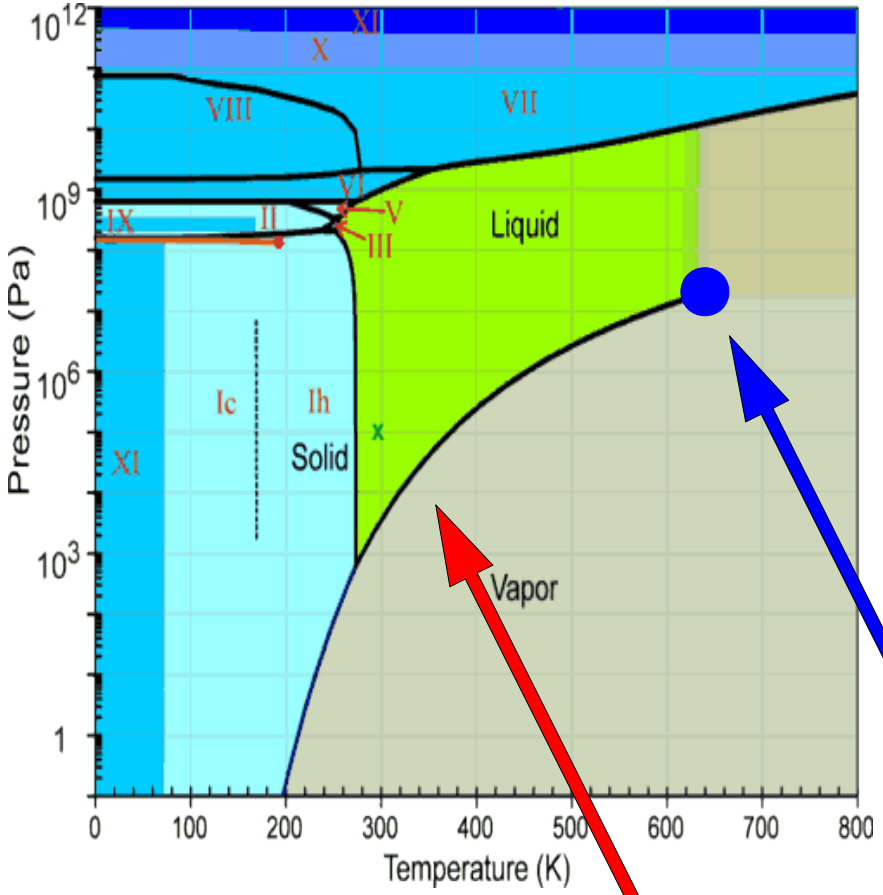


# 2009 run: strongly interacting matter

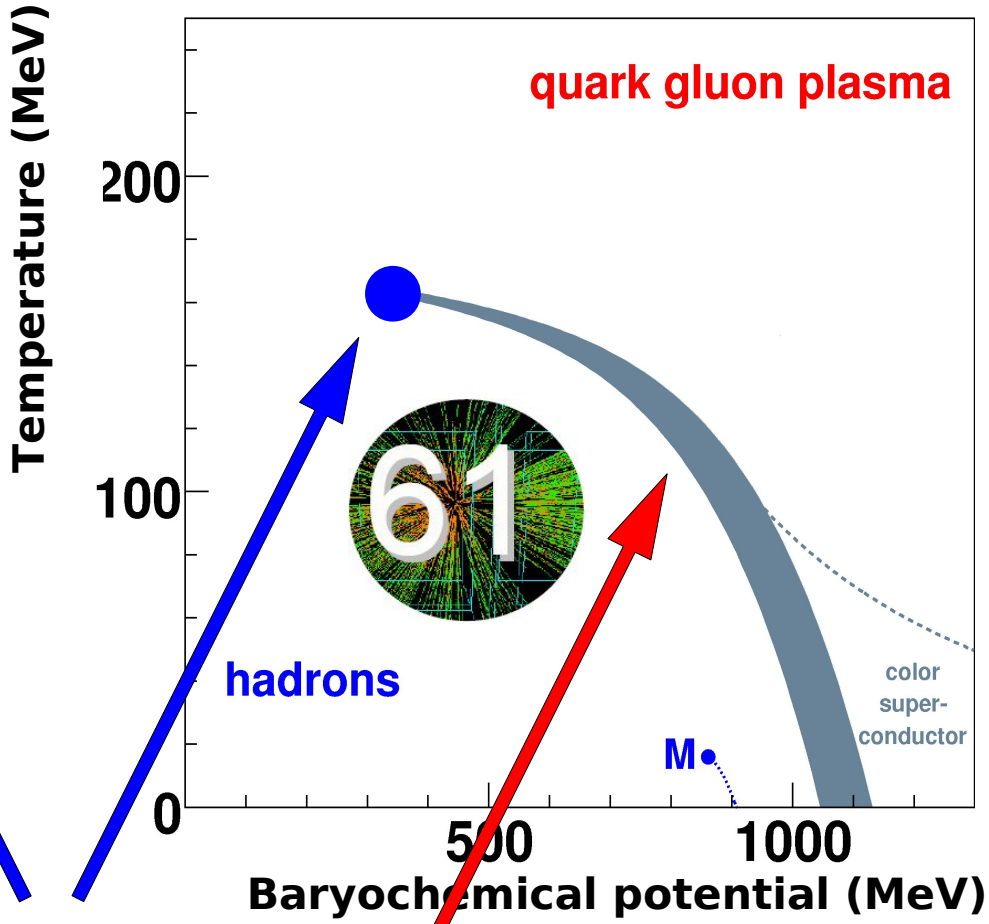


# Study the onset of deconfinement and Search for the critical point

**water**



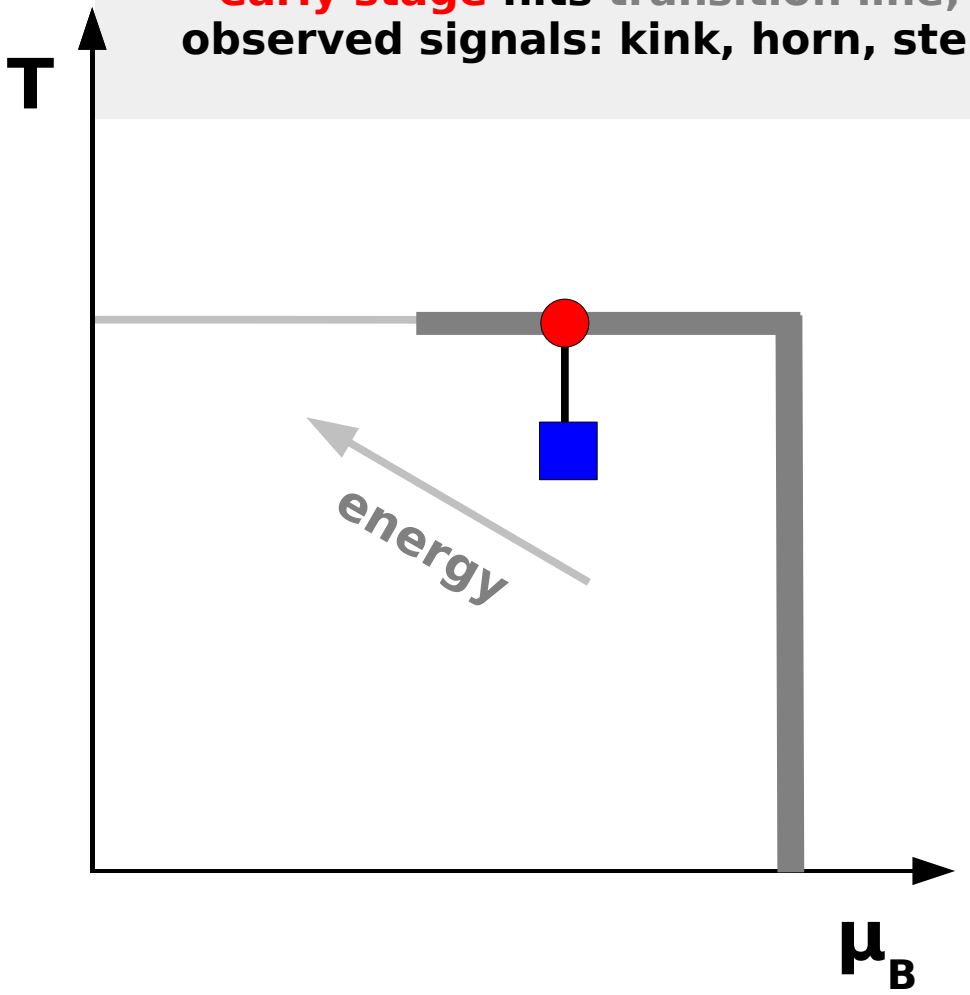

**strongly interacting matter**

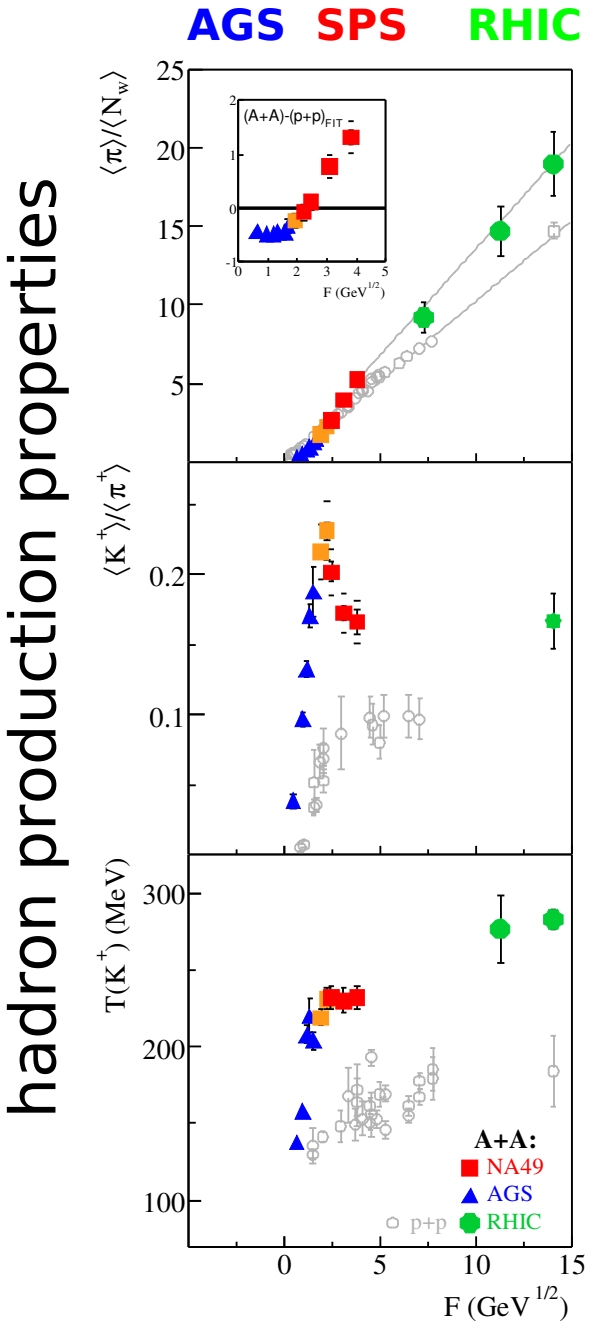



**1st order phase transition**

# Study the onset of deconfinement

**Onset of Deconfinement:**
**early stage hits transition line,**
**observed signals: kink, horn, step**




**Kink**

**Horn**

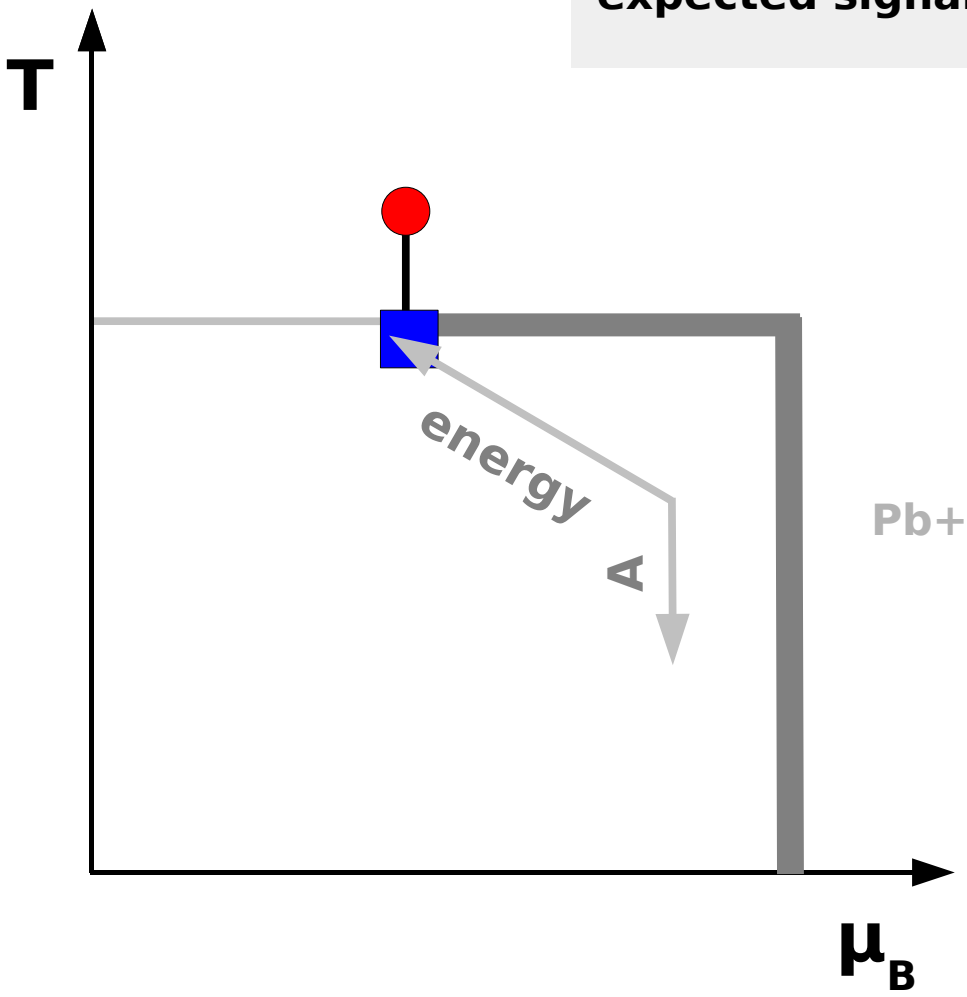
**Step**

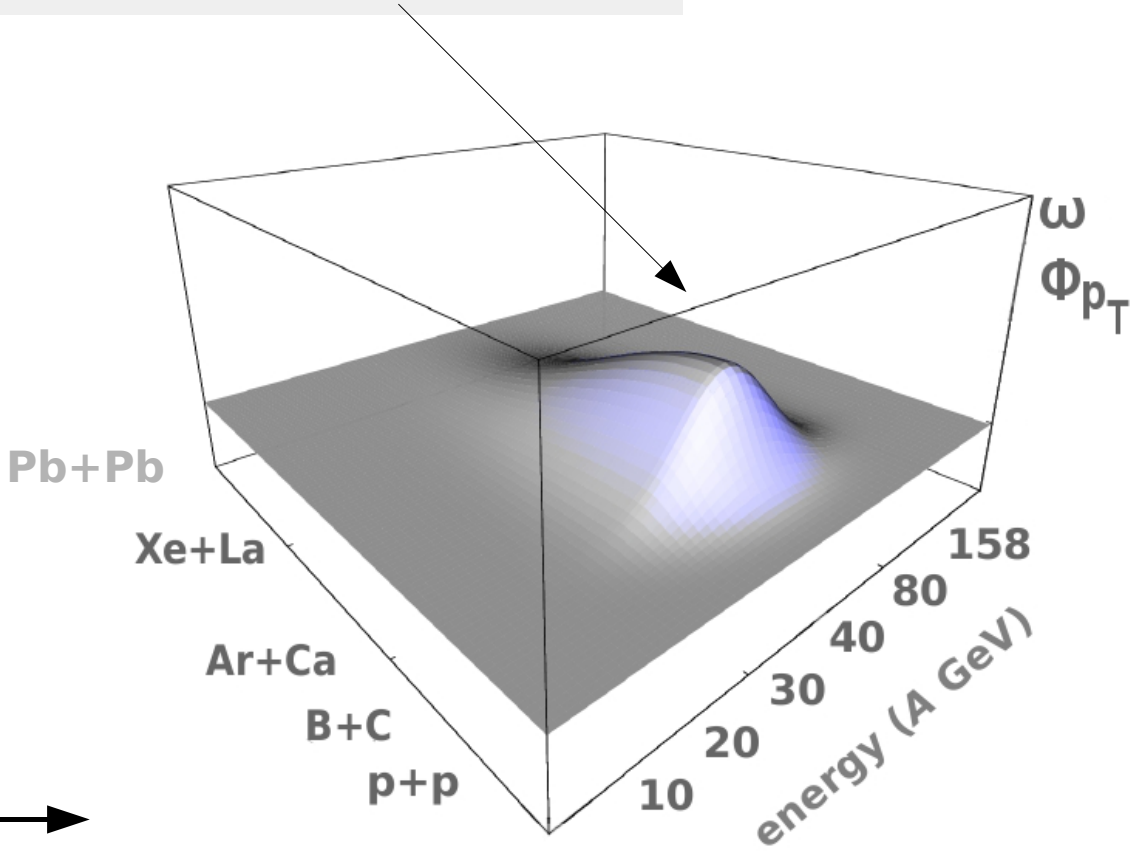


*M.G., M. Gorenstein, APPB30:2705*
*NA49, PRC77:024903*

# Search for the critical point

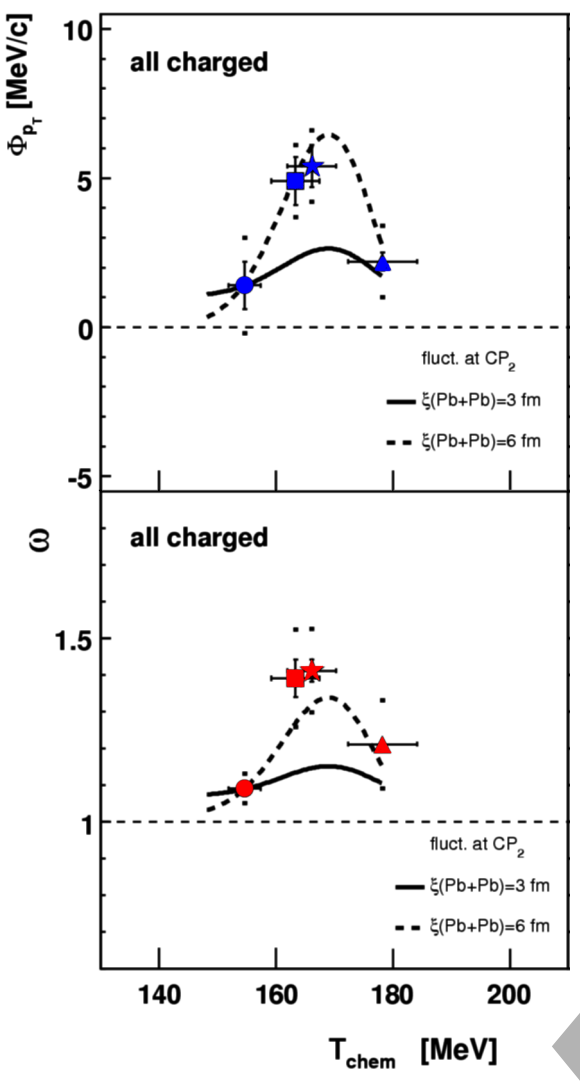
**Critical Point:**
**freeze-out close to critical point,**
**and system large enough,**
**expected signal: a hill in fluctuations**

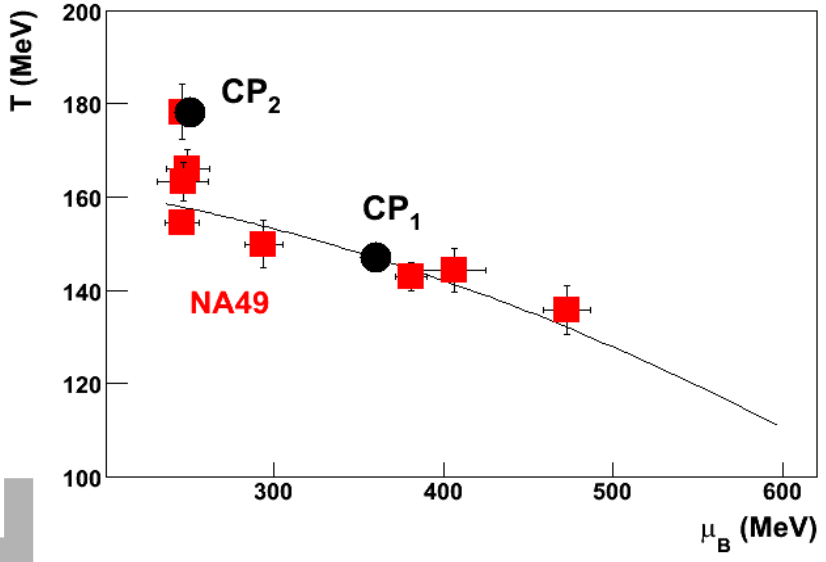


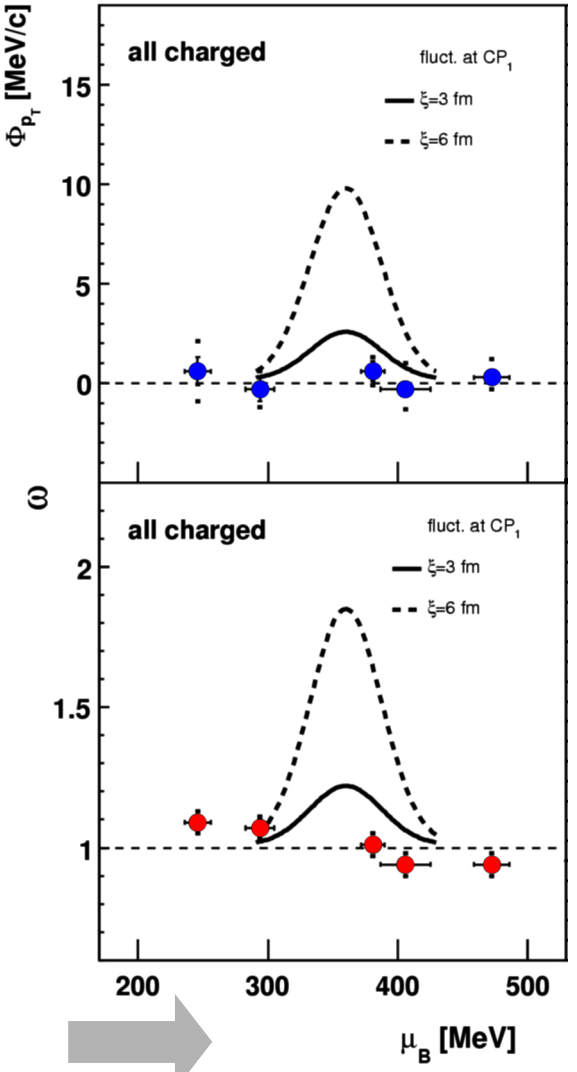




*Stephanov et al., PRD60:114028*
*NA61 (M.G.), PoS CPOD2006:016*

# NA49 search for the critical point



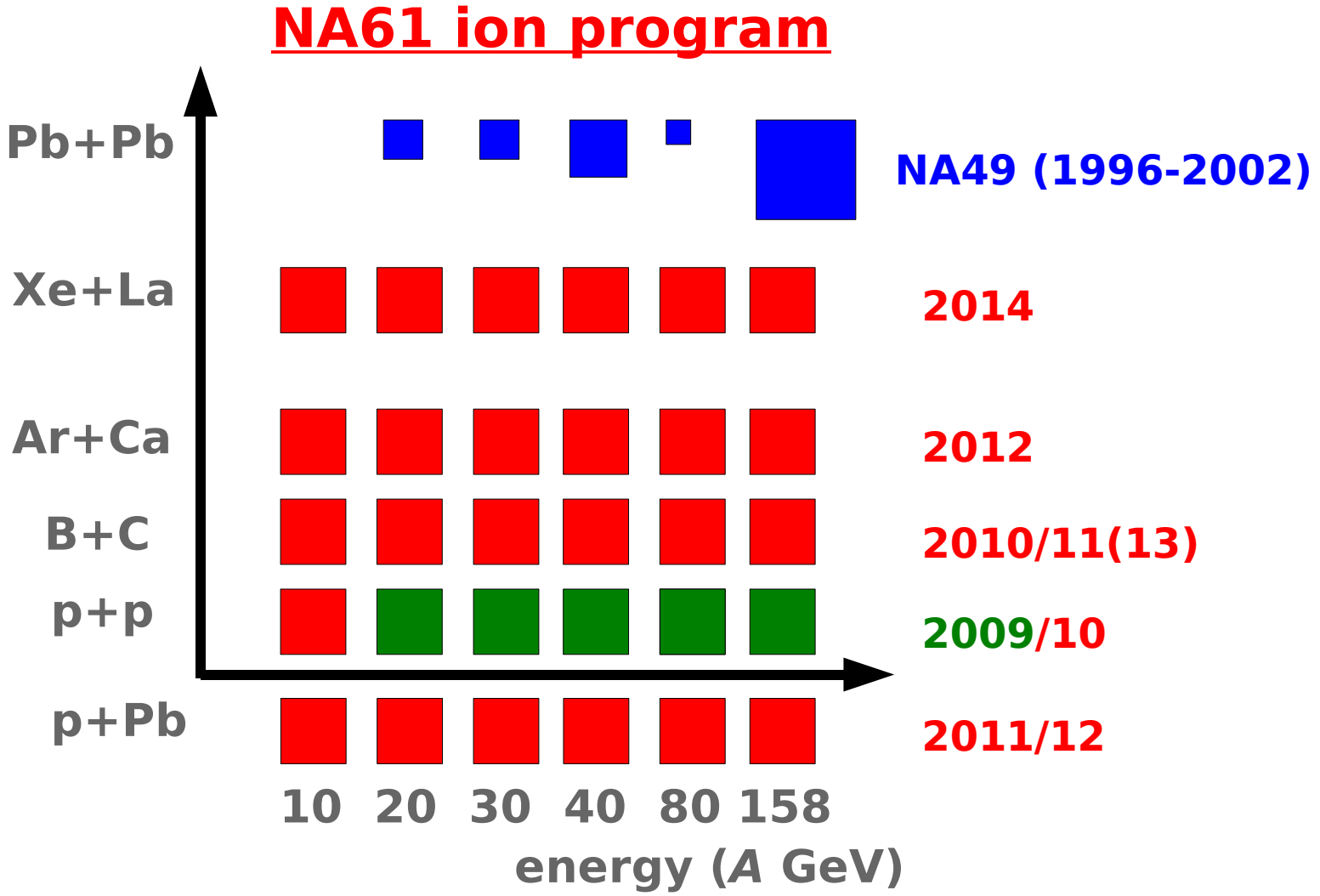




**First hint of the fluctuation hill?**

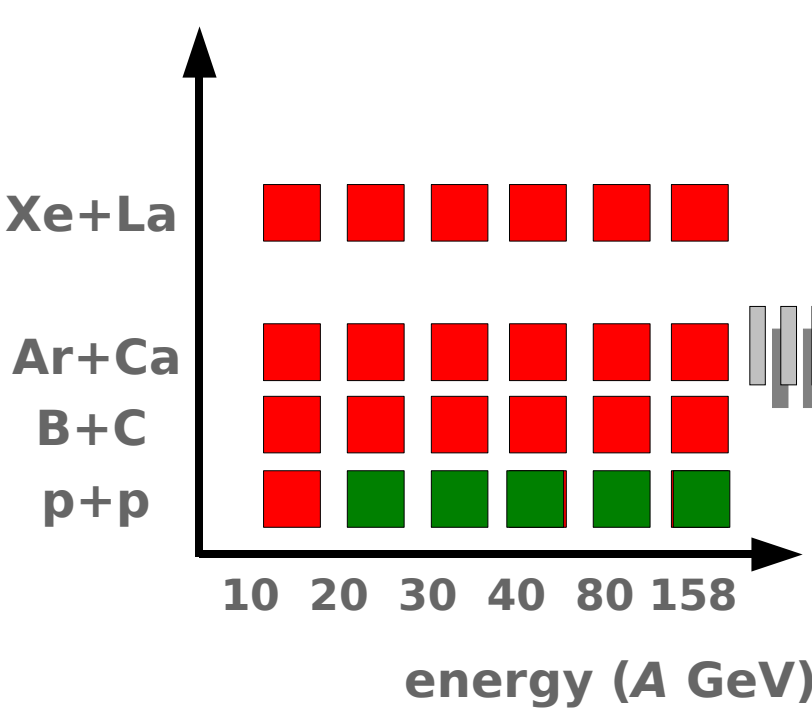
*PRC78:034914*
*PRD60:114028*
*arXiv:0810.5510*

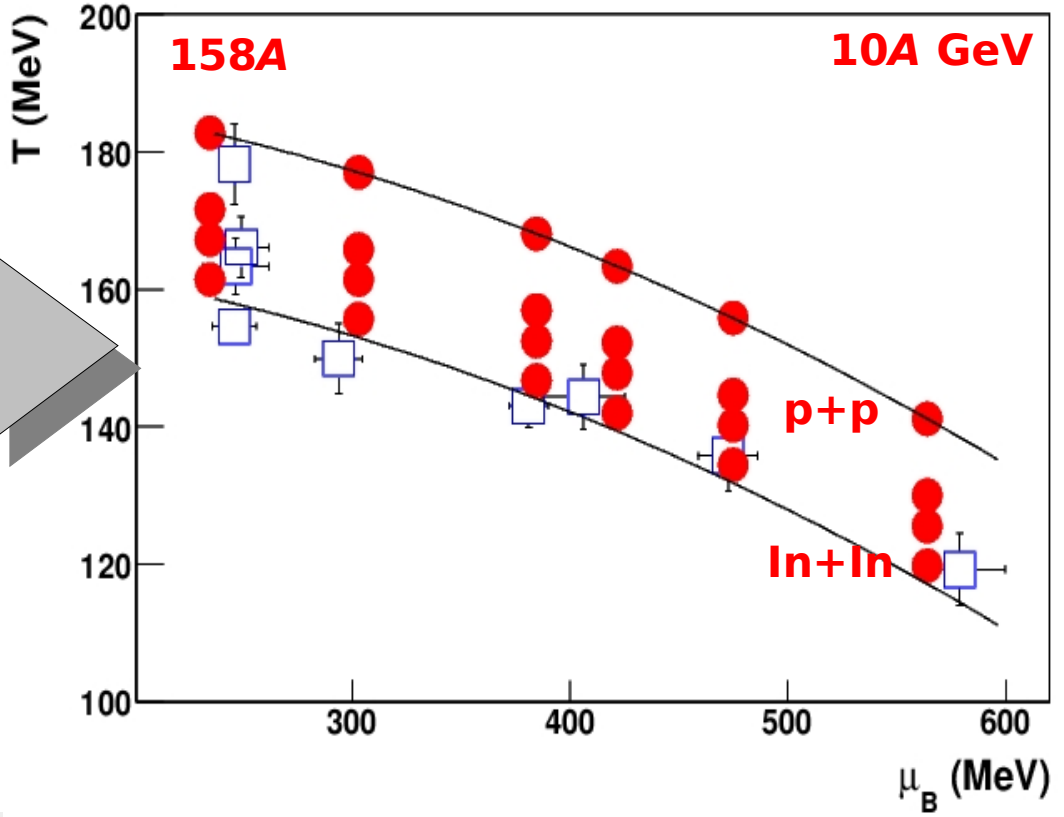
# Data taking schedule with ion beams

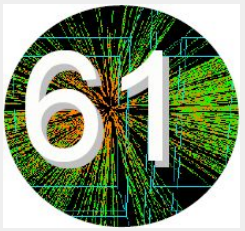


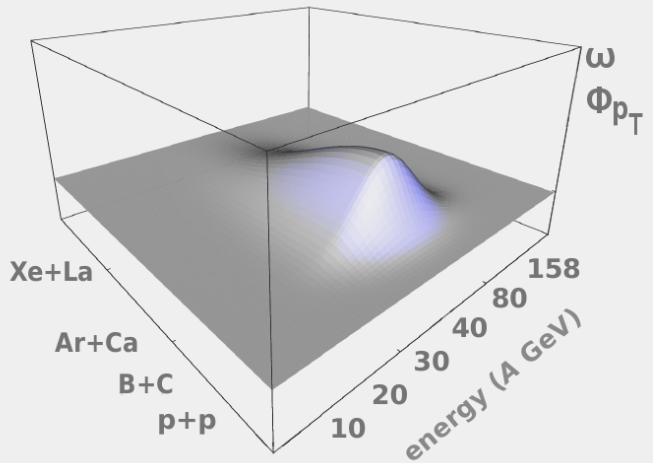

**The first 2D scan in history of A+A collisions**

# Searching for the critical point



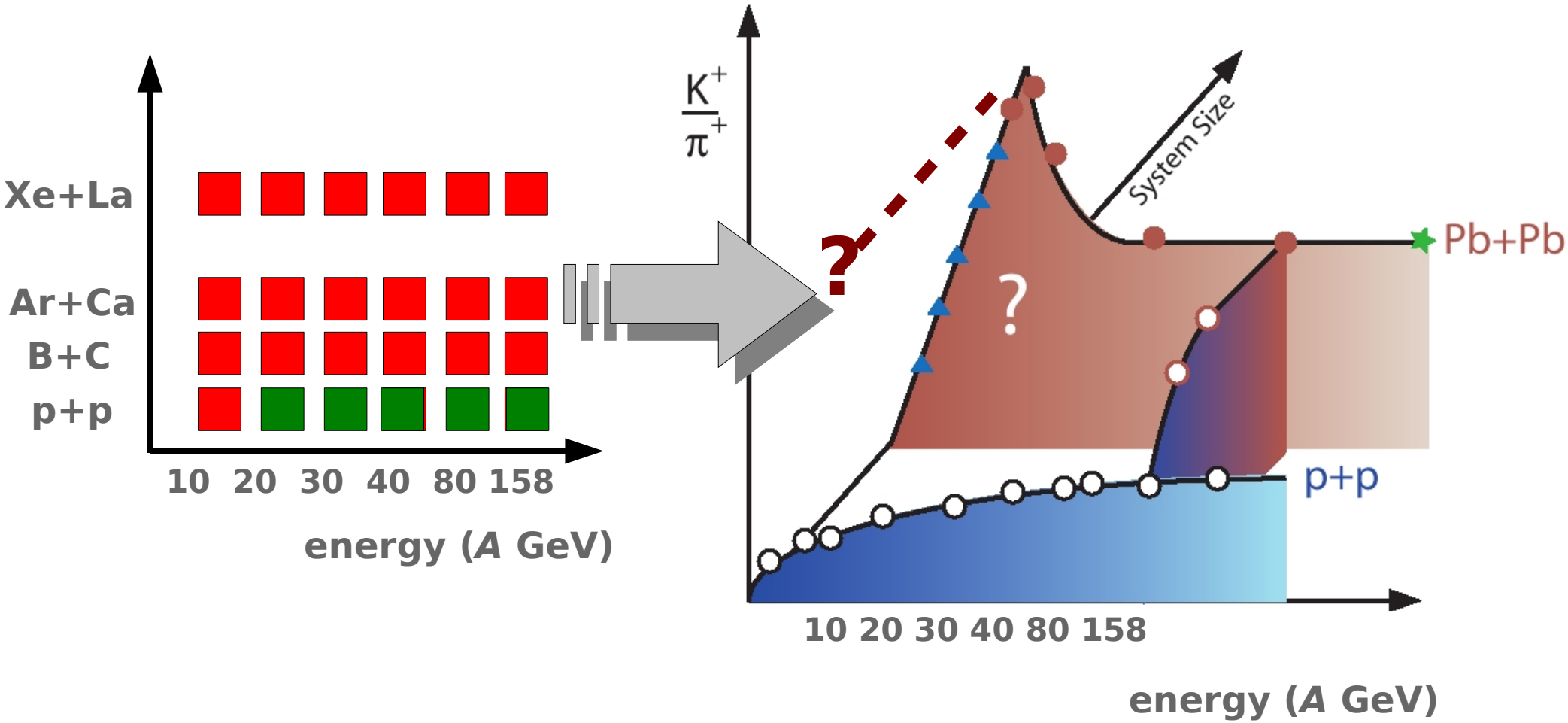




**Search for the hill of fluctuations**

**Discovery potential**

# Study the onset of deconfinement




**Search for the onset of the horn in collisions of light nuclei**



**Precision measurements following the NA49 discovery**

# The NA61 revised data taking plan

| Beam Primary | Beam Secondary | Target | Energy ($A$ GeV) | Year | Duration days/MDs | Physics | Status |
|---|---|---|---|---|---|---|---|
| p | p | p | 400<br>158 | 2010 | 77 d | High $p_T$ | *recommended* |
| Pb | $^{11}$B | none | 20,80<br>20,80 | 2010 | 10 MDs | FS test-1 | *to be discussed* |
| p | p | Pb | 400<br>158 | 2011 | 77 d | High $p_T$ | *recommended* |
| Pb | $^{11}$B | C | 10,20,30,40,80,158<br>10,20,30,40,80,158 | 2011 | 20 d | FS test-2 | *to be discussed* |
| p | p | Pb | 400<br>10,20,30,40,80,158 | 2012 | 6x8 d | CP,OD | *recommended* |
| Ar | | Ca | 10,20,30,40,80,158 | 2012 | 6x8 d | CP,OD | *recommended* |
| Pb | $^{11}$B | C | 10,20,30,40,80,158<br>10,20,30,40,80,158 | 2013 | 6x10 d | CP,OD | *to be discussed* |
| Xe | | La | 10,20,30,40,80,158 | 2014 | 6x8 d | CP,OD | *to be discussed* |

**FR test-1**

**secondary (FR test-2)**

**primary**

**(secondary)**

**primary**

# SPSC recommendations, September 2009

- **The SPSC notes** that secondary light ion beams can be used for atomic weights up to and including Boron, but that primary beams are required for the heavier ion species necessary to complete the proposed NA61 program.
- **The SPSC recommends** that the necessary preparations for a secondary Boron beam be started in 2010, and that an energy scan with this Boron beam be performed as soon as technically possible.

In addition, **the SPSC also supports** carrying out the necessary preparatory work for possible energy scans with primary beams of heavier ion species in timely manner.

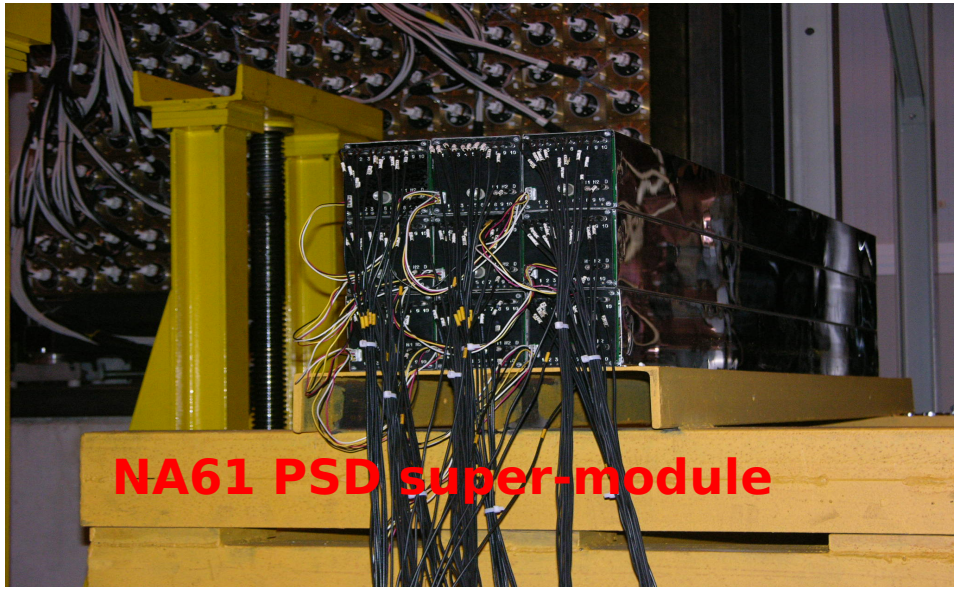
**Research Board on March 2, 2010 approved the SPSC recommendations**

# Additional slides

# Detector upgrades for runs with ion beams

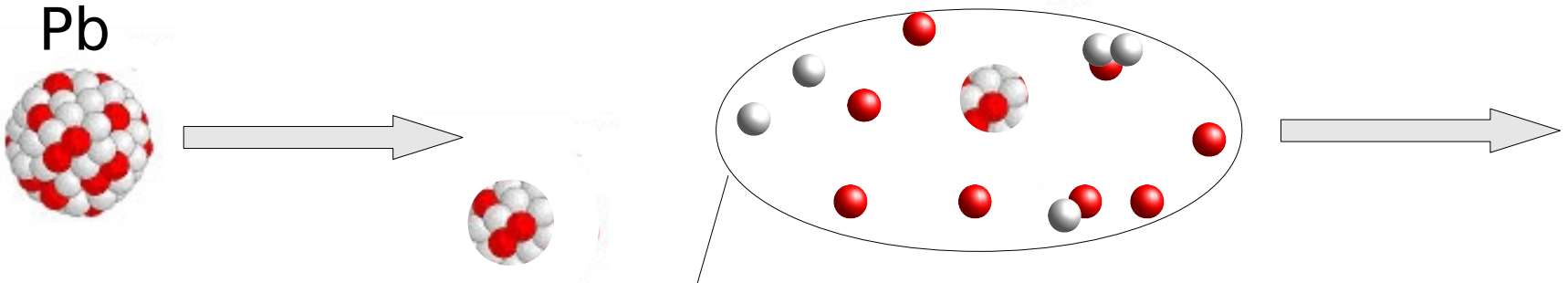
**Projectile Spectator Detector:**
- **-construction of modules in progress,**
- **-tests of the read-out electronics and integration with the NA61 DAQ,**
- **-expected to be ready for 2011**

**He beam pipe:**
- **-technical design ready,**
- **-construction of the the prototype and installation test to be started soon,**
- **-expected to be ready in 2011**



# Secondary Ion Beam Line for NA61

## The basic idea

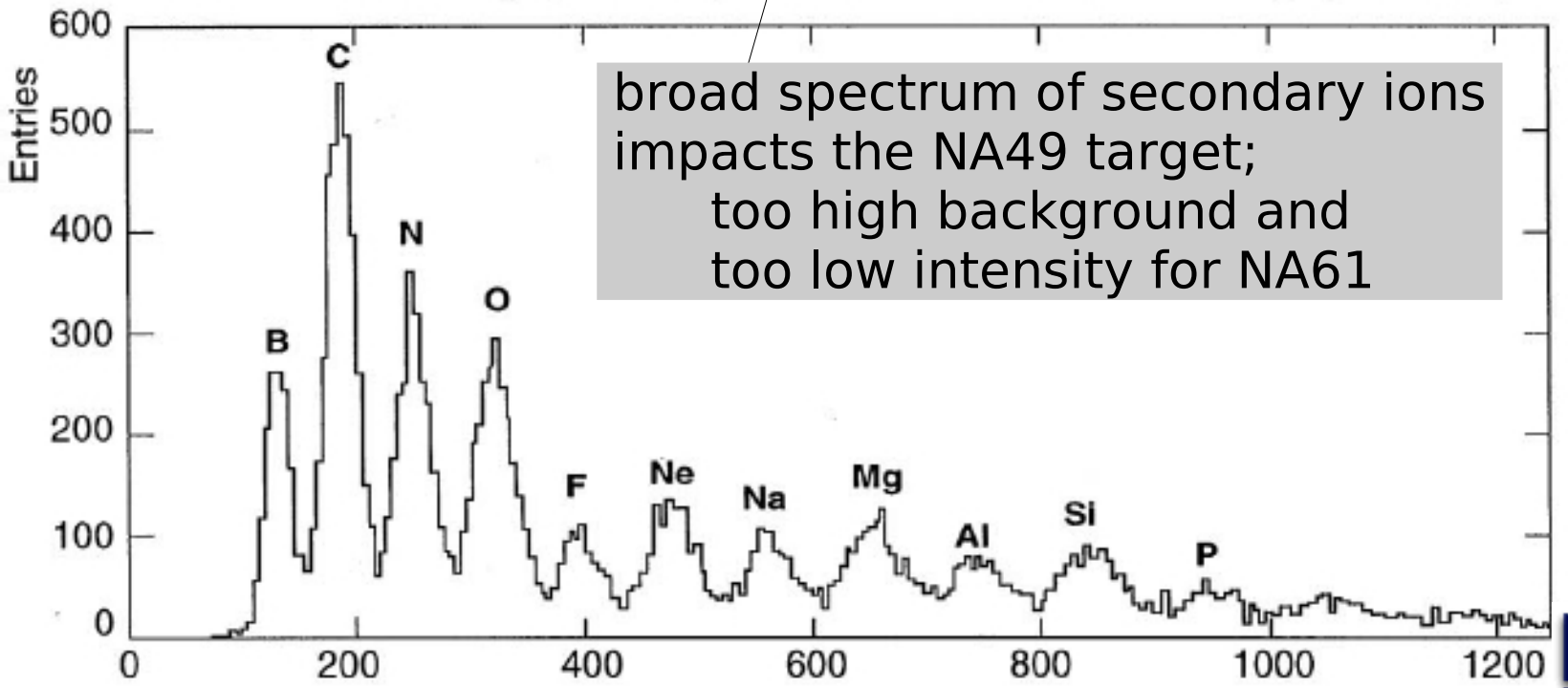



primary Pb beam from the SPS

fragmentation target

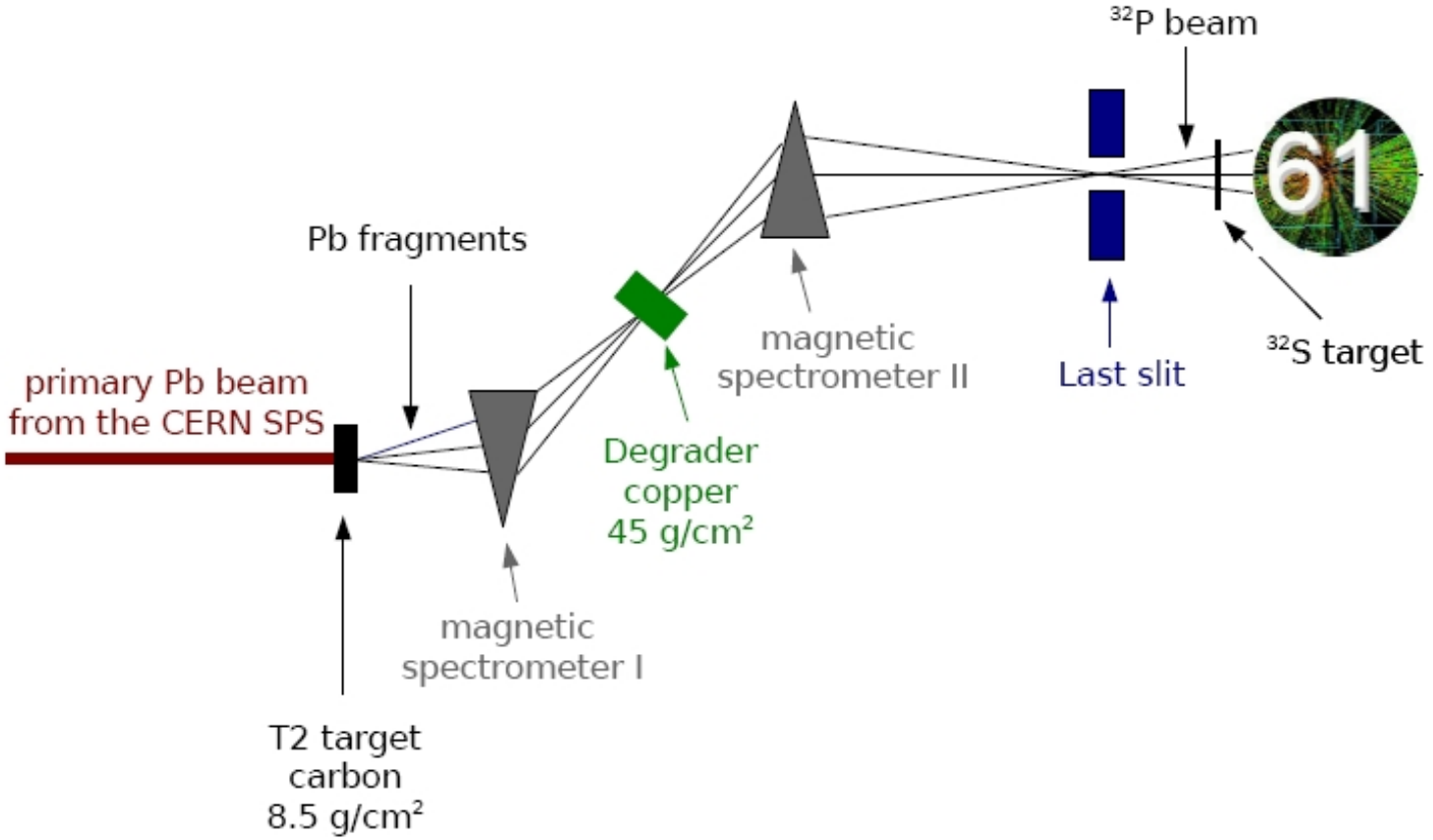
secondary light ion beam to NA49

## The pilot NA49 studies




broad spectrum of secondary ions impacts the NA49 target;
too high background and
too low intensity for NA61

# Secondary Ion Beam Line for NA61:




-selects beam of nuclei with close Z and A,
-further ion identification possible by Z (charge) measurements
-momentum per nucleon cannot be changed

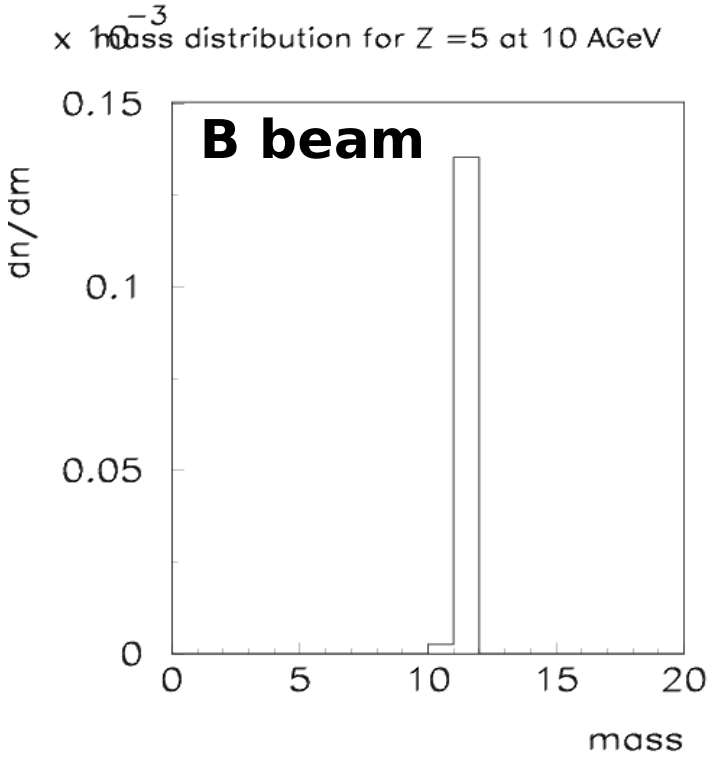
# Performance with secondary $^{11}$B beam

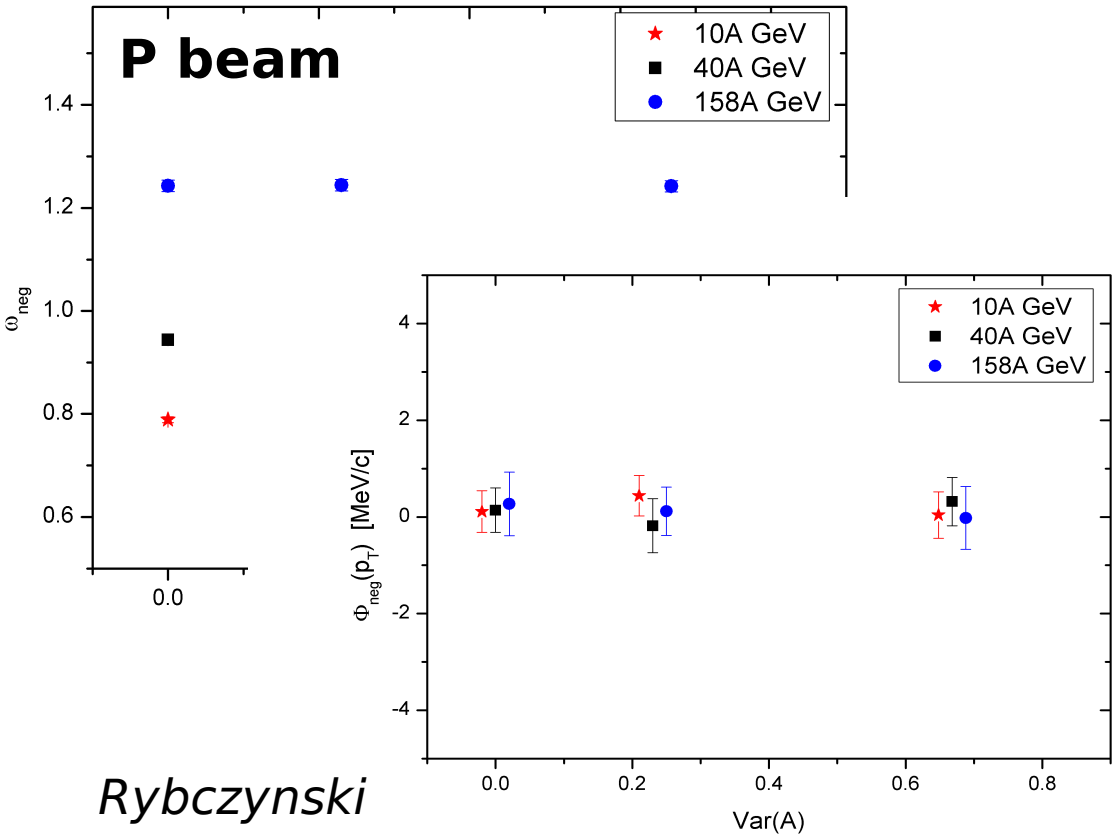
**Summary based on detailed results of simulations Presented in Addendum 5:**

**At low energies the event rate 2 times lower than for the primary beams**

**High beam purity**

**Insignificant increase of systematic uncertainties**






*Stroebele*

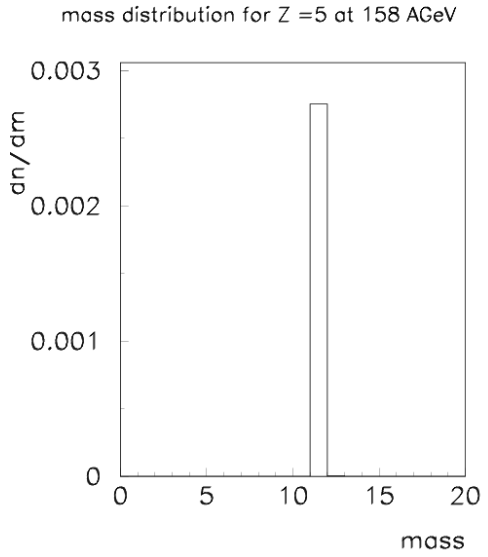
*Rybczynski*

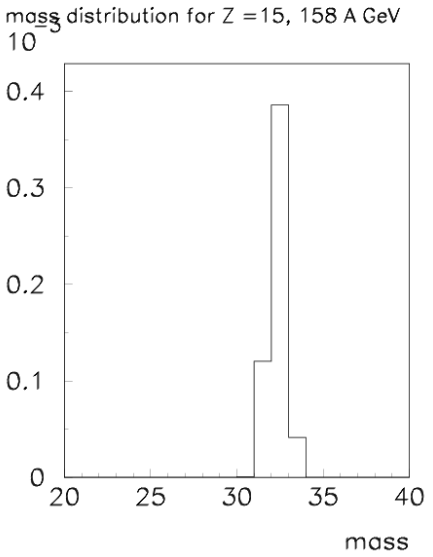
# Performance with secondary heavy ion (Sn) beam

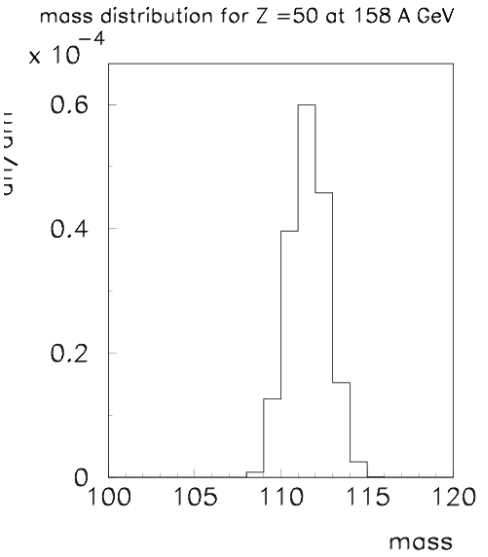
**Summary based on detailed results of simulations Presented in Addendum 5:**

**At low energies the event rate up to 10 times lower than for the primary beams**

**Significant contamination of un-wanted ions**



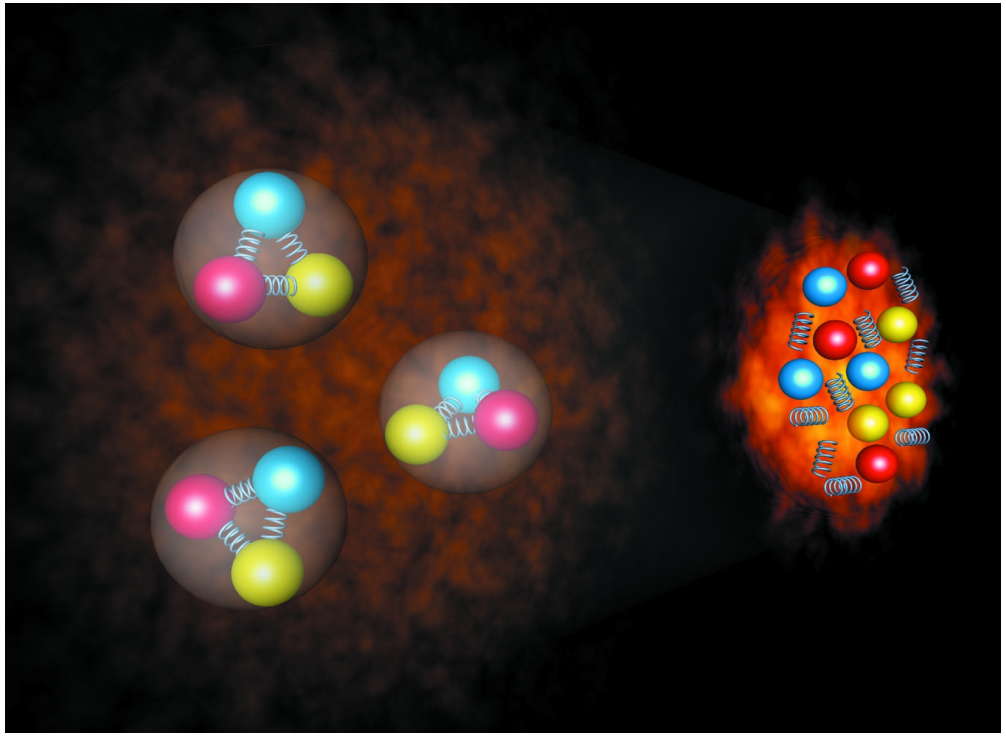




**The NA61 ion program is not possible with secondary ion beams alone**

# Onset of deconfinement

**hadrons** **mixed** **QGP**



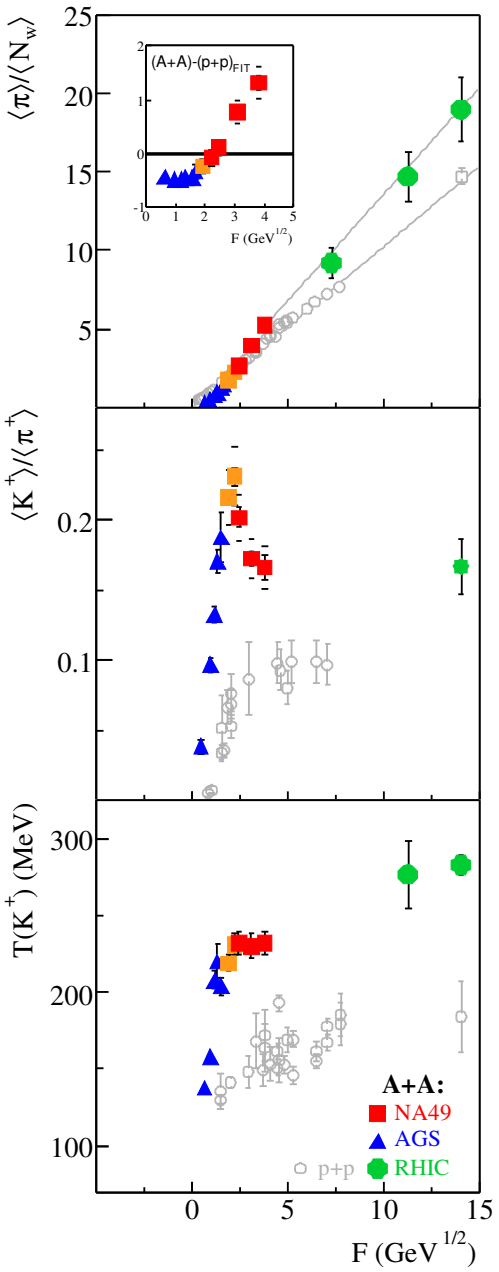
**AGS** **SPS** **RHIC**

collision energy

NA49 results (PRC77:024903): evidence for the onset of deconfinement at the low CERN SPS energies

**AGS** **SPS** **RHIC**

hadron production properties




**Kink**

**Horn**

**Step**

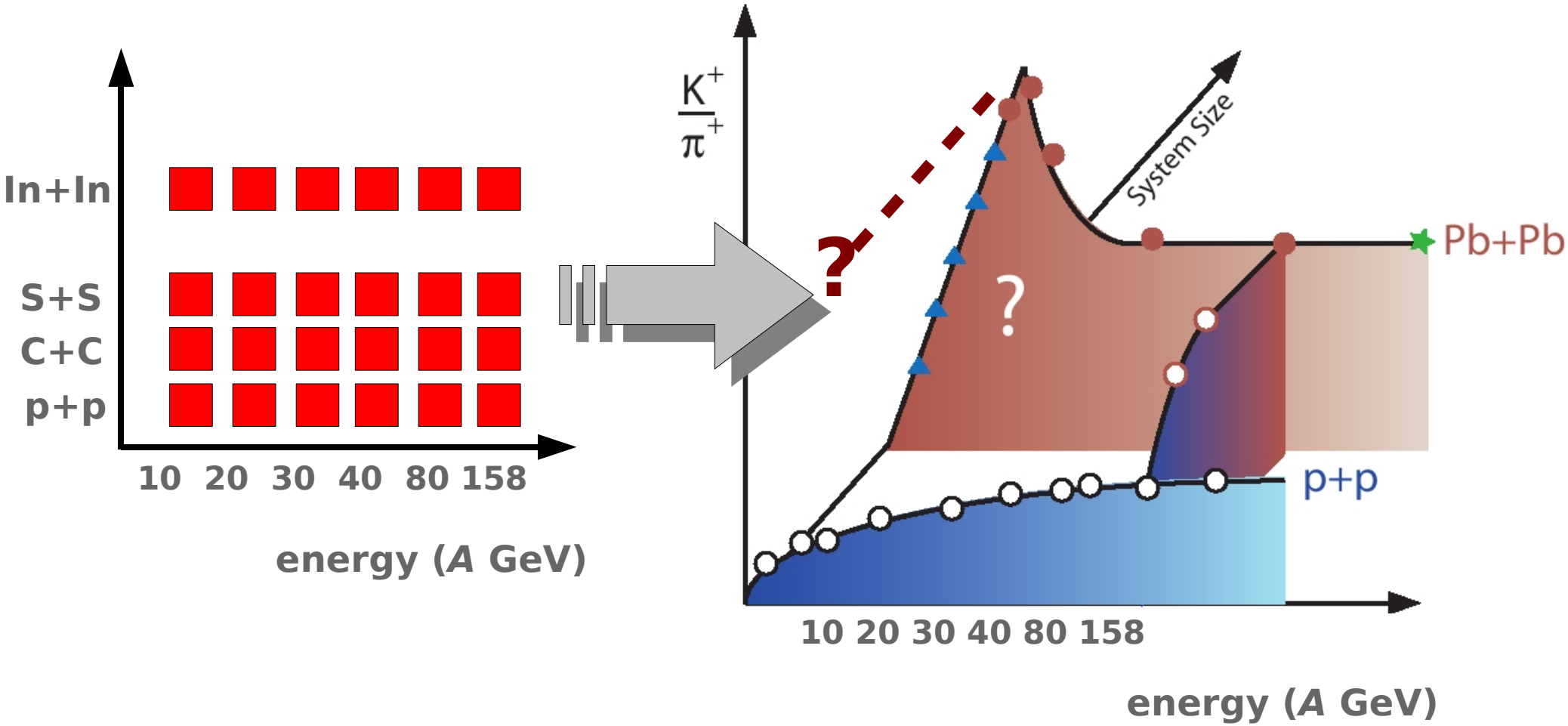
collision energy

# Experimental landscape of complementary programs of nucleus-nucleus collisions around the SPS energies

| | | | | |
|---|---|---|---|---|
| **Facility:** | **SPS** | **RHIC** | **NICA** | **SIS-100 (SIS-300)** |
| **Exp.:** | **NA61** | **STAR PHENIX** | **MPD** | **CBM** |
| **Start:** | **2011(2)** | **2011** | **2015** | **2017 (2019)** |
| **Pb Energy:** (GeV/(N+N)) | **4.9-17.3** | **4.9-50** | **≤9** | **≤5 (<8.5)** |
| **Event rate:** (at 8 GeV) | **100 Hz** | **1 Hz(?)** | **≤10 kHz** | **≤10 MHz** |
| **Physics:** | **CP&OD** | **CP&OD** | **OD&HDM** | **HDM (OD)** |

*CP – critical point*
*OD – onset of deconfinement, mixed phase, 1$^{st}$ order PT*
*HDM – hadrons in dense matter*

# Study the onset of deconfinement



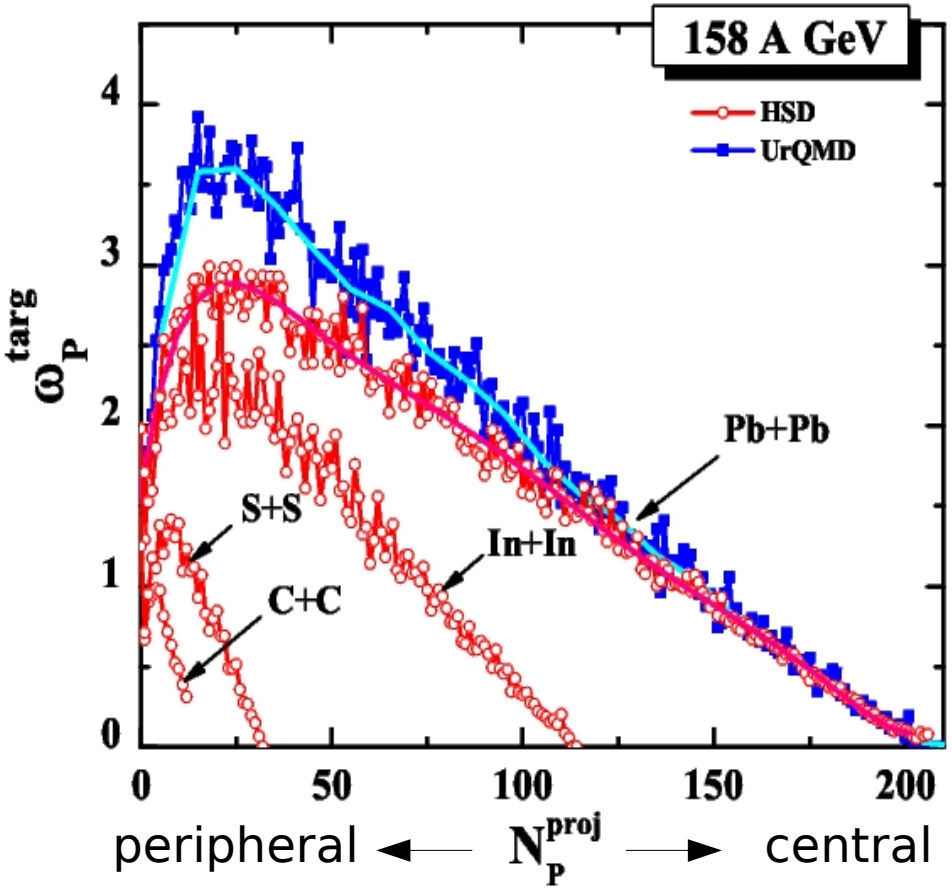

**Search for the onset of the horn in collisions of light nuclei**



**Precision measurements following the NA49 discovery**

# Central collisions of light and medium size nuclei are required for the proposed fluctuation studies

Fluctuations of target participants




Number of projectile participants

**Event-by-event fluctuations in the number of interacting (participant) nucleons are the main source of the background in the fluctuation studies**

**The fluctuations of the number of projectile participants are suppressed by selecting collisions with fixed number of projectile spectators (in NA61 measured by PSD)**

**The fluctuations of the number of target participants can be suppressed only by selection of very central collisions**



*Konchakovski et al., Phys. Rev. C 73, 034902*