PROBING OF XYZ MESON STRUCTURE WITH NEAR THRESHOLD pp & pA COLLISIONS

Mikhail Barabanov, Alexander Vodopyanov

(Joint Institute for Nuclear Research, Dubna, Russia)

in collaboration with

Stephen Olsen

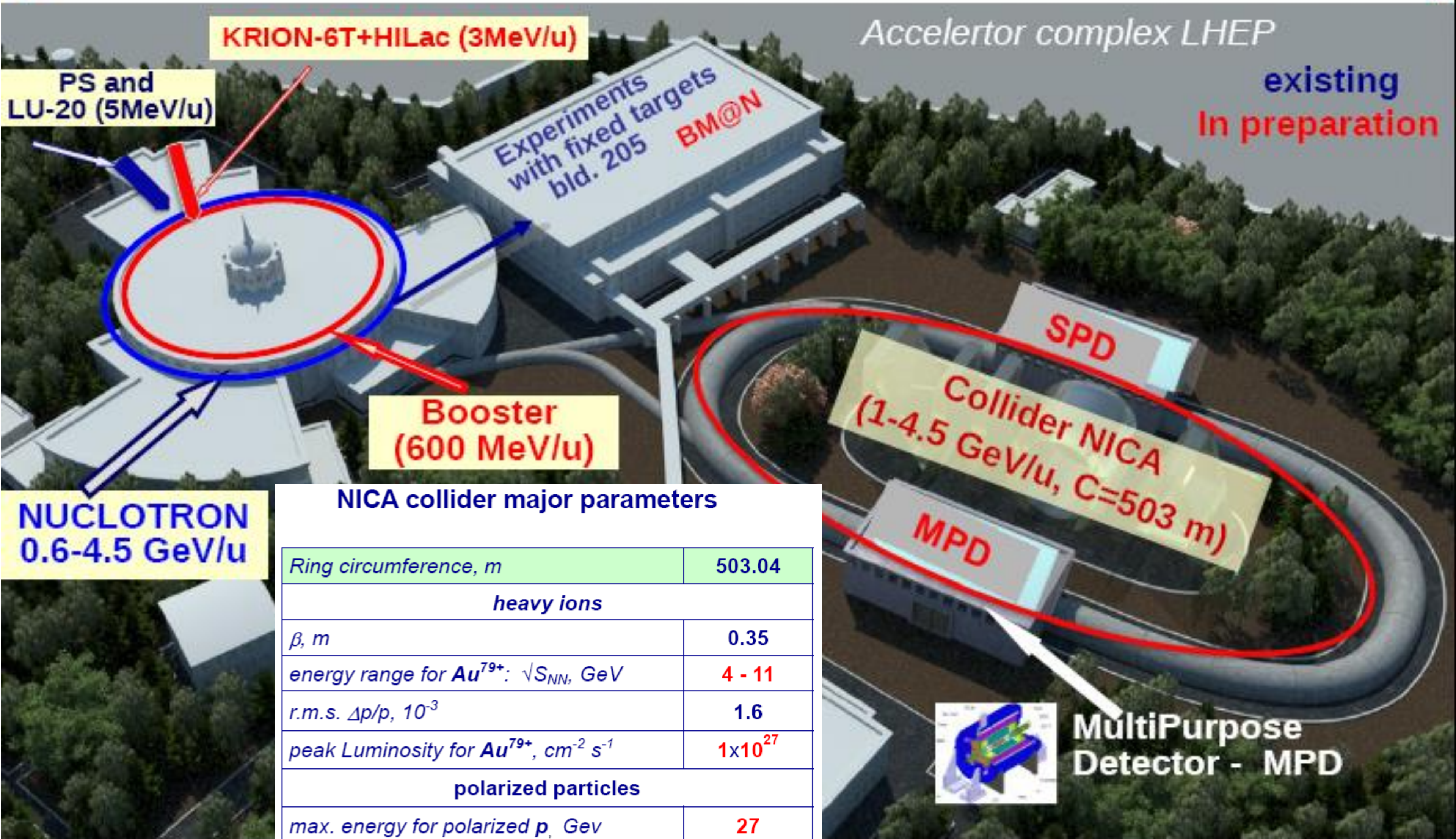
(University of the Chinese Academy of Science, Beijing, Republic of China)

&

(Institute for Basic Science, Daejeon, Republic of Korea)

Complex NICA

Collider basic parameters: *beams: from* p to Au;
L~10^{27} cm^{-2} c^{-1} (Au), $\sqrt{s_{NN}}$ = 4-11 GeV; ~10^{32} cm^{-2} c^{-1} (p), $\sqrt{s}$ = 12-26 GeV;

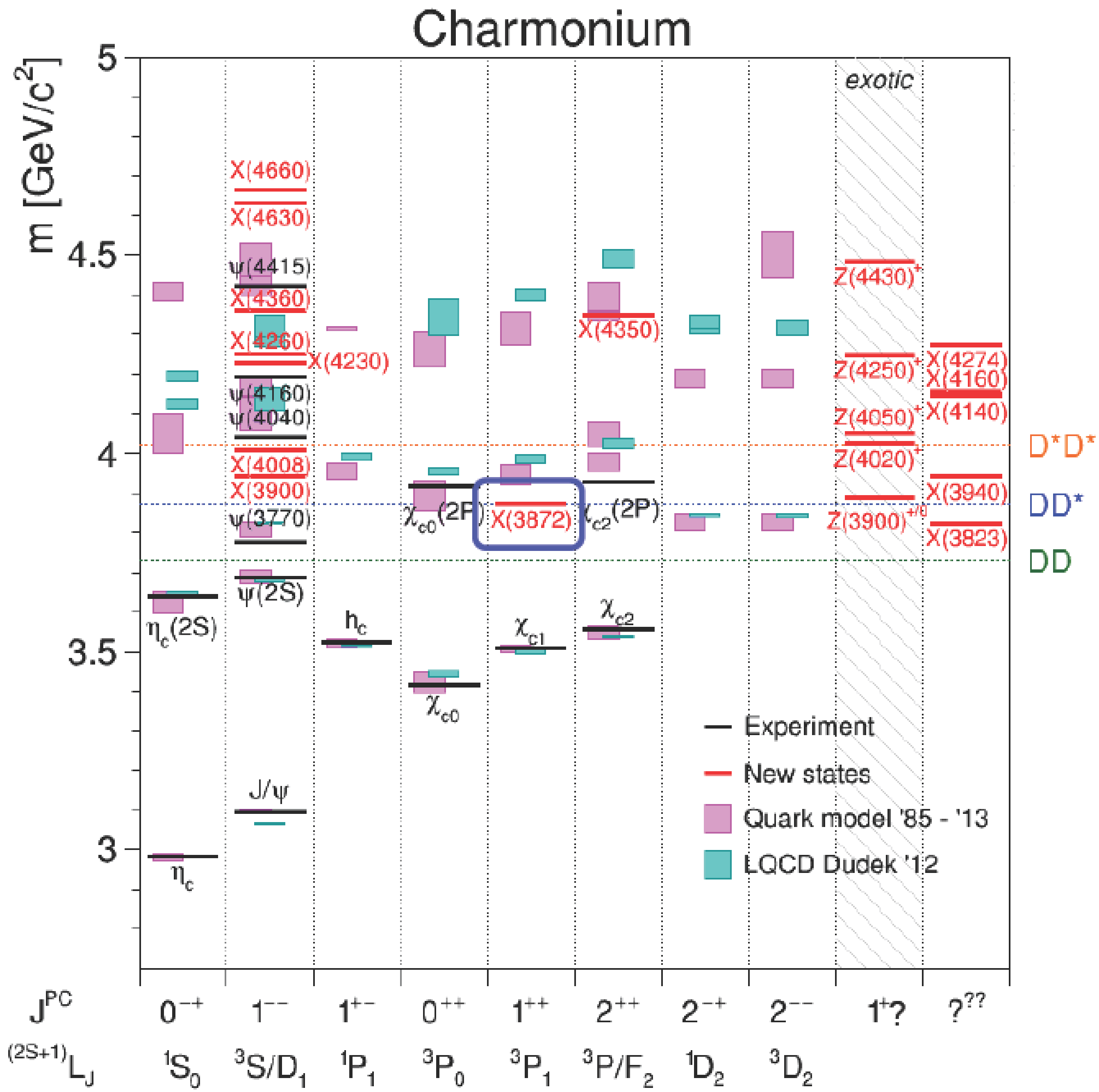


NICA collider major parameters

Ring circumference, m	**503.04**
heavy ions	
β, m	**0.35**
energy range for ***Au^{79+}****: $\sqrt{S_{NN}}$, GeV*	**4 - 11**
r.m.s. Δp/p, 10^{-3}	**1.6**
peak Luminosity for ***Au^{79+}****, cm^{-2} s^{-1}*	$1x10^{27}$
polarized particles	
max. energy for polarized ***p****, Gev*	**27**
peak Luminosity for ***p****, cm^{-2} s^{-1}*	$1x10^{32}$

MOTIVATION

To look for different charmonium-like states (conventional and exotic) in *pp* and *pA* collisions to obtain complementary results to the ones from *e+e-* interactions, *B*-meson decays and *pp\bar* interactions


Charmonium
m [GeV/c²]
5
4.5
4
3.5
3
exotic
X(4660)
X(4630)
ψ(4415)
X(4360)
X(4260)
X(4230)
ψ(4160)
ψ(4040)
X(4008)
X(3900)
ψ(3770)
ψ(2S)
J/ψ
ηc(2S)
ηc
hc
χc0
χc0(2P)
X(3872)
χc1
χc2
χc2(2P)
X(4350)
Z(4430)+
Z(4250)+
Z(4050)+
Z(4020)+
Z(3900)+/0
X(4274)
X(4160)
X(4140)
X(3940)
X(3823)
D*D*
DD*
DD
Experiment
New states
Quark model '85 - '13
LQCD Dudek '12
JPC
0−+
1−−
1+−
0++
1++
2++
2−+
2−−
1+?
???
(2S+1)LJ
1S0
3S/D1
1P1
3P0
3P1
3P/F2
1D2
3D2

The quark potential models have successfully described the charmonium spectrum, which generally assumes short-range coulomb interaction and long-range linear confining interaction plus spin dependent part coming from one gluon exchange. The zero-order potential is:

$$V_0^{(c\bar{c})}(r) = -\frac{4}{3}\frac{\alpha_s}{r} + br + \frac{32\pi\alpha_s}{9m_c^2}\tilde{\delta}_\sigma(r)\vec{S}_c \cdot \vec{S}_{\bar{c}},$$

where $\tilde{\delta}_\sigma(r) = (\sigma/\sqrt{\pi})^3 e^{-\sigma^2 r^2}$ defines a gaussian-smeared hyperfine interaction.

Solution of equation with $H_0 = p^2/2m_c + V_0^{(c\bar{c})}(r)$ gives zero order charmonium wavefunctions.

*T. Barnes, S. Godfrey, E. Swangon, Phys. Rev. D 72, 054026 (2005), hep-ph/ 0505002 & Ding G.J. et al., arXiV: 0708.3712 [hep-ph], 2008

The splitting between the multiplets is determined by taking the matrix element of the $V_{spin\text{-}dep}$ taken from one-gluon exchange Breit-Fermi-Hamiltonian between zero-order wave functions:

$$V_{\text{spin-dep}} = \frac{1}{m_c^2}\left[\left(\frac{2\alpha_s}{r^3} - \frac{b}{2r}\right)\vec{L}\cdot\vec{S} + \frac{4\alpha_s}{r^3}T\right]$$

where α_s - coupling constant, b - string tension, σ - hyperfine interaction smear parameter.

Izmestev A. has shown * Nucl. Phys., V.52, N.6 (1990) & *Nucl. Phys., V.53, N.5 (1991) that in the case of curved coordinate space with radius *a* (confinement radius) and dimension *N* at the dominant time component of the gluonic potential the quark-antiquark potential defines via Gauss equations. If space of physical system is compact (sphere S^3), the harmonic potential assures confinement: * Advances in Applied Clifford Algebras, V.8, N.2, p.235 - 270 (1998) .

$$\Delta V_N(\vec{r}) = \text{const}\, G_N^{-1/2}(r)\delta(\vec{r}), \qquad V_N(r) = V_0\int D(r)R^{1-N}(r)dr/r,\ V_0 = \text{const} > 0.$$

$$R(r) = \sin(r/a),\ D(r) = r/a, \qquad V_3(r) = -V_0\,\text{ctg}(r/a) + B, \quad V_0 > 0, \quad B > 0.$$

When cotangent argument in $V_3(r)$ is small: $r^2/a^2 << \pi^2$,

we get: $ctg(r/a) \approx a/r - r/3a$, $\Longrightarrow$ $\begin{cases} V(r)|_{r\to 0} \sim 1/r \\ V(r)|_{r\to\infty} \sim kr \end{cases}$

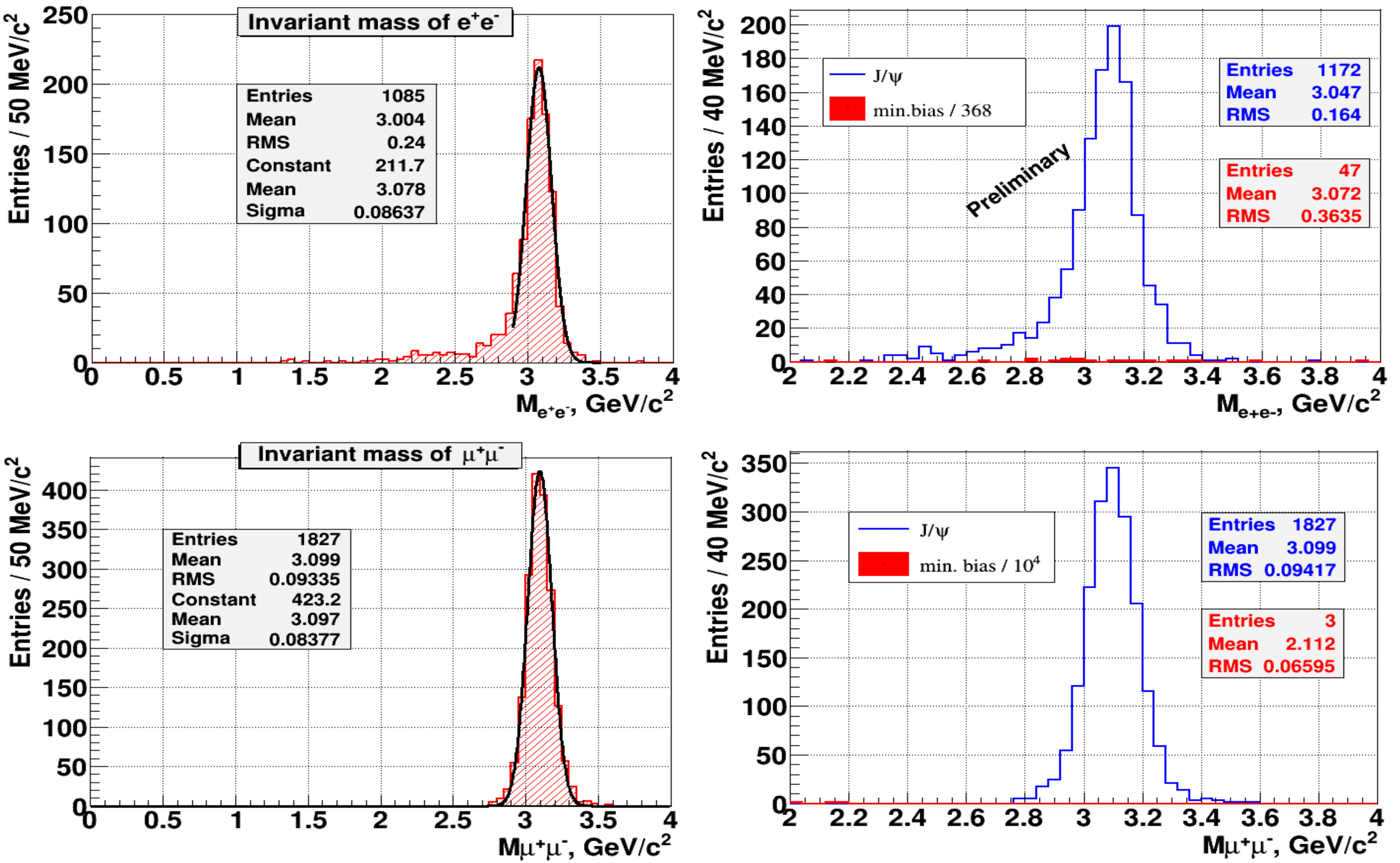
where *R(r), D(r)* and $G_N(r)$ are scaling factor, gauging and determinant of metric tensor $G_{\mu\nu}(r)$.

Software

1. *MpdRoot as a framework*
2. *Pythia8, UrQMD3.3 generators*
3. *MpdRoot Geant3 transport*
4. *MpdRoot TPC Kalman filter – based track and vertex reconstruction*

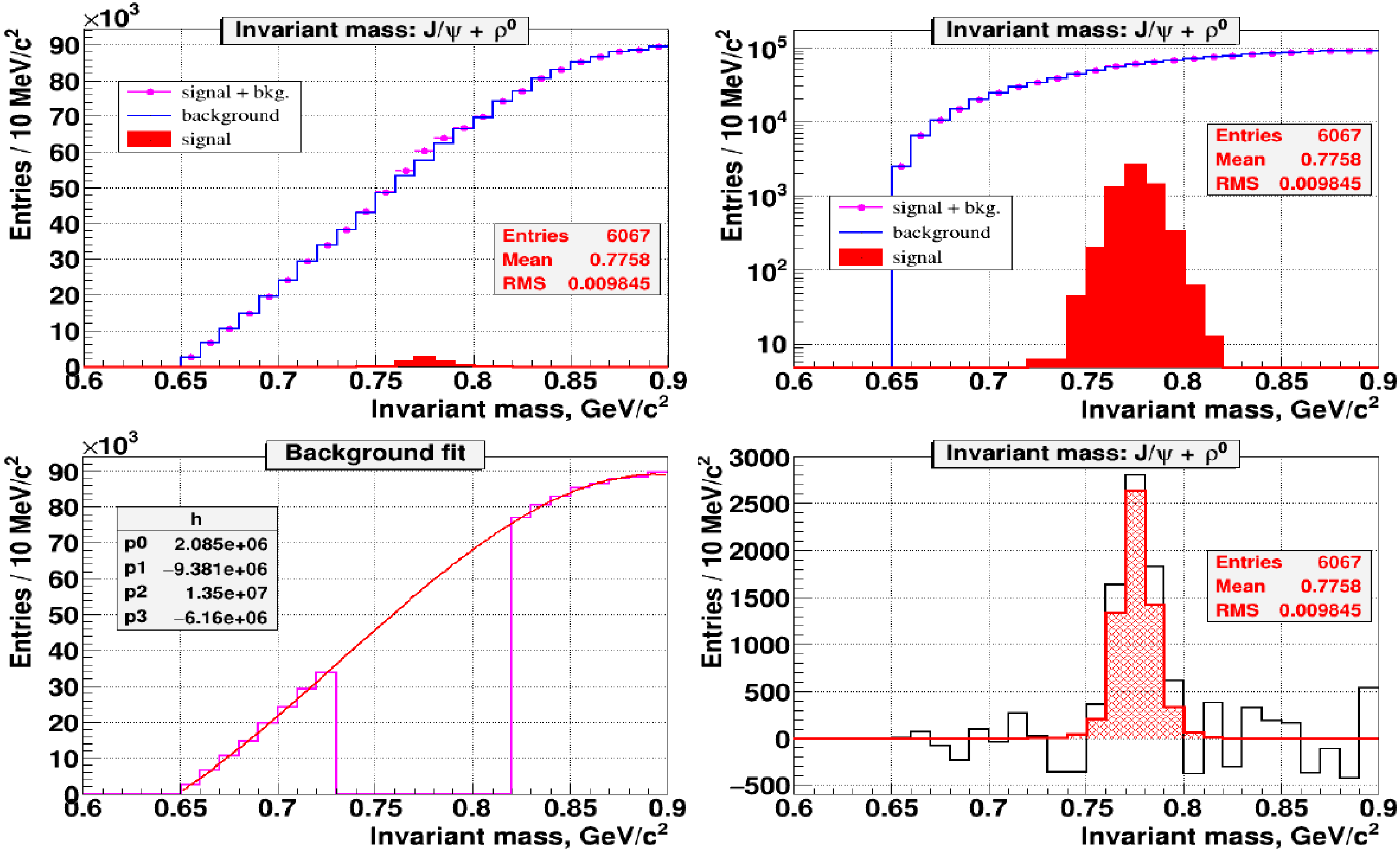
Invariant mass: $e^- + e^+$ or $\mu^- + \mu^+$

7 weeks



$X(3872) \rightarrow J/\psi + \rho^0$

Using mass combination: $M_{e+e-\pi+\pi-} - M_{e+e-}$



Probing the **X(3872)** meson structure with near-threshold pp and pA collisions at NICA

M.Yu. Barabanov[1], S.-K. Choi[2], S.L. Olsen[3†], A.S. Vodopyanov[1] and A.I. Zinchenko[1]

(1) *Joint Institute for Nuclear Research, Joliot-Curie 6 Dubna Moscow region Russia 141980*
(2) *Department of Physics, Gyeongsang National University, Jinju 660-701, Korea*
(3) *Center for Underground Physics, Institute for Basic Science, Daejeon 34074, Korea*

Pythia8 predictions for X(3872)

1. X-section of ψ(3770) with m = 3.872 GeV at pp 12.5+6.5 GeV: 1.3 nb

*2. X-section at pCu: 1.3 * A (=63) = 81.9 nb*

3. Br ($X(3872)\to J/\psi\ \pi+\pi-$) = 5.00%
Br ($X(3872)\to D^+D^-$) = 40.45%
Br ($X(3872)\to D^0D^{*0}bar$) = 54.55% $\Rightarrow$ $D^0D^0bar\pi^0$ = 35.29%

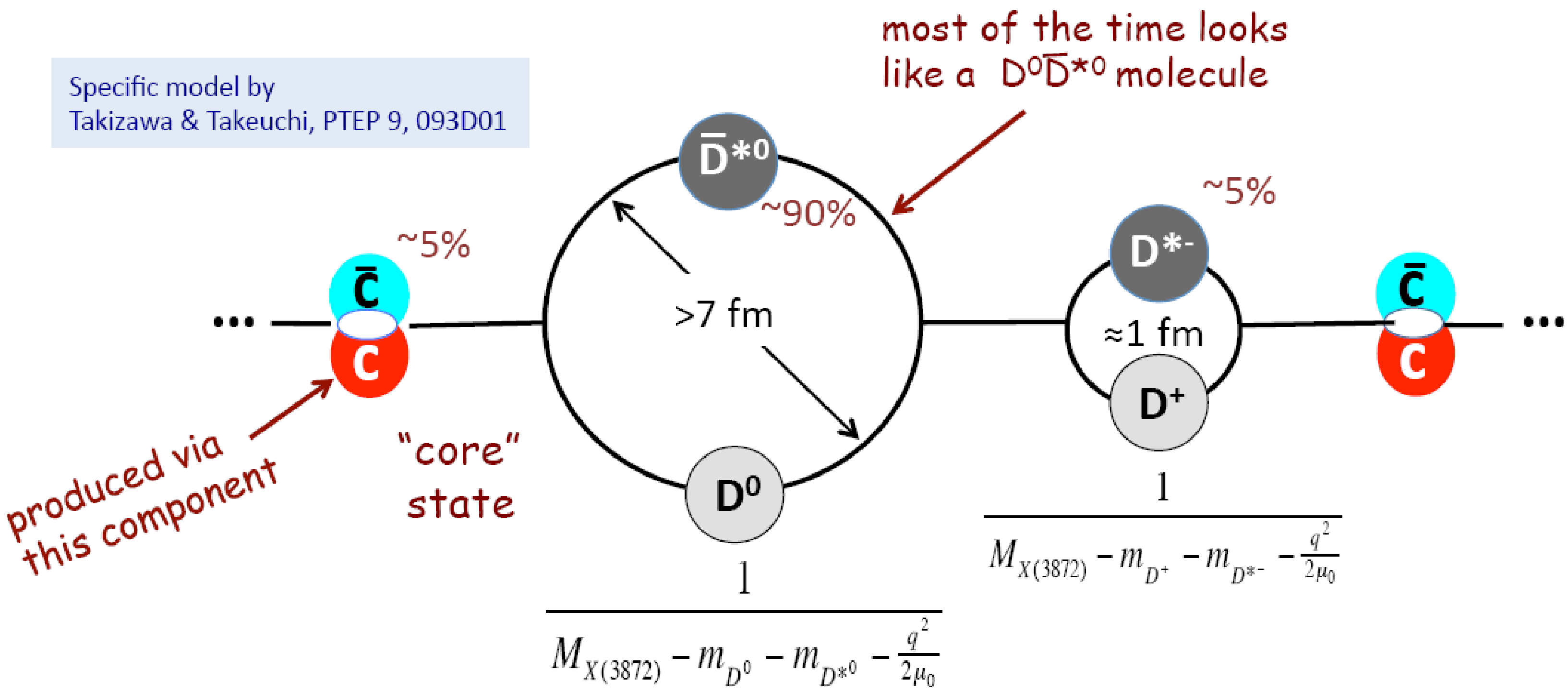
4. Br (D+->K-π+π+) = 9.2%, Br (D0->K-π+) = 3.8%

*5. σ(pCu) * Br(J/ψ π+π–) * Br(e+e-) = 81.9 * 0.05 * 0.06 = 0.246 nb*
*σ(pCu) * Br(D+D-) * Br($K\pi\pi$)^2 = 81.9 * 0.4045 * 0.092 * 0.092 = 0.280 nb*
*σ(pCu) * Br($D^0D^0bar\pi^0$) * Br($K\pi$)^2 = 81.9 * 0.3529 * 0.039 * 0.039 = 0.044 nb*

0.280 nb => L = 5.9 x 10^{29} (1000 events / 10 weeks)

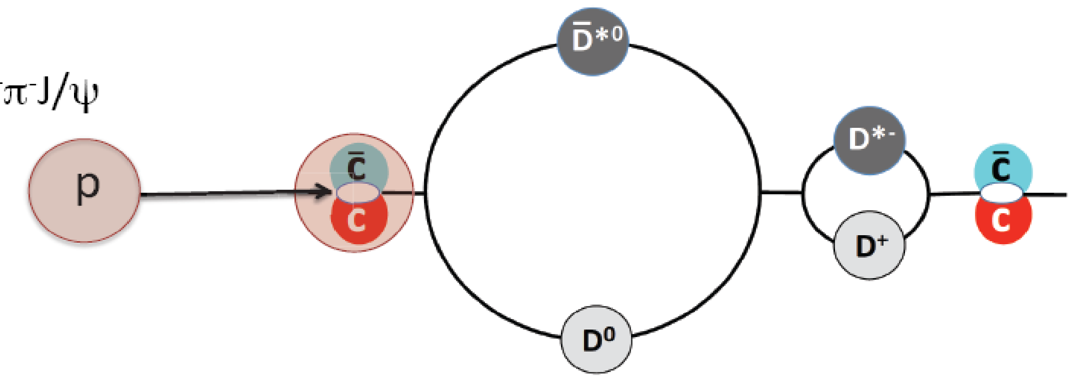
Probably a mixture of $D\bar{D}^*$ & a $c\bar{c}$ "core"

Specific model by
Takizawa & Takeuchi, PTEP 9, 093D01

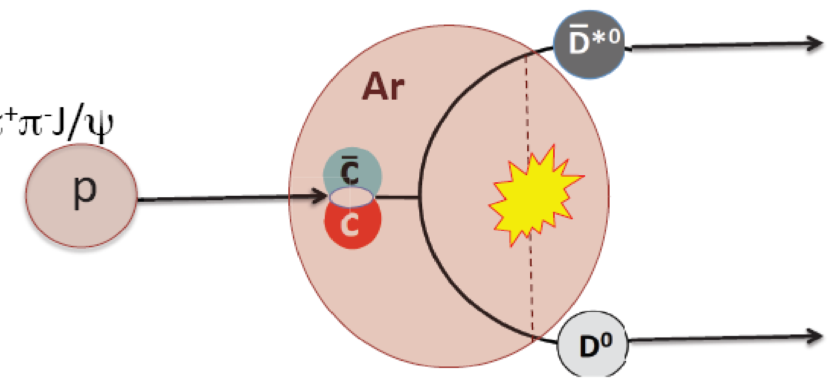


Near-threshold prod. via pp & pA

$pp \rightarrow X(3872) \rightarrow \pi^+\pi^- J/\psi$



$pAr \rightarrow X(3872) \rightarrow \pi^+\pi^- J/\psi$



Strong quenching
for A~40 nuclei??

$$\sqrt{s_{pN}} \simeq 8 \text{ GeV}$$

THANK YOU!