Measurement and control of the Luminosity of the NICA collider

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Abstract. Collider experiments have fundamental limitations on the number of interactions at the intersection point. In this way, they differ from experiments with a fixed target, when, within certain limits, the number of interactions (counting rate) can be changed by changing the thickness of the target. The counting rate is proportional to the reaction cross-section and the collider parameter, which is called luminosity and is denoted by $\mathcal{L}$. Along with the maximum attainable energy, luminosity is a key characteristic of the collider. Knowledge of this parameter, which depends on both the energy of the collisions and the type of colliding particles, is necessary already at the experimental planning stage when estimating the speed of the statistics set.

Luminosity

The luminosity ($\mathcal{L}$) of the collider determines the average number of interactions per unit time (R) for reactions with a known cross section σ: $R = \mathcal{L}\sigma$. The standard unit for measuring the luminosity is $cm^{-2}s^{-1}$. Along with the range of achievable energies, the luminosity is a key characteristic of a collider. In addition to the theoretical definition of the luminosity, there is also another definition used by experimenters. When determining the luminosity experimentally, it is necessary to include the detector efficiency. Then will take the form: $R = \varepsilon\mathcal{L}\sigma$ [1].

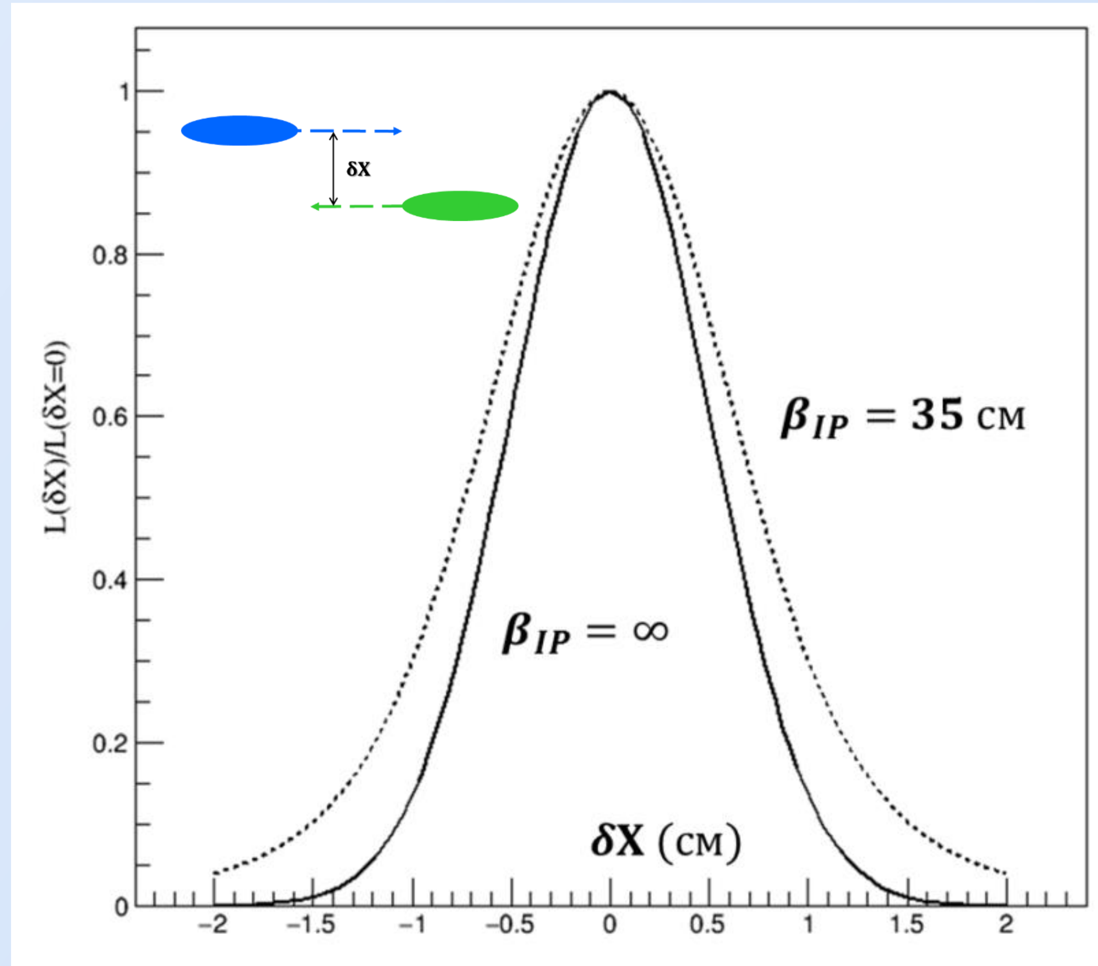
There are several experimental methods for determining the luminosity: direct and indirect ones. When using the direct method, parameters such as the number of events recorded by the detector per second, interaction cross sections and the detector efficiency must be known, which is not always possible. When using the indirect method, the luminosity is determined in accordance with an algorithm from a series of measurements (van der Meer scan[2]), which are based on the form of the equation of luminosity depending on the bunch parameters (without consideration and with consideration of focusing)[3].

Van der Meer scan

The method for determining the effective beam overlap area in a series of measurements of the count rate with different distances between the beam axes was proposed for ISR by van der Meer and is called the van der Meer scan (or Vernier scan). This approach to the determination of spatial parameters is used in most accelerator centers (e.g., at the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC)). The luminosity depends on the beam intensity, and it is assumed in the van der Meer method that the beam intensity is known.

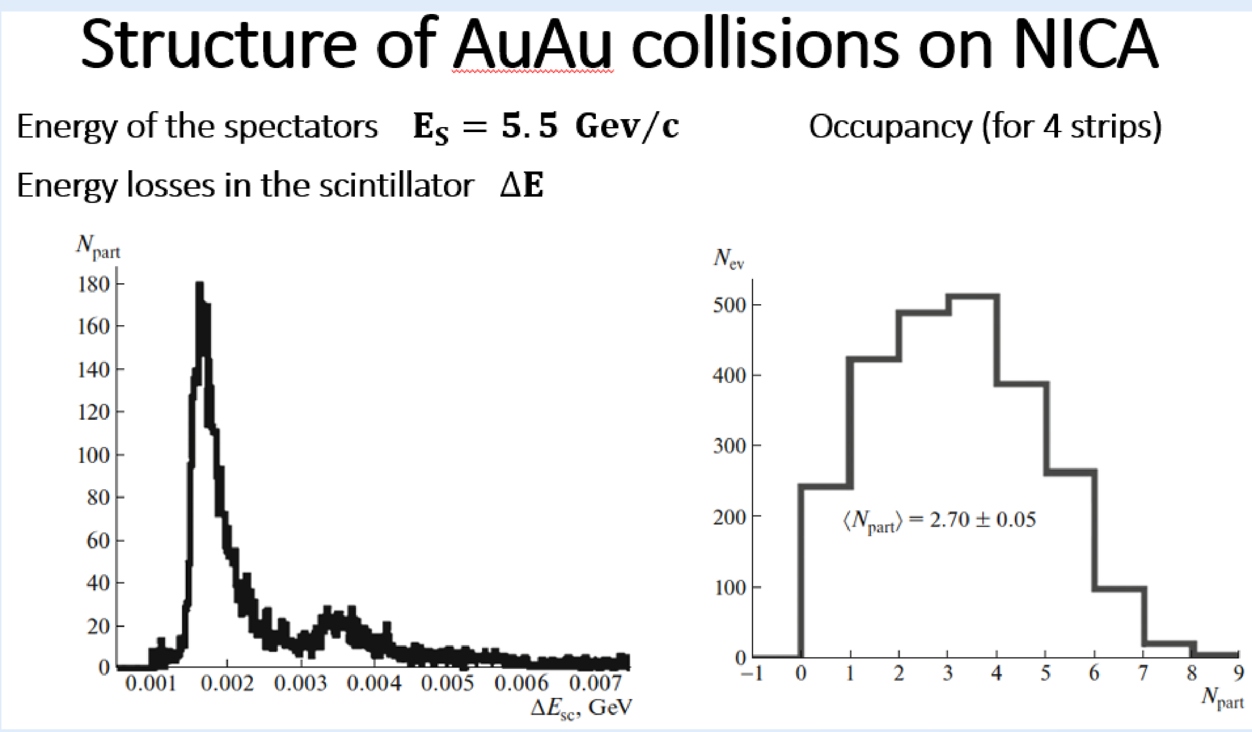
Luminosity structure: $\mathcal{L}(\delta X, \delta Y) = f_r \cdot N_b \cdot \frac{N_L N_R}{S_{eff}(\delta X, \delta Y)}$.

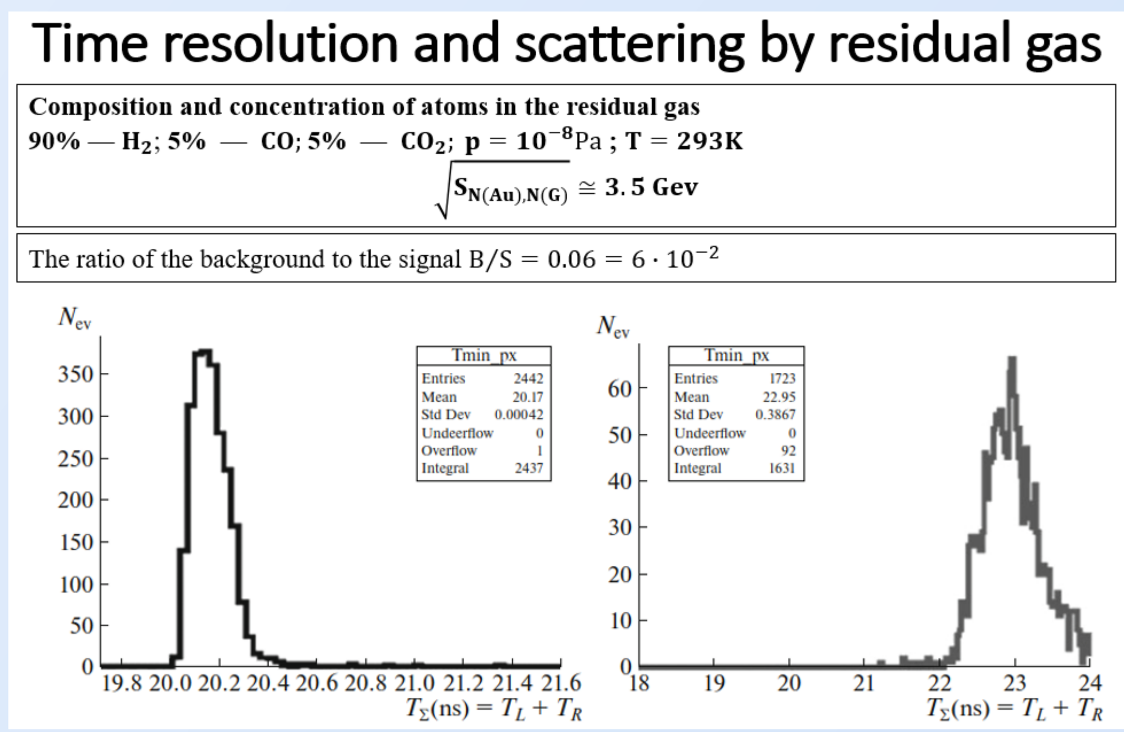
For normal distribution: $\mathcal{L}(\delta X, \delta Y) = f_r \cdot N_b \cdot \frac{N_L N_R}{4\pi\sigma_x\sigma_y} \exp\left(-\frac{\delta X^2}{2\sigma_x^2}\right) \cdot \exp\left(-\frac{\delta Y^2}{2\sigma_y^2}\right)$.

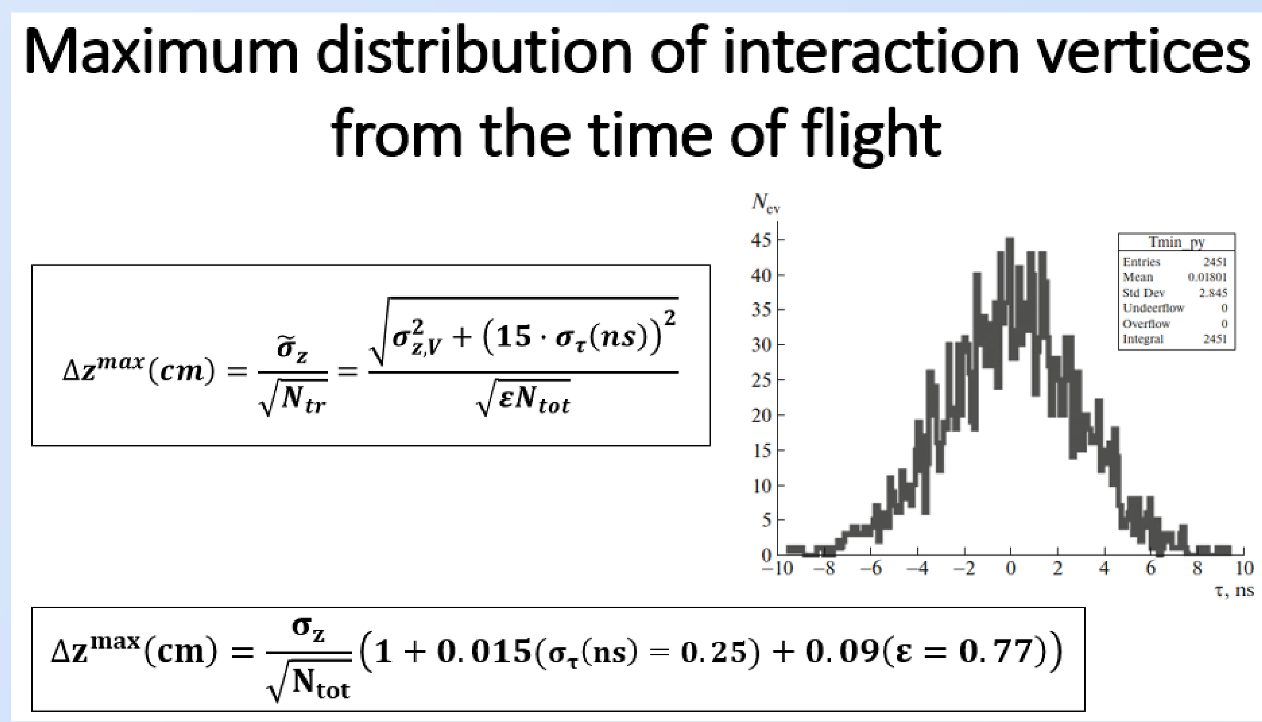


Modeling

In our modeling we used 3000 Au +Au collisions produced by the generator DCM-SMM without selection by the target parameter (minimum bias (MB) events). As a result, we have the total spectrum by the lost energy in four scintillation strips of a single arm closest to the ion guide, distribution over total multiplicity of spectators in four scintillation strips of one arm closest to the ion guide, distribution of events over the total time of flight from the interaction point to the detector arms. Distribution of registered events over the difference of time of flight [4].

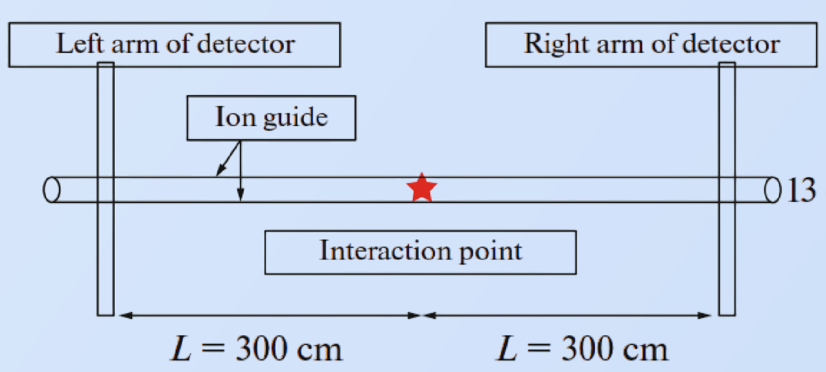


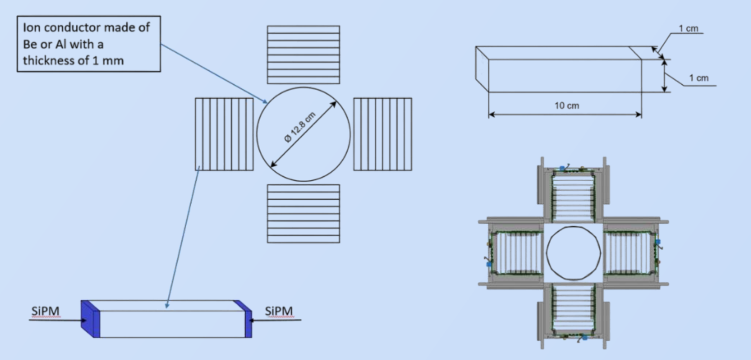




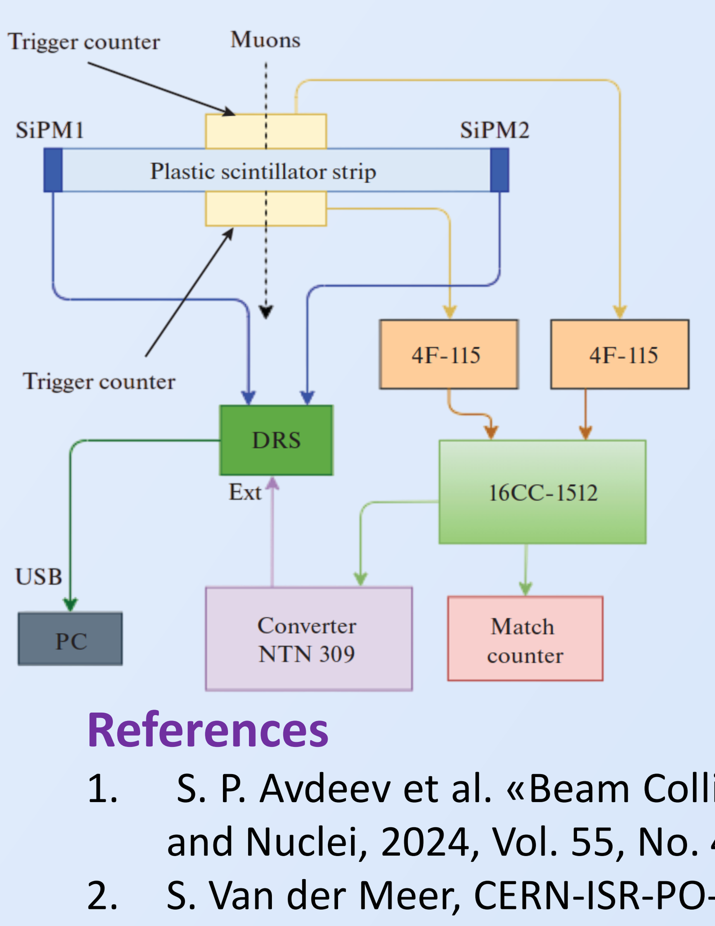
Luminosity detector

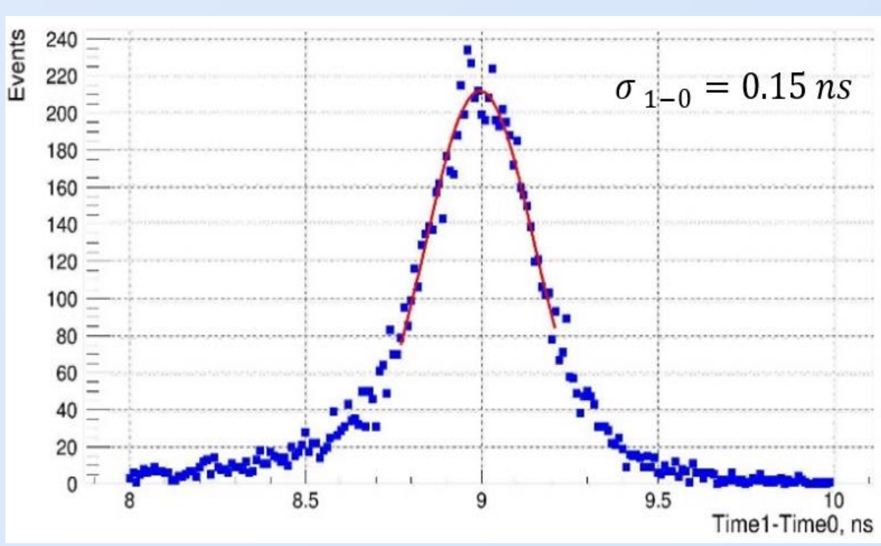
To measure the absolute luminosity in the MPD experiment at the NICA collider, a detector consisting of two "arms" symmetrically located at a distance of 3 m from the interaction point was proposed, the main elements of which are scintillator strips with dimensions of 100 × 10 × 10 mm^3. Each "arm" consists of four modules. Each module includes eight scintillator strips. The strips are viewed from both sides by HAMAMATSUS14160-6050HS silicon photomultipliers (SiPM)[5].



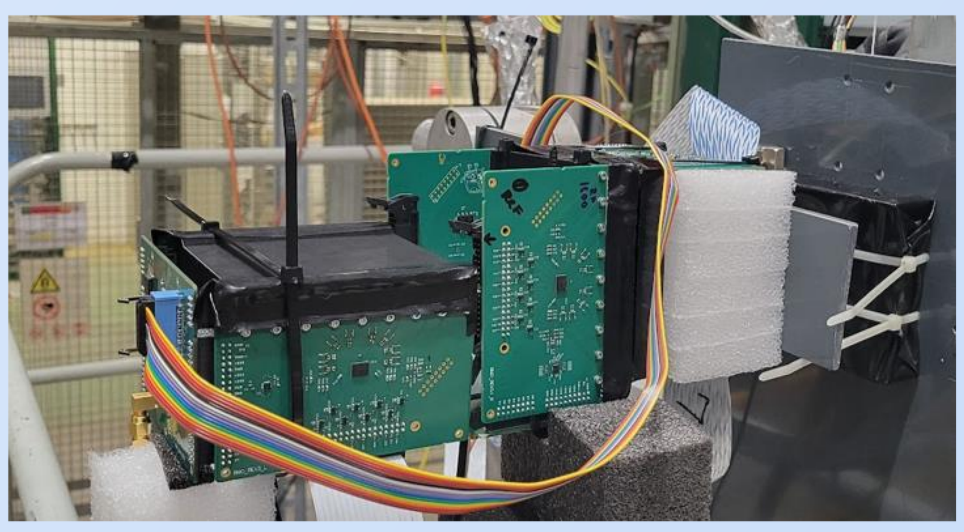


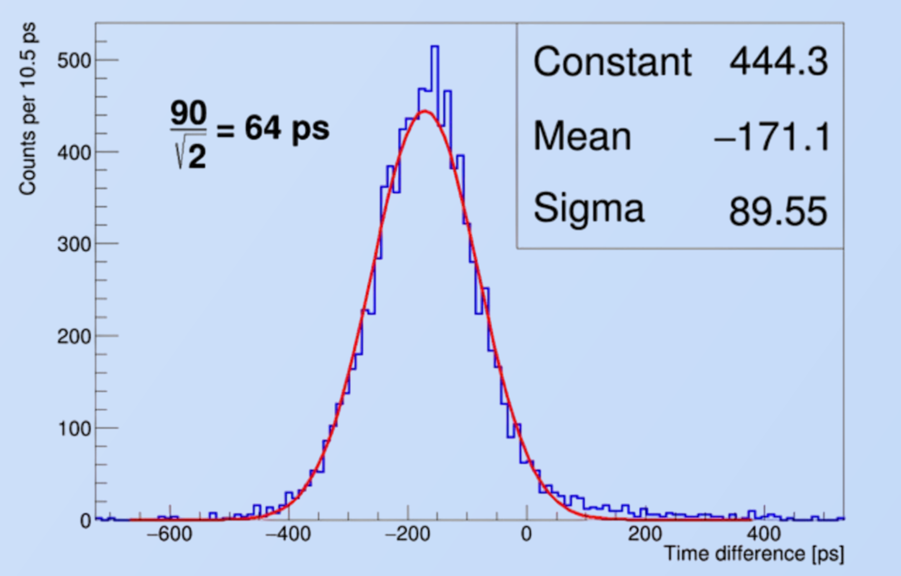
For scintillator counter





For modules





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