"Search for Dibaryons with small energy excitation at SPD detector at NICA collider " - *accuracies and counting rates*

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October 21, 2024

SPD detector

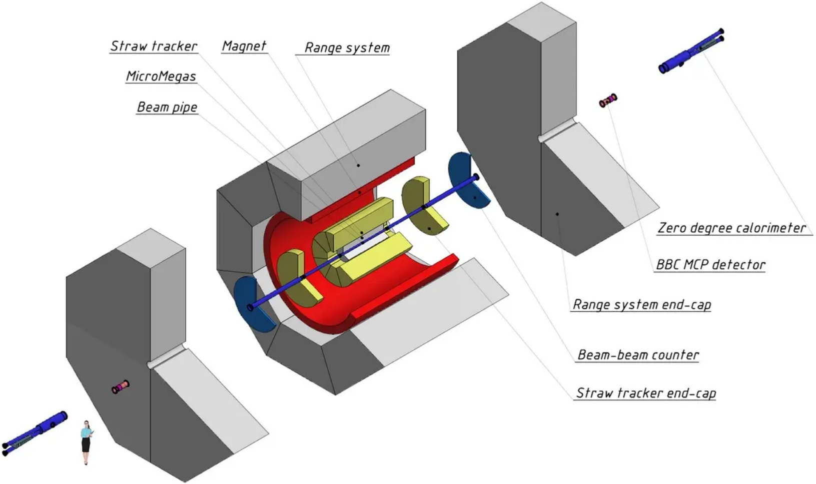

Figure 1: SPD, First phase

SPD detector

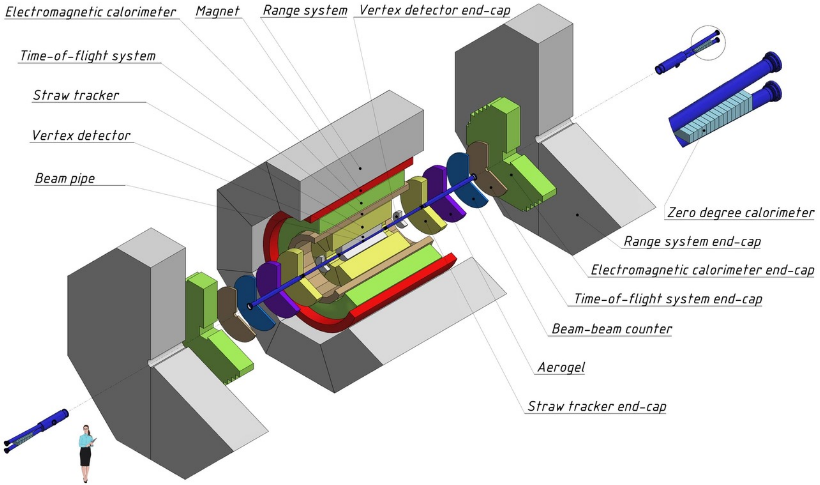

Figure 2: SPD, Full configuration

Extract from Troyan's review,Physics of Particles and Nuclei,**24**,3,1993

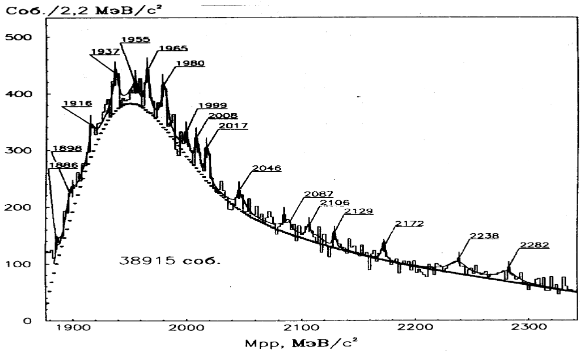

Figure 3: Effective mass of two protons from the reactions $np \to pp\pi^- m\pi^0$, m=0,1 for $P_n = 1.26; 1.33; 1.72; 2.23; 3.86 GeV/c$ and the reactions $np \to pp\pi^+\pi^-\pi^- m\pi^0$, m=0,1 for $P_n = 5.14; 5.18; 5.24; GeV/c$.Solid curve is the approximation by the sum of the background and 17 resonances.

$$\delta(P_b)/P_b = 3\%, \delta(\Omega_b) = 10^{-7} str$$

Remarks about Yu.Troyan's review

Comparatively long time ago Yu.Troyan,staff member of VBLHEP of JINR published the review on the search for diprotons(Yu.Troyan, Physics of Particles and Nuclei,**24**,3,1993) The author analyzed papers about search for diproton resonances, in different experiments(bubble chamber,electronics) published since 1986 till 1993. Diproton resonances were searched for both by effective mass and missing mass methods. At that time no experiment proved convincingly the existence of diproton resonance. Nevertheless in a fig 3 we show one of the pictures from this review due to its colorfulness.
Still, concluding his paper, Yu. Troyan says that"..Effects of narrow diproton esonances exist.."

Extract from Clement's review,arxiv:1610.05591v2

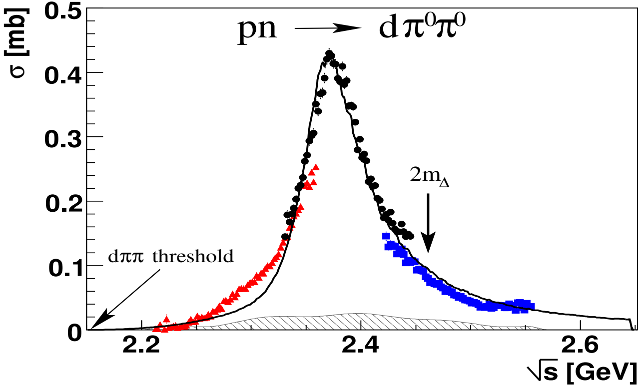

Figure 4: WASA collaboration claims that this is dibarion resonance with quantum numbers $I(J^P) = 0(3^+)$, $M = 2380MeV, \Gamma \approx 80MeV$,calls it as $d^*(2380)$.Triangles - for 1.0GeV,dots - for 1.2GeV,squares - for 1.4GeV

Remarks about Clement's review

Perhaps the latest and most complete review on the existence of dibarion resonances is a publication of Clement(WASA-at-COSY,H.Clement,arxiv:1610.05591v2 [nucl-ex];Progress in Particle and Nuclear Physics **93**,2017, Pp. 195-242)
Originally similar behavior of the reaction $pn \to d\pi^0\pi^0$ was observed when fixed deuteron target was used and the events were selected by detecting proton-spectator(with the momentum $p_{sp} <\approx 170 MeV/c$) together with deuteron and γ rays.
Momentum of proton-spectator was being estimated by kinematical fit(Lagrange Multiplier Method).
To cover more angular range WASA group measured this process in reverse kinematics with deuteron beam and hydrogen as a target. The conclusion is :
H.Clement:"..a single firmly established non-trivial dibaryon state, the one with $I(J^P) = 0(3^+)$ at 2380 MeV..."

Baldin-Stavinsky experiment

In a figure 5 we show the results of Baldin-Stavinsky experiment(Baldin et al.,Communication of the JINR, Dubna 1979,1-12397) where on fixed target dd interaction at 8.9GeV/c was studied. .

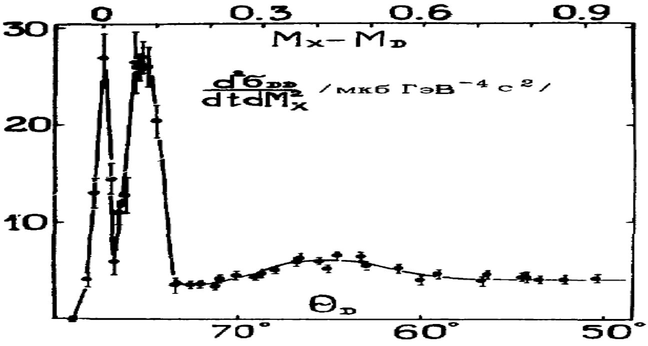

Figure 5: $d\sigma/(dtdM_X{}^2)$ $D + D \rightarrow M_X + D$ $-t = 0.5(GeV/c)^2$

Proposal for the search for dibaryons with SPD

Our proposal is to do the similar experiment , aimed to investigate the reaction $D + D \rightarrow M_X + D$ **in the region of Missing Mass below pion production (**$M_X < M_d + m_{\pi^0}$**) at collider deuteron momentum** $P_d = 2.6 GeV/c$**(equivalent to 8.9GeV/c on fixed target)**. Here M_d, M_X are masses of the deuteron and of the missing system , starting with the first version of SPD setup and continuing it in the process of improving it till full configuration. Remind that the first version of SPD is shown in a Fig. 1

In what follows we consequently show the accuracies(or resolutions) in dibaryon mass measurement, achievable in a different detector configuration, where under the resolution we understand a σ of the Gaussian function approximating peak region of the distribution(selected by eye!). In that we follow the practice acceptable in the electronics where the width of any signal is characterized by so called FWHM(Full Width at Half Maximum) and if the signal is pure Gaussian, sigma of this Gauss is $\sigma = FWHM/2.35$.

Accuracies in a "real" conditions(SPD in full configuration!)

Three vesions of Vertex Detector(VD)(arXiv:2404.08317) :

- Micromegas-based Central Tracker(MVD)
- Double-Sided Silicon Detector(DSSD)
- MAPS-based vertex detector(MAPS)

"Real" conditions :

- Mass of the dibarion X in the reaction $d + d \rightarrow d + X$ was taken again as $M_X = md + E_{exc}$,where md is deuteron mass, E_{exc} is the excitation energy equal to $E_{exc} = 3/4m_{\pi^0}$ and m_{π^0} is the π^0 mass
- The width of dibarion X was equal zero(this was done specially to estimate resolution)
- Momentum of deuteron in dd collisions 2.6GeV/c
- The distribution of Transfer momentum for recoiled deuteron is taken from Baldin-Stavinsky experiment obtained for dd elastic scattering , see fig. 9
- Cooridinates of primary vertex were generated by Gaus - for Z with $\sigma = 40cm$,for X,Y with $\sigma = 0.08cm$
- For the analysis only the events with $-35cm < Z < 35cm$ were selected
- Accuracies were estimated for two types of Vertex Detector - MVD and DSSD and SPD detector was in full assembly

Resolution for MVD option,full configuration of SPD

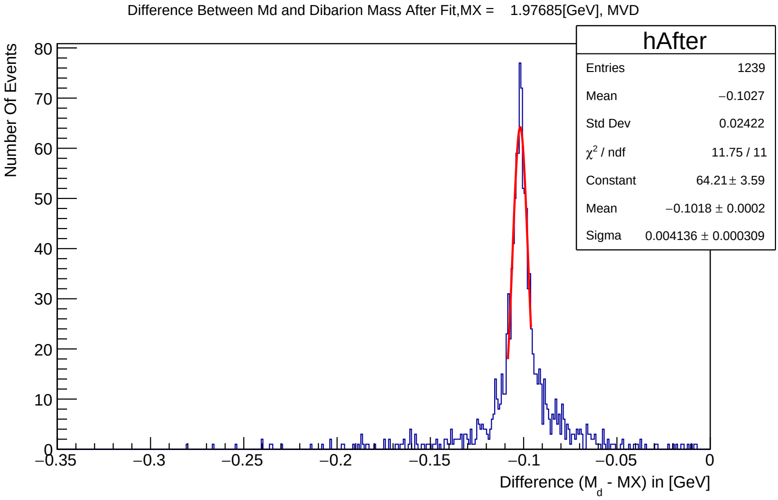

Figure 6: Difference $M_d - M_X$ in GeV,M_d, M_X are deuteron and dibarion masses respectively

Resolution for DSSD option,full configuration of SPD

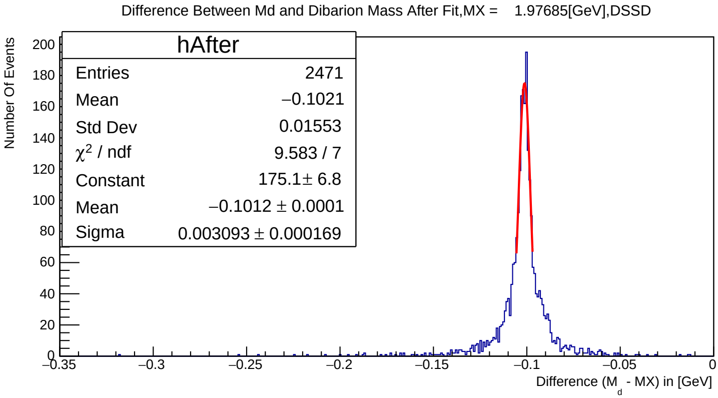

Figure 7: Difference $M_d - M_X$ in GeV,M_d, M_X are deuteron and dibarion masses respectively

Accuracy with the first phase of SPD

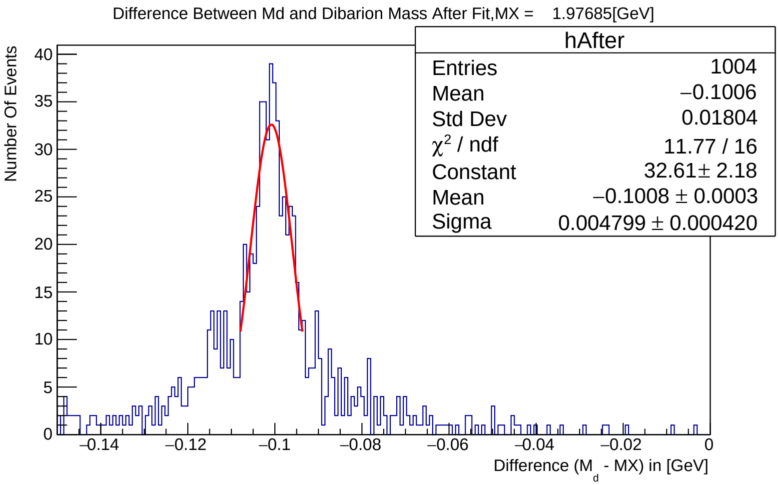

Figure 8: Difference $M_d - M_X$ in GeV,M_d, M_X are deuteron and dibarion masses respectively

t-dependence for the recoiled deuteron

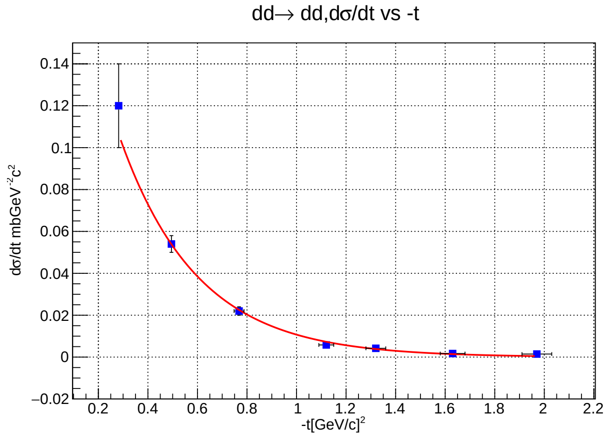

Figure 9: Transfer momentum distribution from Baldin-Stavinsky experiment

Possible experiment with the first phase of SPD

To do such a study first version of SPD should include Vertex Detector(MVD version) and two End Cups, each of them containing only tracking system.
In a Fig. 8 we show the accuracy in a Missing Mass reconstruction in a SPD configuration mentioned above. It was obtained as the result of the simulation at the same conditions as before - for so-called "real" experiment As is seen the estimated resolution will be $\sigma \approx 4.8 MeV$.
Remark: Adding TOF system in End Cups improves resolution to $\sigma \approx 4.1 MeV$; change Vertex Detector to DSSD option gives $\sigma \approx 3.1 MeV$

Counting rate for the first phase of SPD

Factors for the estimation of Counting Rate:

- Luminosity of dd for Collider Momentum $2.6 GeV/c$ is $\approx 1.7 \cdot 10^{29} cm^{-2} sec^{-1}$
- Cross section of $d + d \to d + X$ for $(0.282 < -t < 1.97)(GeV/c)^2$ is $0.033 mb$.It was taken equal to elastic dd cross section; in fact it is bigger according to Baldin-Stavinsky experiment
- Fraction of the Luminosity corresponding to the probability of having primary vertex in the selected region is 0.382

Counting rate $\approx 2.1 sec^{-1}$

Luminosity of dd collisions

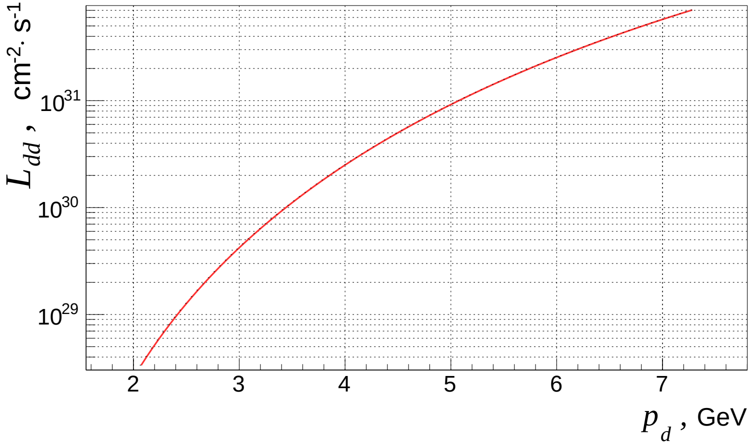

Figure 10: Luminosity of deuteron beam in a symmetric mode(prepared by A.Philippov, staff member of VBLHEP)

Conclusion

Creation of such a complicated detector requires a lot of time and human activity and now it seems very distant. Still the earlier we start the preparation of all the parts of stable running the SPD experiment the more qualitative physics results we will get.
Here we are talking about first possible experiment at the SPD, particularly about analysis of the primary data in $D + D \rightarrow M_X + D$ reaction below pion threshold.

Having suitable support we are planning to start the necessary works to produce "embryo" of such an analysis.