Search for Baryonium

and

J/Ψ decays

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(with J-P.Dedonder, B.Loiseau,Paris)

content

- old estimates
- contemporary signals - BES

$J/\Psi \rightarrow N\ \bar{N}\ ,\ \gamma$ => X(1868)

$J/\Psi \rightarrow 6\ \pi$ => X(1835)

Weak signal antiprotonic atoms

Weak signal radiochemical studies of p-bar cold capture in nuclei

other purpose : PANDA- experiments

- baryonium = $2q + 2\bar{q}$?
- $\bar{N} - N$ quasi-bound states ?

30 years of search

appeared at CERN
disappeared at CERN / LEAR

p-pbar → γ + X

Adiels /LEAR (1990) no baryonium E < 1770 , Γ< 25 MeV

Against heavy background, many partial waves

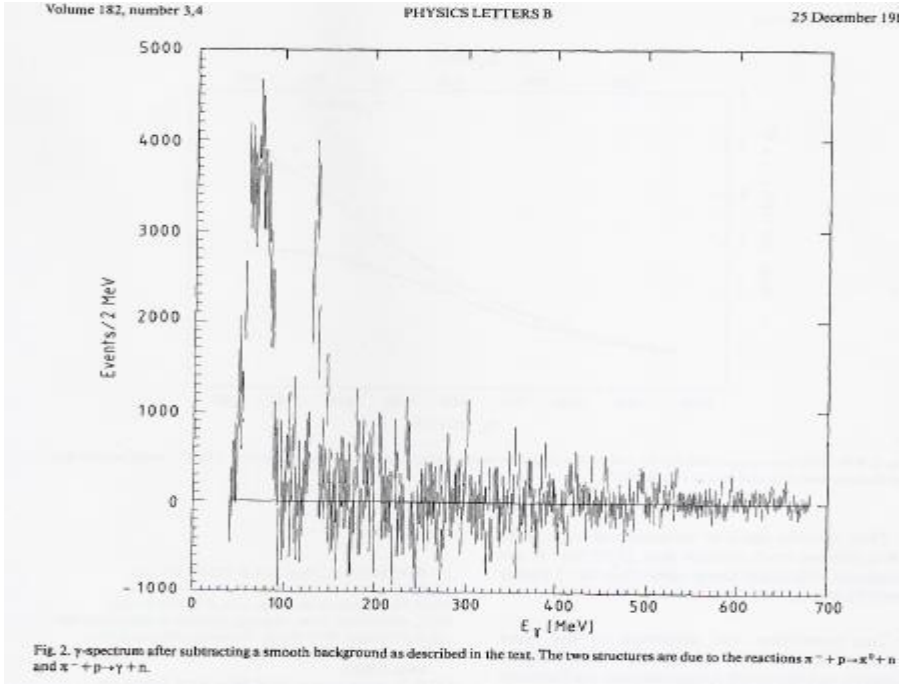


Fig. 2. γ-spectrum after subtracting a smooth background as described in the text. The two structures are due to the reactions $\pi^- + p \to \pi^0 + n$ and $\pi^- + p \to \gamma + n$.

MODERN-selective- SIGNALS

$J/\psi \rightarrow (\bar{p}\,p)\,,\gamma$

BES collaboration,

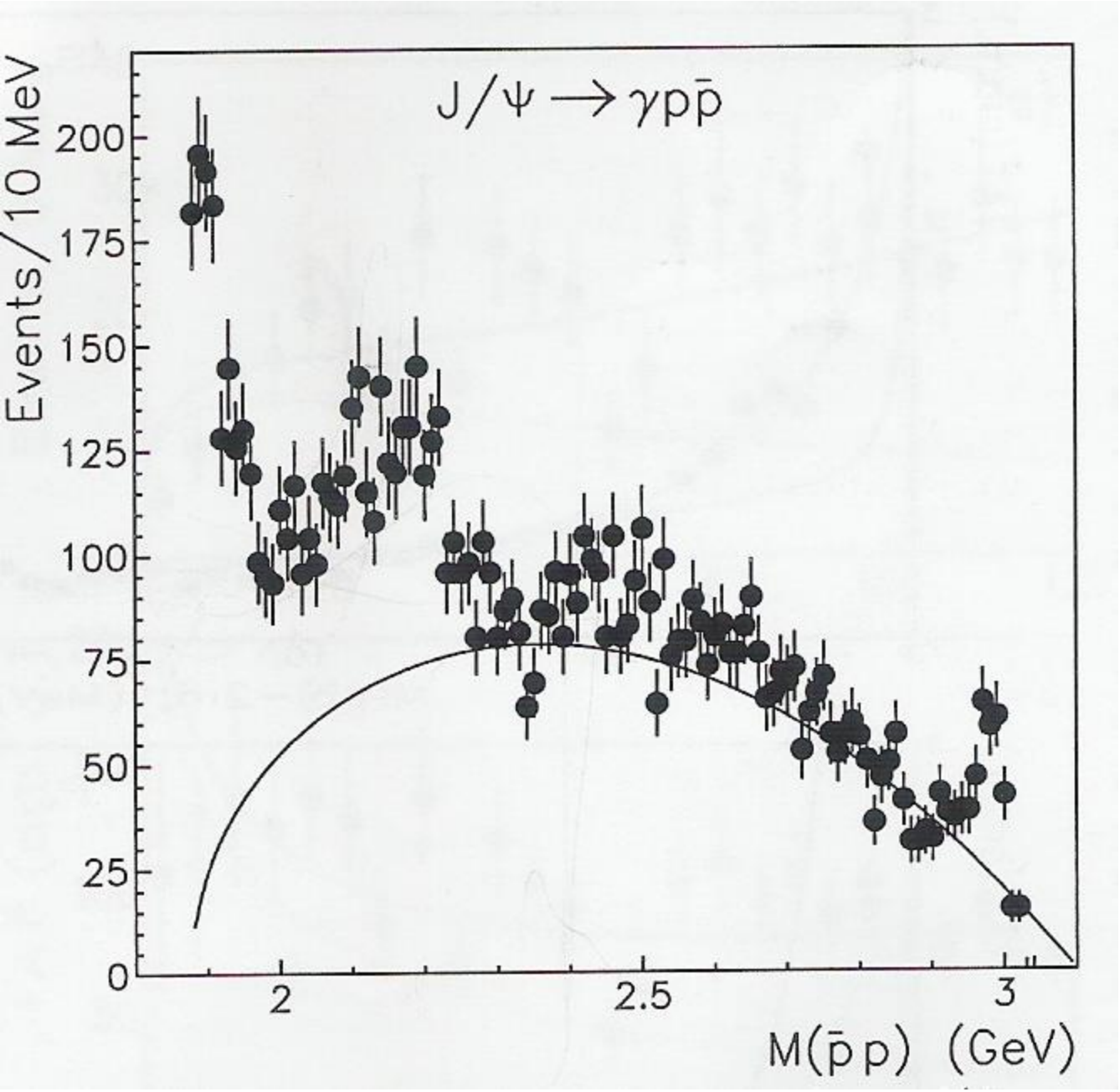
CP : selects 3 possible partial waves

1So (magnetic M1 transition)

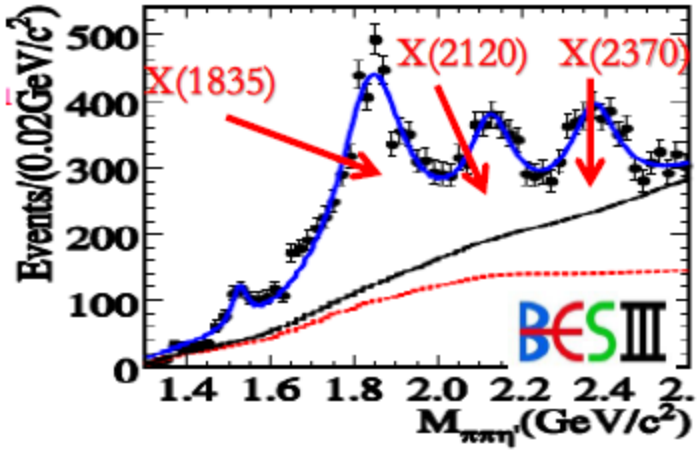
and two P-waves (electric E1)

Nonselective - weak evidence from p-bar atoms

proton-antiproton $^1S_0$

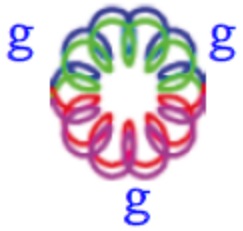


2013: BESIII confirmed X(1835) and observed X(2120) & X(2370)



BESIII:

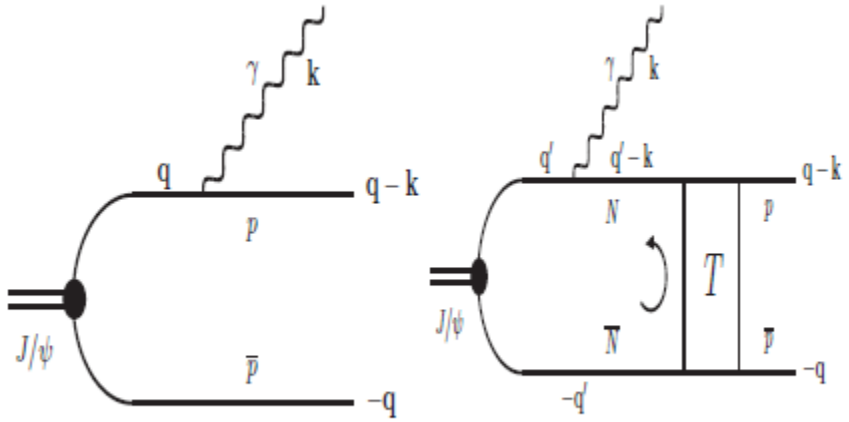
PRL. 108 (2011)112003



- First observation of high mass resonances in J/ψ radiative decays
- LQCD predicts 0^{-+} glueball to be at 2.4 GeV/c^2.
- X(2120)/X(2370) ?
  - ✓ 0^{-+} glueball?

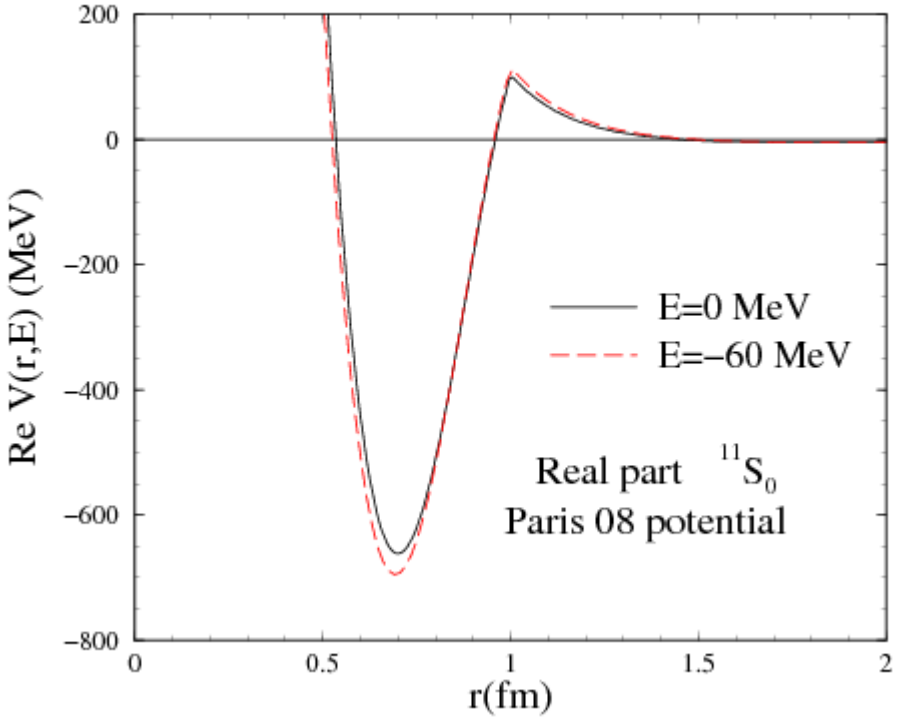
- spin-parity ?
- more decay modes?
  - Nature of X(2120)/X(2370) ? 0^{-+} glueball ?
  - X(1835) ? multi-quark state?

(first) MODEL – Baryonic current FS Interactions



Photon emission from J/ψ : left graph Born term, right graph with final state corrections

Potential in N $\bar{N}$ ^{11}S Bonn , Paris



- G-transformed NN
- Quasi-bound state
- E_B = 5 MeV , Γ ~ 50 Mev

decay modes : success with rates

(one parameter –source radius 0.28 fm)

	rate	CP allowed $p\,p_{BAR}$
$J/\psi \rightarrow p\,p_{BAR}$	$2.17(7)\ 10^{-3}$	^3S
$J/\psi \rightarrow n\,n_{BAR}$	$2.2(4)\ 10^{-3}$	^3S
$J/\psi \rightarrow p\,p_{BAR}\,\gamma$	$3.8(1.0)\ 10^{-4}$	$^1S\ ^3P$
$J/\psi \rightarrow p\,p_{BAR}\,\omega$	$2.2(4)\ 10^{-3}$	$^1S\ ^3P$
$J/\psi \rightarrow p\,p_{BAR}\,\Phi$	$4.5(1.5)\ 10^{-5}$	$^1S\ ^3P$
$J/\psi \rightarrow p\,p_{BAR}\,\pi^0$	$1.19(8)\ 10^{-3}$	$^3S\ ^1P$
$J/\psi S \rightarrow p\,n_{BAR}\,\pi^-$	$2.00(10)\ 10^{-3}$	$^3S\ ^1P$

FAILURE :J/ψ → ($\bar{p}$ p) γ

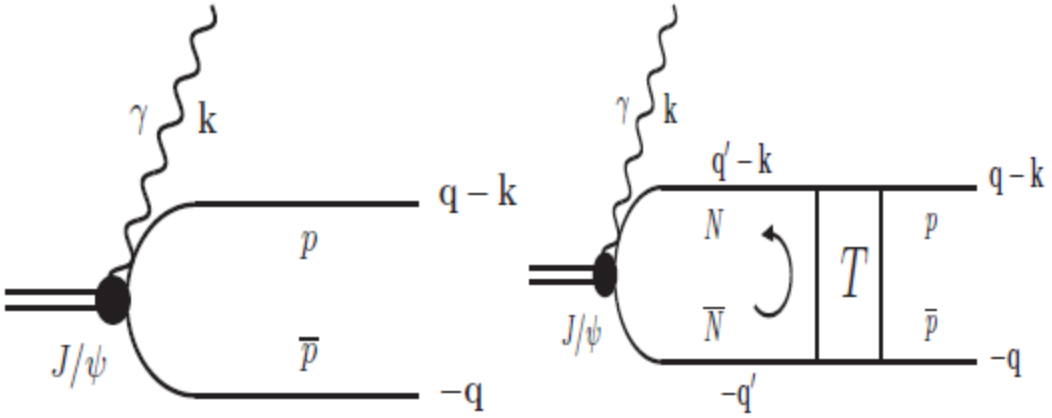
1/3 of rate

J/ψ → ($\bar{n}$ n) γ →($\bar{p}$ p) γ

J/ψ → ($\bar{p}$ p) γ

DESTRUCTIVE INTERFERENCE – IN MAGNETIC PHOTON EMISSION no peaks

(second model) Internal photon emission

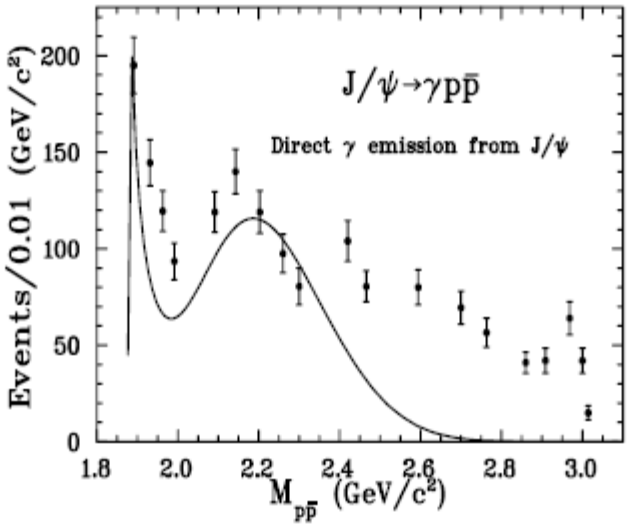


IG. 1: Photon emission from J/ψ : left graph Born term, right graph with final state corrections calculated with Paris otential ^1S half-off-shell scattering T-matrix.

$$V^{dir}_{\lambda,\boldsymbol{\xi}}(\mathbf{k}) = g\ \boldsymbol{\epsilon}^*(\lambda)\cdot(\boldsymbol{\xi}\wedge\mathbf{k})$$

Three peaks explained

with two parameters : initial and final source radii: 0.28, 0.39 fm



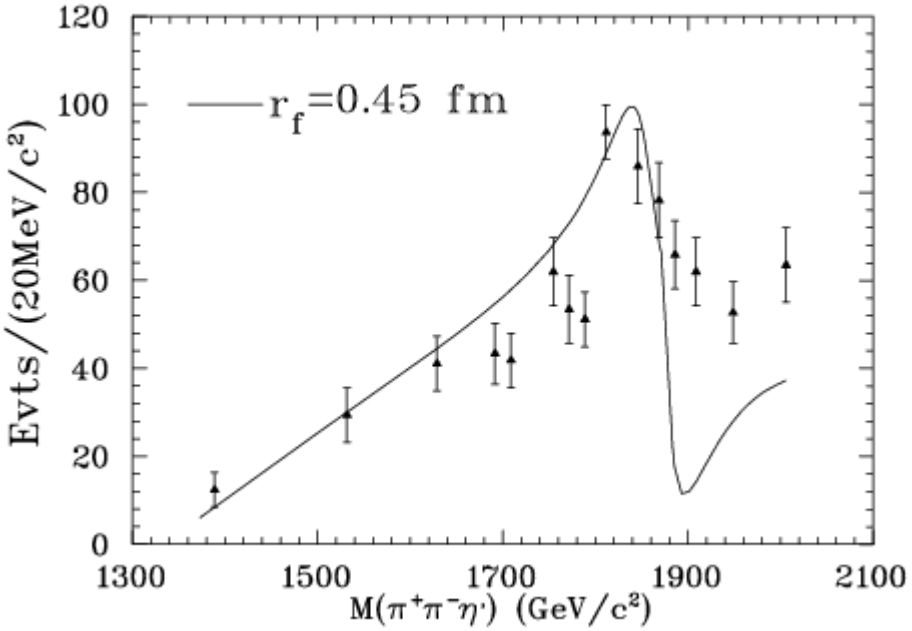
nt $M(p\overline{p})$ mass distribution calculated within the direct radiative decay model.

- Higher M segment explained by FSI model

J/ψ → (ππη') , γ

BES experiment

Paris model understanding



summary

Three baryonia peaks from J/ψ decays

follow from conventional hadronic model as

1) Quasi-bound $N\bar{N}$ ^{11}S (1878)

2) Shape $N\bar{N}$ ^{11}S resonance (2120)

3) Broad shoulder due to

energy dependent width (1835)

Expected extension

1) QCD calculation of internal radiative process

2) Several experiments at PANDA/FLAIR /GSI : Collisional formations , atoms,..

3) Formation of J/ψ inside nuclei

Thanks

Potential model

Brian – Philips, Paris (Vinh Mau)

$N\ N \rightarrow N\ \bar{N}$

G – parity transformation

$V_\pi \rightarrow -V_\pi$

No Pauli exclusion - many allowed states

Strong attraction - in many states

Annihilation at distances $R < 1$ fm

Scattering data

~4000 data + hydrogen p-bar atom

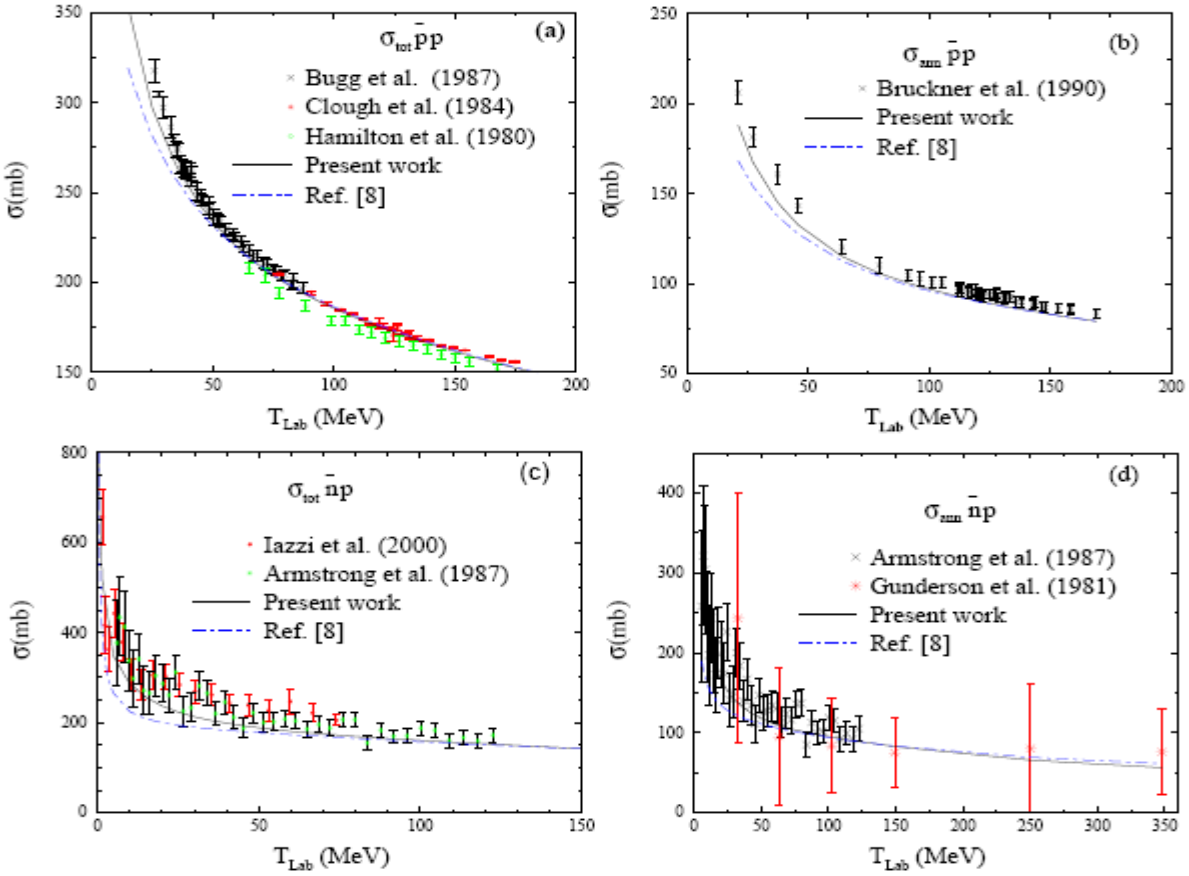
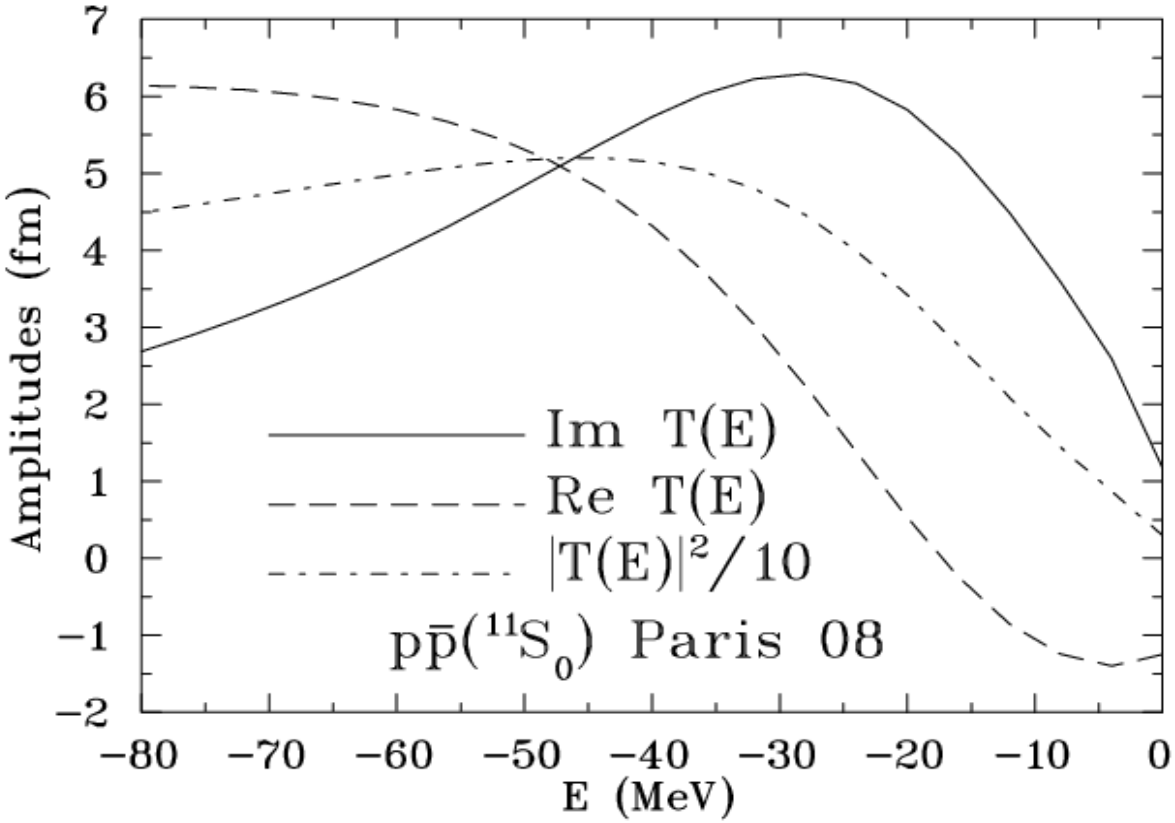


FIG. 1: Total and annihilation cross sections for the $\bar{p}p$ and $\bar{n}p$ systems. The references of the experimental data can be found in Ref. [7]. The data of Iazzi *et al.* in Fig. 1(c) are from Ref. [9].

Nature of X(1835)

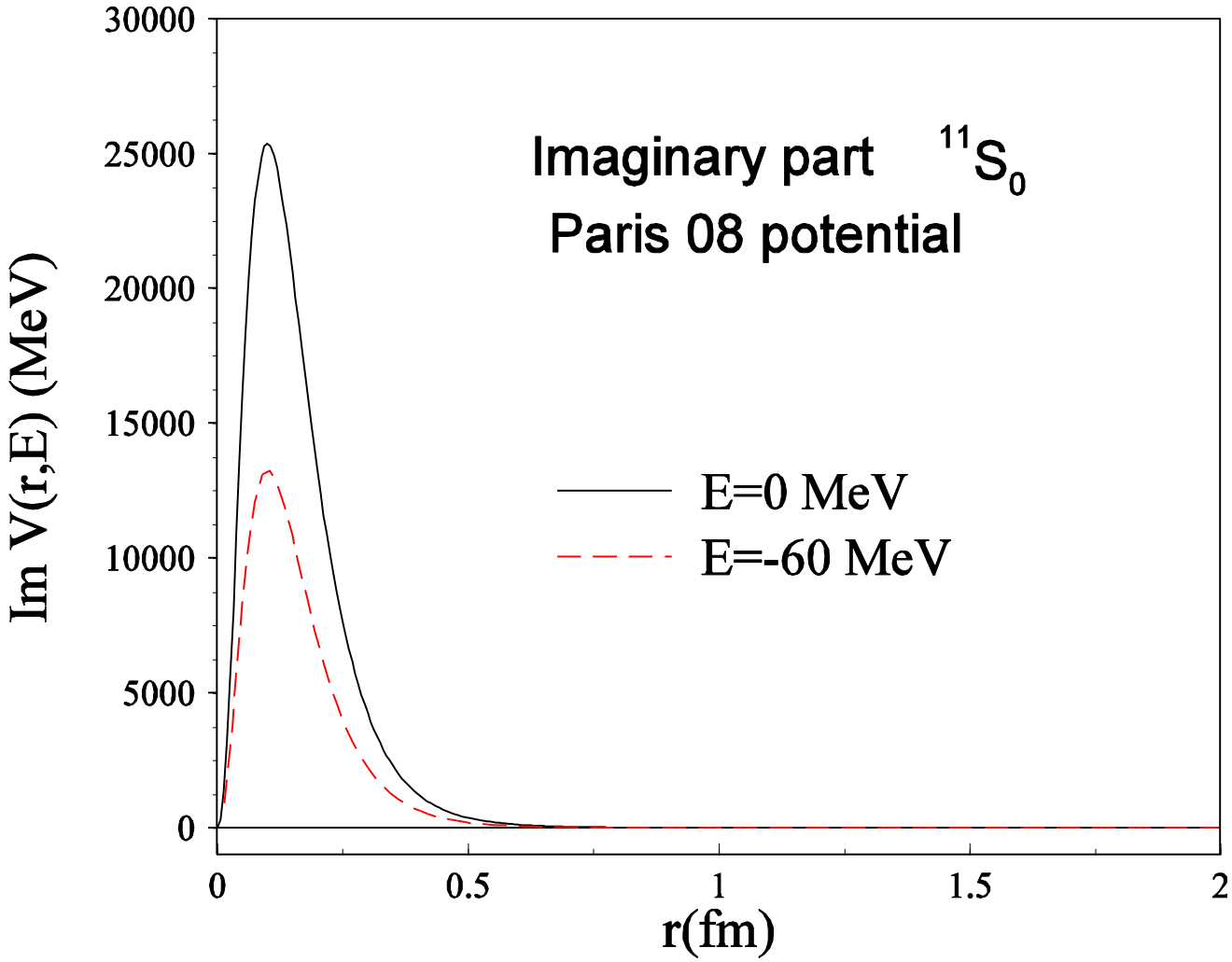
^{11}S amplitude below threshold

Dedonder,Loiseau,S.W.Phys.Rev.C80



Absorbtive potential

model dependent



Guidelines : Paris N-Nbar potential model 2009

TABLE III: Binding energy in MeV of the close to threshold quasi-bound states of the present model and of the Paris 99 potential [8].

$^{2T+1\ 2S+1}L_J$	Present work	Paris 99
$^{11}S_0$	-4.8-i26	
$^{33}P_1$	-4.5-i9.0	-17-i6.5

- But no bound state in ^{11}S Juelich potential

Paris potential : M. Lacombe, B. Loiseau, S.W. **...**C79(09)054001

ATOMIC EVIDENCE of BARYONIUM

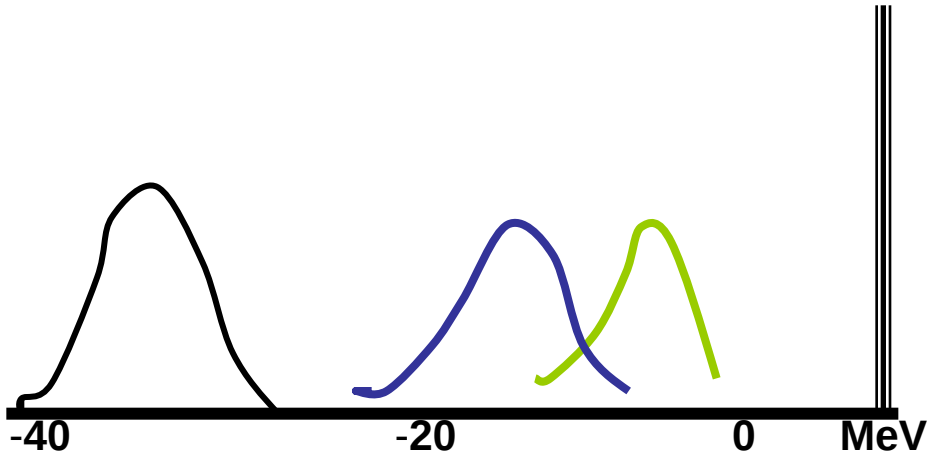
Look below $N\bar{N}$ threshold

Additional evidence needed

Antiprotonic atoms → bound nucleons

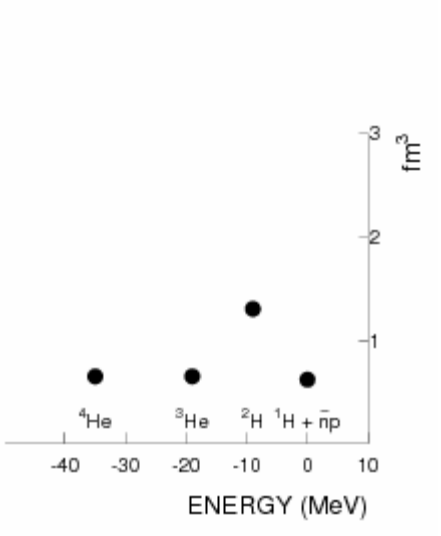
Final state interactions in decay channels

$\bar{p}$ N subthreshold energies antiprotonic atoms

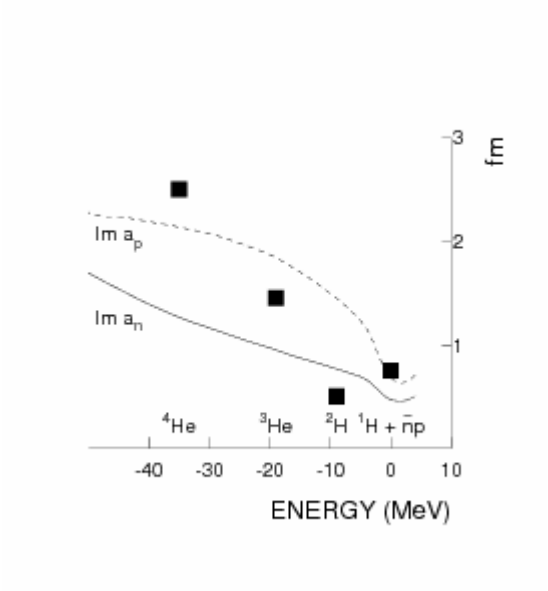


- P
- D
- T
- He 4

Absorptive P-wave $\bar{p}$ N amplitude from light atoms



Absorptive parts of S-wave $\bar{p}$ N ampltiude obtained from light atoms



Radiochemical measurements of residual nuclei after p-bar absorption

Ratio $\sigma(\bar{p}\,n)/\sigma(\bar{p}\,p)$ in nuclei PS203

	↓ Lower level ,	↓ Upper level ,	↓ cold capture	
96 Zr	1.61(6)	1.91(6)	2.6(3)	
116 Cd	2.60(35)	3.33(37)	5.6(5)	neutron
124 Sn	3.09(7)	3.43(25)	5.4(7)	halo

Anomalies (4 cases)

106 Cd	1.65(80)	5.13(80)	0.5(1)	proton halo ???

weakly bound proton , strongly bound neutron

P wave narrow quasi-bound state ?

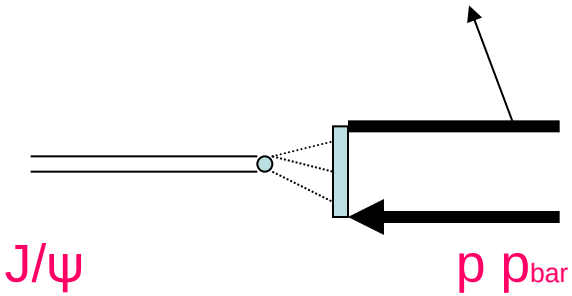
SW,PhysReVC76,034316

Applications

Further studies

Put J/ψ into nucleus- PANDA

$\bar{p}\,p \rightarrow J/\psi + \text{meson}$



Reasonable description :π, γ, ω,Φ

Decays of J/ψ in nucleus

production with fast antiproton

→ fast J/ψ leaves nucleus

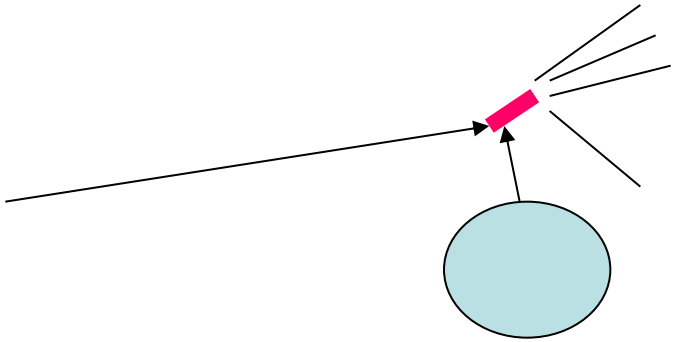
$\bar{p}\,p \rightarrow J/\Psi + \pi \;\; (\text{or } \omega)$

There is a special momentum :

J/Ψ goes backward in CM

Peripheral $\bar{p}$ nucleus collisions

- Invariant mass of pions to measure



Peaks at the end of heavy background

New clarifying experiments

Fine structure resolution in

deuterium, helium atoms

PAX – polarized beam proposal

$\bar{p}\,p \rightarrow (\bar{p}\,p)\,,\gamma$

Peripheral collisions

Could be studied at FAIR

consistent evidence of ^{11}S broad quasi-bound state

(the structure is less certain)

some evidence of ^{33}P quasi bound state

calculated narrow „ nuclear state in ^{3}He

Appendix

More recent attempts

- A. Abele , Crystal Barrel..Eur Phys Journ.C 17(2000) 583

$\bar{p}\,d$ annihilation into mesons

nB(1855) → 3pi0+n

Gamma < 10 MeV could not be seen on 5*10^(-4)

level from n momentum distribution

- *B.Bertini N.Phys B209 (1982) 269*

p $\bar{p}$ -> pi- , X

no signal , X not excluded. ,

- l.Adiels ..Phys. Lett 182

ppbar → gamma +X ,

no X Below 1770 MeV , Gamma < 25 Mev