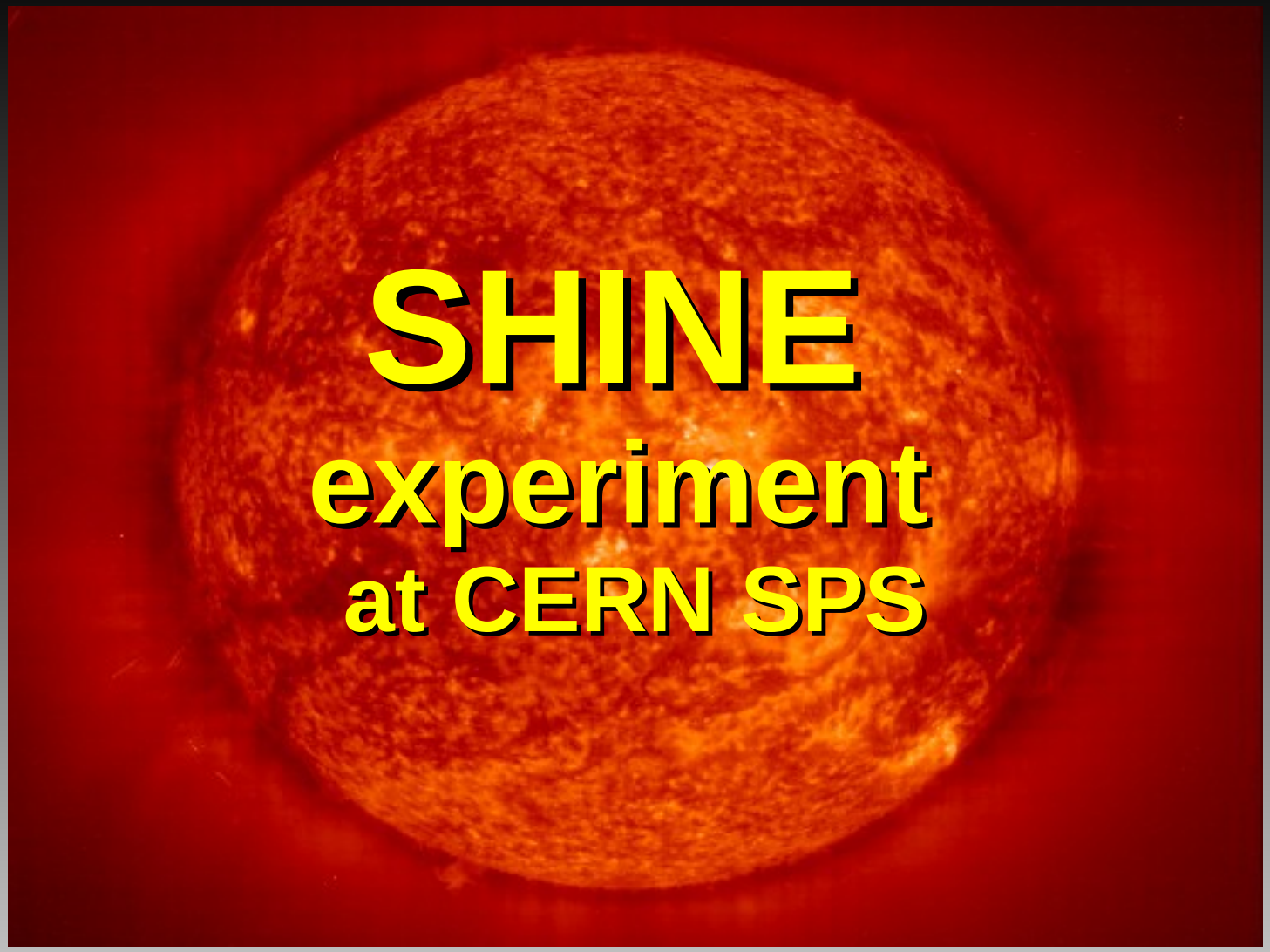

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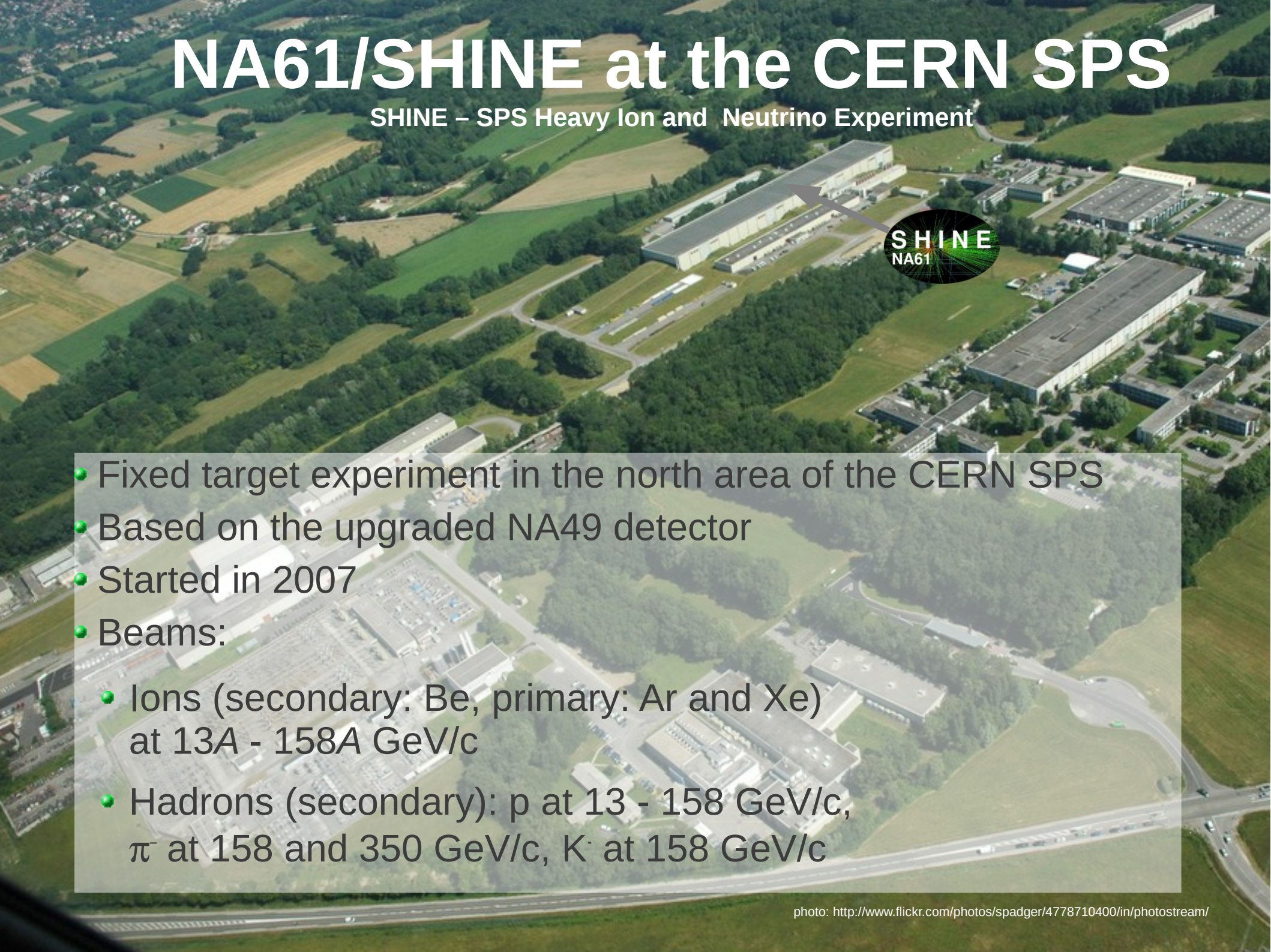
NA61/SHINE at the CERN SPS

SHINE – SPS Heavy Ion and Neutrino Experiment



- Fixed target experiment in the north area of the CERN SPS
- Based on the upgraded NA49 detector
- Started in 2007
- Beams:
  - Ions (secondary: Be, primary: Ar and Xe) at 13*A* - 158*A* GeV/c
  - Hadrons (secondary): p at 13 - 158 GeV/c, π^- at 158 and 350 GeV/c, K^- at 158 GeV/c

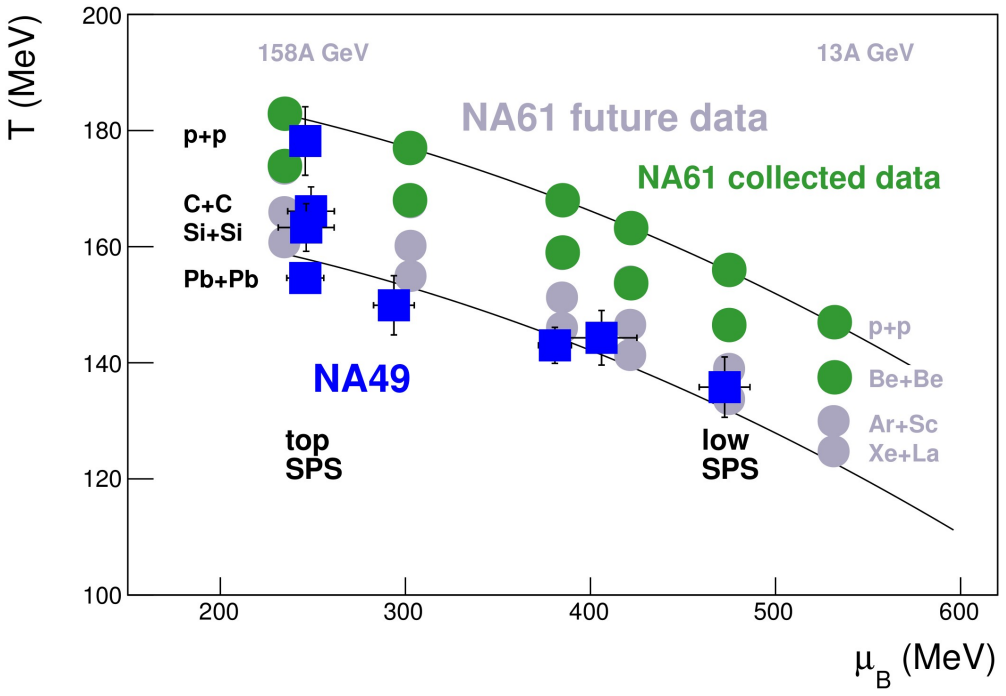
photo: http://www.flickr.com/photos/spadger/4778710400/in/photostream/

NA61/SHINE physics program

- **Strong interactions program - spectra, fluctuations, correlations**
  - search for the **critical point** of strongly interacting matter
  - study of the **properties of the onset of deconfinement**
  - study **high p_T particles** (energy dependence of nuclear modif. factor)
- **Neutrino and cosmic-ray physics programs - precision data on hadron production (spectra)**
  - **reference measurements** of p+C interactions **for the T2K experiment** for computing initial neutrino fluxes at J-PARC
  - **reference measurements** of p+C, p+p, π+C, and K+C interactions **for cosmic-ray physics** (Pierre-Auger and KASCADE experiments) for improving air shower simulations
- **Considered extensions beyond the approved program**
  - measurements of **Pb+Pb** collisions for the ion program (+ open charm and multi-strange particles, high p_T spectra)
  - measurements for the **Fermilab neutrino program**

Looking for the **critical point**

- The Holy Grail of modern heavy ion physics

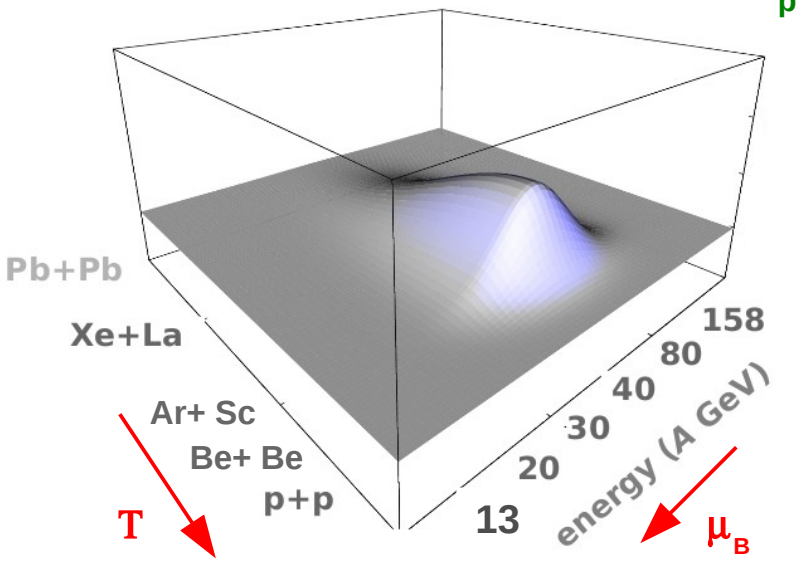


Search for the critical point

Search for a maximum of CP signatures (**hill of fluctuations**): fluctuations of N, average p_T, etc., intermittency, when system freezes out close to CP

CP signal

ω, Φ_{pT}, ...



Non-monotonic dependence of critical point signal on control parameters (energy, centrality)

NA61 group from Faculty of Physics, Warsaw University of Technology

K. Grebieszkow, M. Maćkowiak-Pawłowska, M. Słodkowski, K. Dynowski
PhD students: **T. Czopowicz, B. Maksiak, R. Sarnecki**
2 students + 1 expected: (UrQMD simulations+Geant, K^{0*} analysis, MC generators)

1. Analysis

- Transverse momentum and multiplicity fluctuations of non-identified particles in p+p Be+Be, and Ar+Sc → Tobiasz Czopowicz, Rafał Sarnecki, Katarzyna Grebieszkow
- Azimuthal angle and pseudorapidity correlations in p+p → Bartosz Maksiak
- Chemical (particle type) and multiplicity fluctuations of identified particles in p+p (via *identity method*) → Maja Maćkowiak-Pawłowska
- Multiplicity fluctuations of non-identified particles in Be+Be → Maja Maćkowiak-Pawłowska, Tobiasz Czopowicz

2. Hardware

- NA61 Detector Control System → Tobiasz Czopowicz (NA61 expert), Bartosz Maksiak, Krzysztof Dynowski

3. Simulations, reconstruction, production

- Reconstruction (production of data sets for NA61) → Bartosz Maksiak
- Production of Monte Carlo data sets (VENUS/EPOS + Geant + reconstruction) → Marcin Słodkowski

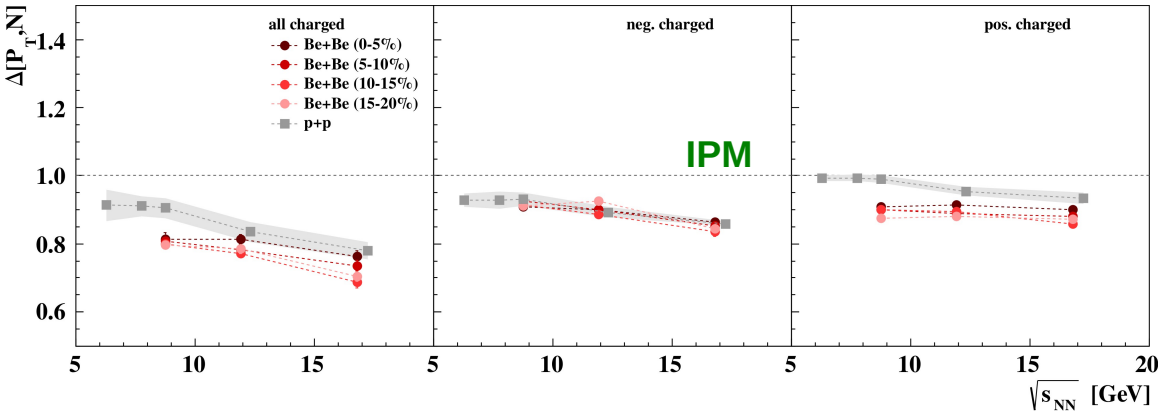
4. Web-based utilities

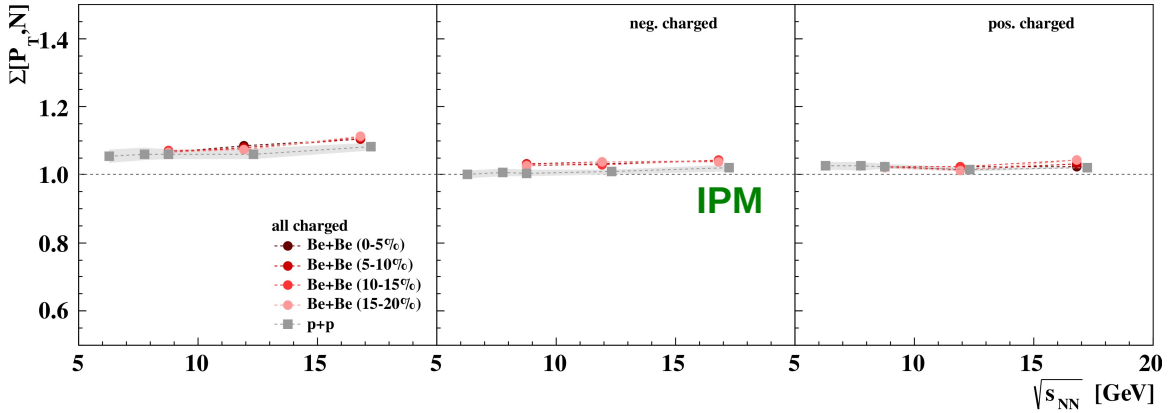
- NA61 Shift Scheduler → Mateusz Piwek (outsourcing), currently Tobiasz Czopowicz

NA61: p_T fluctuations in ^{7}Be+^{9}Be and p+p

Search for the critical point (CP) of strongly interacting matter

- **Strongly intensive measures Δ and Σ** PRC 88, 024907 (2013); in Grand Canonical Ensemble they do not depend on volume and volume fluctuations
- No fluctuations → $\Delta = \Sigma = 0$; Independent Particle Model (IMP) → $\Delta = \Sigma = 1$





$$P_T = \sum_{i=1}^{N} p_{T,i}$$

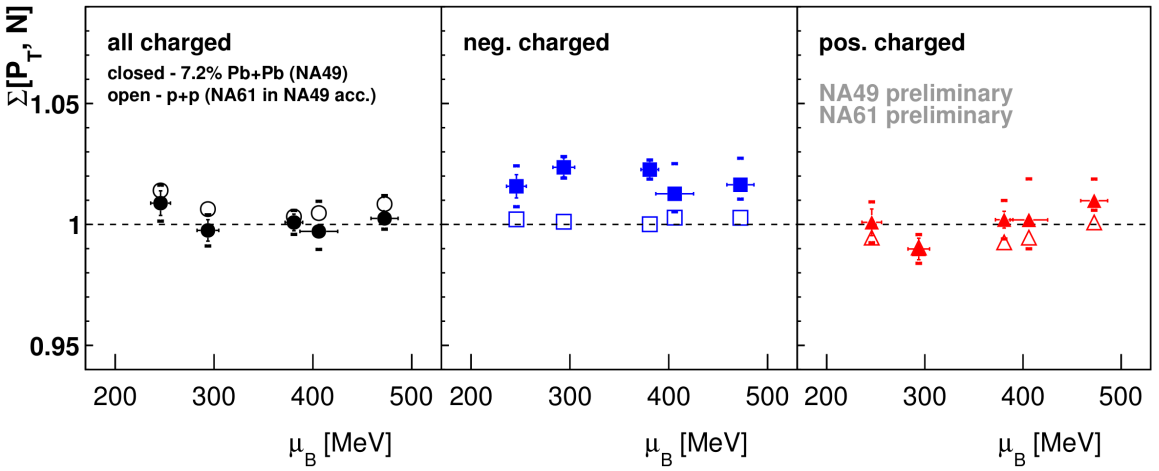
- **No sign of any anomaly that can be attributed to CP** (both in p+p and Be+Be)
- **Σ[P_T, N]** shows fluctuations slightly **above IPM** and **Δ[P_T, N] below IPM.**

  Possible explanations:
  - **Bose-Einstein statistics** PLB 730, 70 (2014); PRC 88, 024907 (2013); PLB 439, 6 (1998); PLB 465, 8 (1999)
  - **P_T/N versus N correlation in p+p** PRC 89, 034903 (2014)

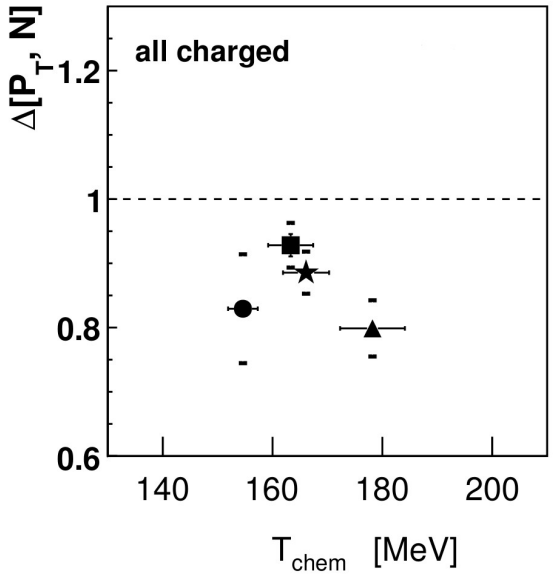
NA49: p_T fluctuations in A+A

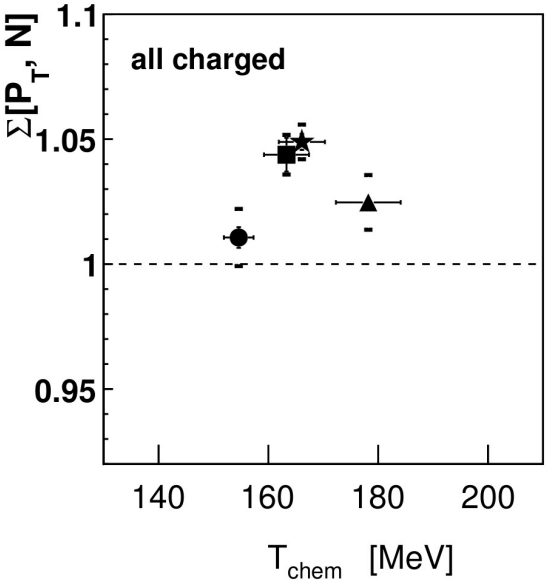
NA49 data on Pb+Pb/A+A collisions remain reference for NA61

Forward-rapidity; common (limited) azimuthal acceptance for the energy scan

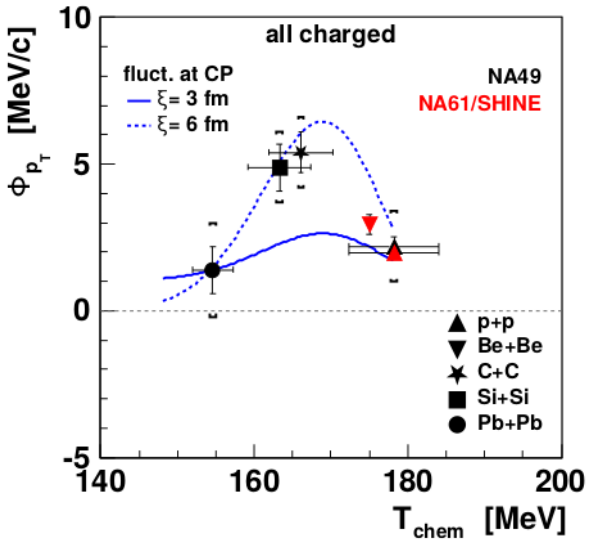


- **Maximum of transverse momentum fluctuations in C+C and Si+Si at 158*A* GeV/c;** may be attributed to CP (see NP A830, 549C (2009) for details)

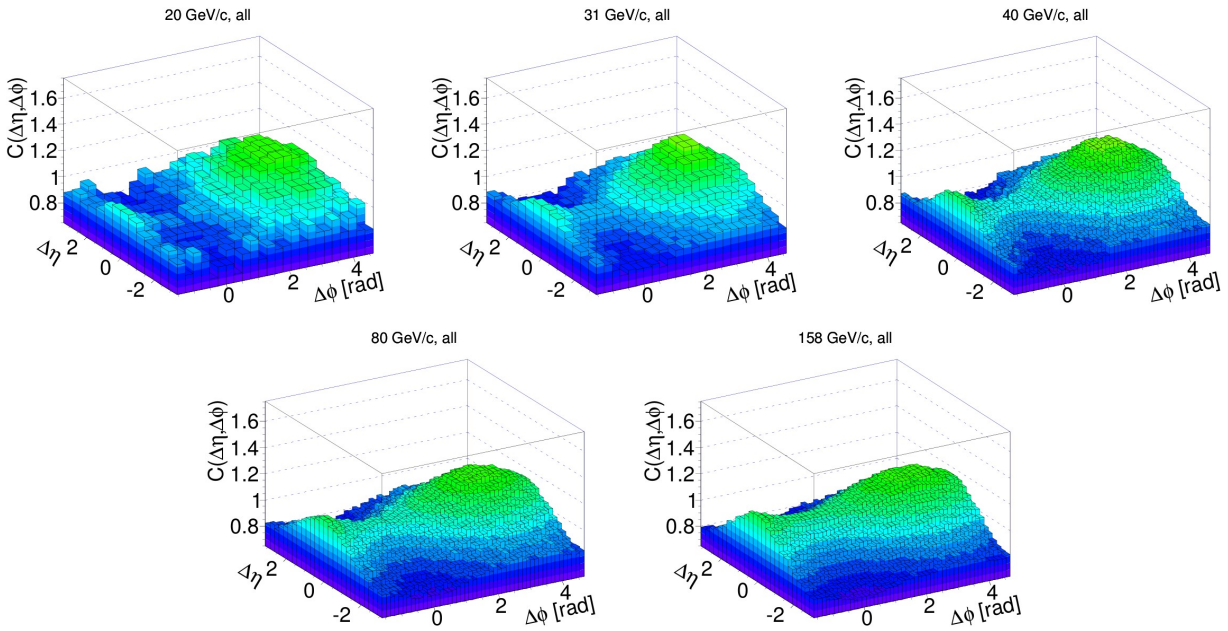




$$\Phi_{p_T} = \sqrt{\overline{p_T}\,\omega[p_T]}\left[\sqrt{\Sigma[P_T, N]} - 1\right]$$

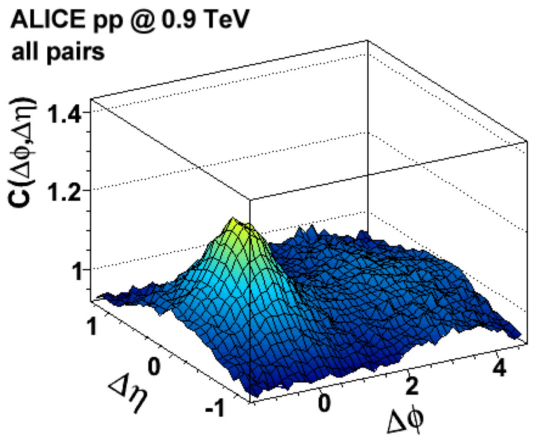


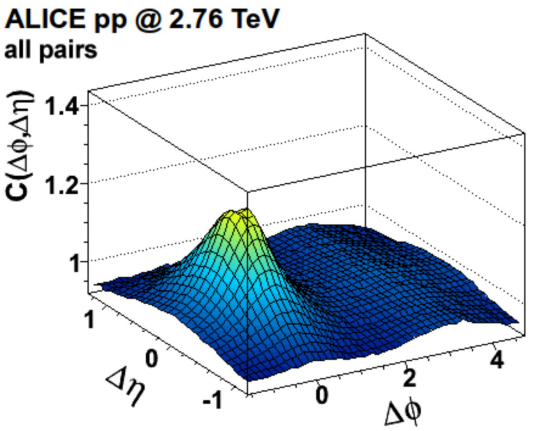
NA61: Correlations in $\Delta\eta$, $\Delta\phi$ in p+p

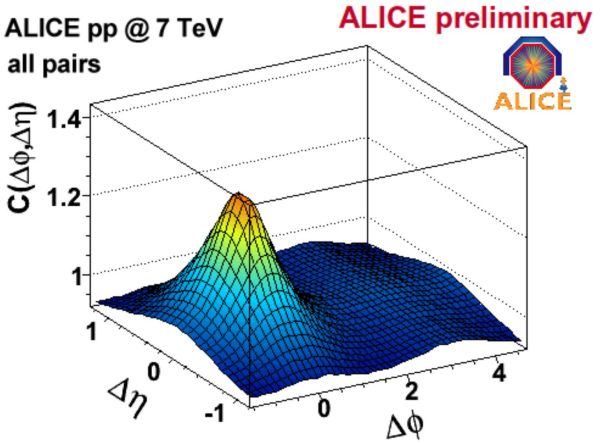


Pairs of **all charged particles** - comparison with ALICE

- NA61: maximum at $(\Delta\eta,\Delta\phi) = (0,\pi)$ probably due to resonance decays and momentum conservation
- NA61 results show stronger enhancement in $\Delta\phi \approx \pi$ and no "jet peak" at $\Delta\phi \approx 0$







PoS (WPCF2011), 026

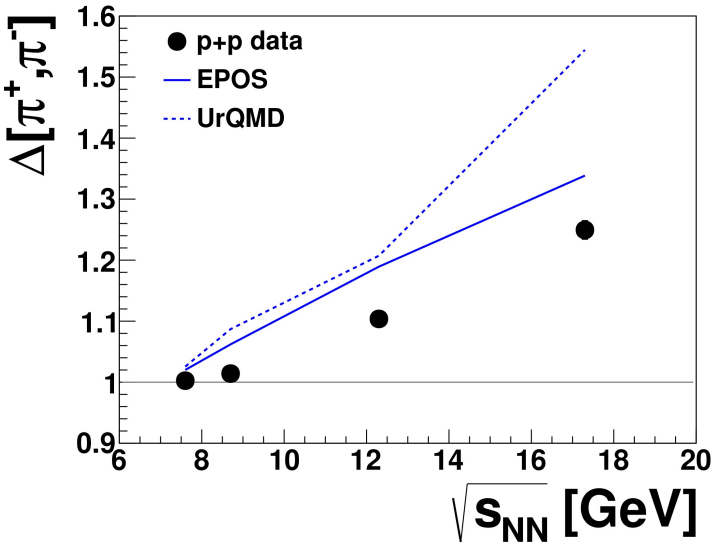
NA61: Fluctuations of charged pions in p+p

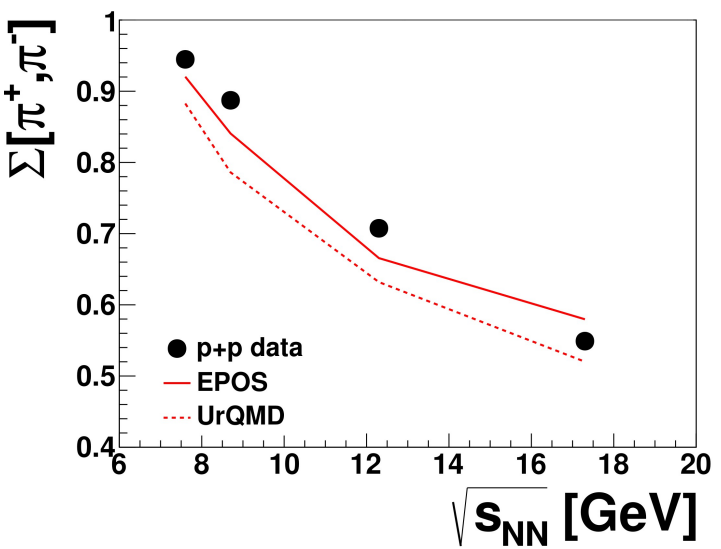
- Fluctuations of charged pions can be sensitive to critical point (long-wavelength fluctuations of the magnitude of the σ-field (PRD 60, 114028; PRL 81, 4816)
- Resonance abundances at chemical freeze-out can be found by measuring fluctuations of π^+ and π^- (arXiv:1409.3023)

$$\Delta[\pi^+,\pi^-]=\frac{1}{\langle\pi^-\rangle-\langle\pi^+\rangle}\left[\langle\pi^-\rangle\omega[\pi^+]-\langle\pi^+\rangle\omega[\pi^-]\right]$$

$$\Sigma[\pi^+,\pi^-]=\frac{1}{\langle\pi^+\rangle+\langle\pi^-\rangle}\left[\langle\pi^+\rangle\omega[\pi^-]+\langle\pi^-\rangle\omega[\pi^+]-2\left(\langle\pi^+\pi^-\rangle-\langle\pi^+\rangle\langle\pi^-\rangle\right)\right]$$

$$\omega[\pi^+]=\frac{\langle\pi^{+2}\rangle-\langle\pi^+\rangle^2}{\langle\pi^+\rangle}\qquad\omega[\pi^-]=\frac{\langle\pi^{-2}\rangle-\langle\pi^-\rangle^2}{\langle\pi^-\rangle}$$





- NA61 results are in rather good agreement with models
- p+p collisions show no effects of critical point

For both π^+ and π^- the same (smaller) acceptance of π^- was used, see:
https://edms.cern.ch/document/1237791/1