J/ψ studies at LHC beams in a fixed target mode.

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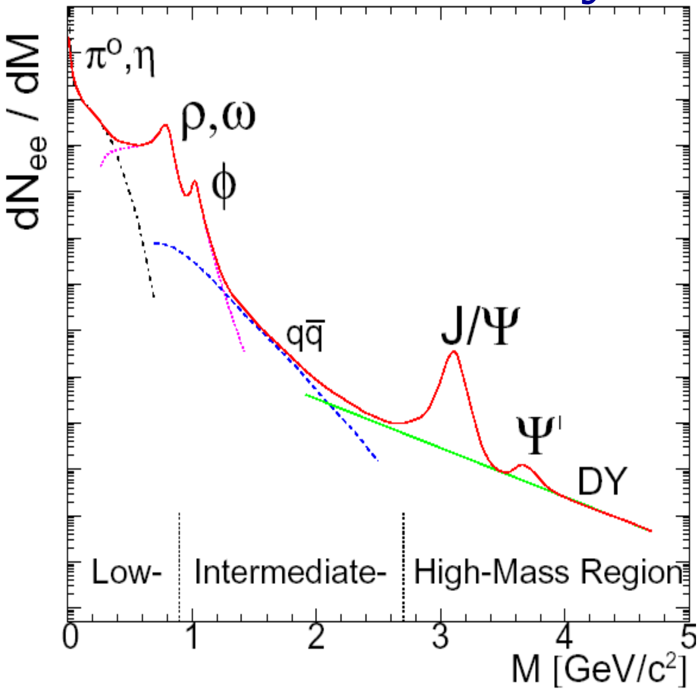
1. Physical motivaion.
2. Experimental situation.
3. Fixed target suggestion.
3. Summary.

Charmonium

- 1974 г.: discovery of J/ψ, 1986 г.: Matsui & Satz:



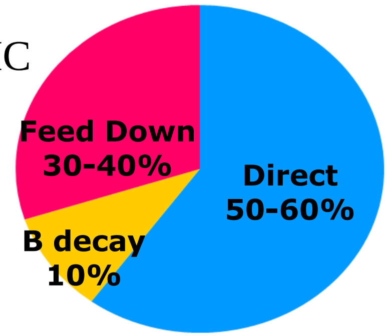
colour screening in deconfined matter
→ J/ψ suppression
→ possible signature of QGP formation
Experimental and theoretical investigations
→ situation is more complicated

cold nuclear matter (CNM)/initil states.

- **"normal" nuclear suppression**
- **(anti)shadowing**
- **saturation, color glass condensate**

suppression via comovers
feed down from χ_c, ψ'
sequential screening (first : χ_c, ψ', J/ψ only well above T_c)
regeneration via statistical hadronization or charm coalescence

CDF-LHC



J/ψ production from *B*-hadron

Important for "large" charm yield, i.e. RHIC and LHC

Charmonium production

Fixed-target data (SPS, FNAL, HERA)

AA collisions

NA38

S-U 200 GeV/nucleon, $0<y_{cm}<1$, $\sqrt{s}=19.4$ GeV

NA50

Pb-Pb 158 GeV/nucleon, $0<y_{cm}<1$, $\sqrt{s}=17.3$ GeV

NA60

In-In 158 GeV/nucleon, $0<y_{cm}<1$, $\sqrt{s}=17.3$ GeV

pA collisions

HERA-B

p-Cu,(Ti),W 920 GeV, $-0.34<x_F<0.14$, $\sqrt{s}=41.6$ GeV

E866

p-Be, Fe, W 800 GeV, $-0.10<x_F<0.93$, $\sqrt{s}=38.8$ GeV

NA50

p-Be,Al,Cu,Ag,W,Pb 400/450 GeV, $-0.1<x_F<0.1$, $\sqrt{s}=27.4/29.1$ GeV

NA51

p-p, d 450 GeV, $-0.1<x_F<0.1$, $\sqrt{s}=29.1$ GeV

NA3, NA38

p-p,Pt, Cu,U 200 GeV, $0<x_F<0.6$, $\sqrt{s}=19.4$ GeV

NA60

p-Be,Al,Cu,In,W,Pb,U 158/400 GeV, $-0.1<x_F<0.35$, $\sqrt{s}=17.3/27.4$ GeV

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Charmonium production

Colliders (RHIC,LHC)

AA collisions

RHIC CuCu, AuAu $\sqrt{s}$ =130 GeV, 200 GeV
LHC PbPb $\sqrt{s}$ = 2.76 TeV (max 5.5 TeV)

pA collisions

RHIC pp, dAu $\sqrt{s}$ =62 GeV, 130 GeV, 200 GeV
LHC pp $\sqrt{s}$ = 2.76, 7, 8 TeV (max 14TeV)
pPb $\sqrt{s}$ = 5.02 TeV

2010 -2011.

At LHC in *p-p* and Pb-Pb collisions:

- **measured suppression of charmonium and bottomonium states production.**
- **the importance of regeneration process for charmonium production was shown, and feed-down contribution from B ~ 10%.**

2012.

Measuring of *p-p* at 2.76, 7 and 8 TeV.

Test measuring *p*-Pb collisions.

2013.

Measuring *p*-Pb collisions at 5.02 TeV (CNM effects).

Our suggestion to measure charmonium production at LHC with fixed target for lower energy with high statistic to clarify the mechanism of production.

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Charmonium production in fixed-target experiments with SPS and LHC beams at CERN.

Phys.Atom.Nucl.74:446-452, 2011,
Yad.Fiz.74:467-473, 2011.

Fixed-target (LHC) – new opportunity – energy between SPS and RHIC

AA collisions

Pb-Pb 2750 GeV/nucleon, $\sqrt{s}$ = 71.8 GeV

pA collisions

p-A 7000 GeV , $\sqrt{s}$ = 114.6 GeV
(5000 GeV, $\sqrt{s}$ = 96.9 GeV)

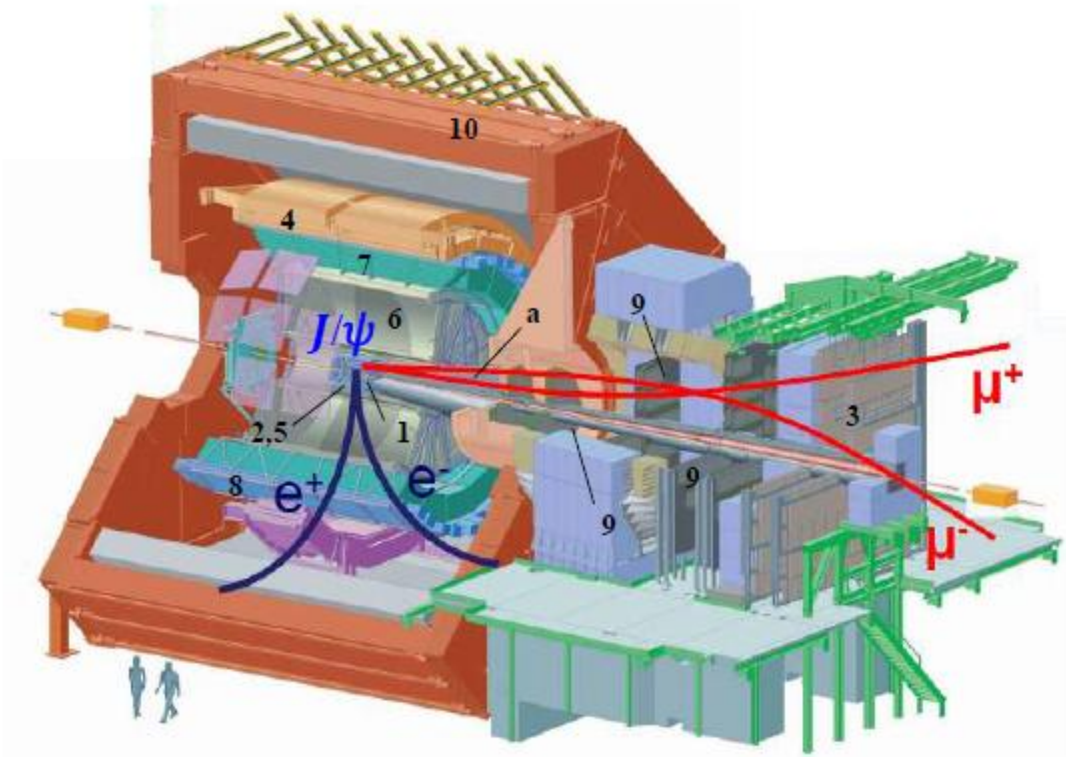
No theoretical model that could reproduce all data.

Fixed target experiment at LHC for charmonium production at the energy range between SPS and RHIC in p-A and A-A collisions with planning proton beam at T=7 TeV ($\sqrt{s}$ = 114.6 GeV) and Pb beam at 2.75 TeV ($\sqrt{s}$ = 71.8 GeV) is possibility to clarify the mechanism of charmonium production, to separate two possibilities:

i): hard production and suppression in QGP and/or hadronic dissociation or

ii): hard production and secondary statistical production with recombination, since the probability of recombination decrease with decreasing energy of collision in thermal model.

J/ψ Measurements in ALICE



DETECTION

$J/\psi \rightarrow e^+ + e^-$

CENTRAL BARREL ($|\eta| < 0.9$)

MAGNTET + ITS + TPC (tracking)

TPC+TRD+TOF (PID)

ITS (secondary Vertex)

DETECTION

$J/\psi \rightarrow \mu^+ + \mu^-$

MUON SPECTROMETER

($-4 < \eta < -2.5$)

MCH (tracking)

ABSORBERS[a] (hadron rejection)

TRIGGER

V0 ($2.8 < \eta < 5.1, -3.7 < \eta < -1.7$)

SPD ($|\eta| < 1.4$)

MTR (muon pairs) ($-4 < \eta < -2.5$)

EMCal ($|\eta| < 0.7$)

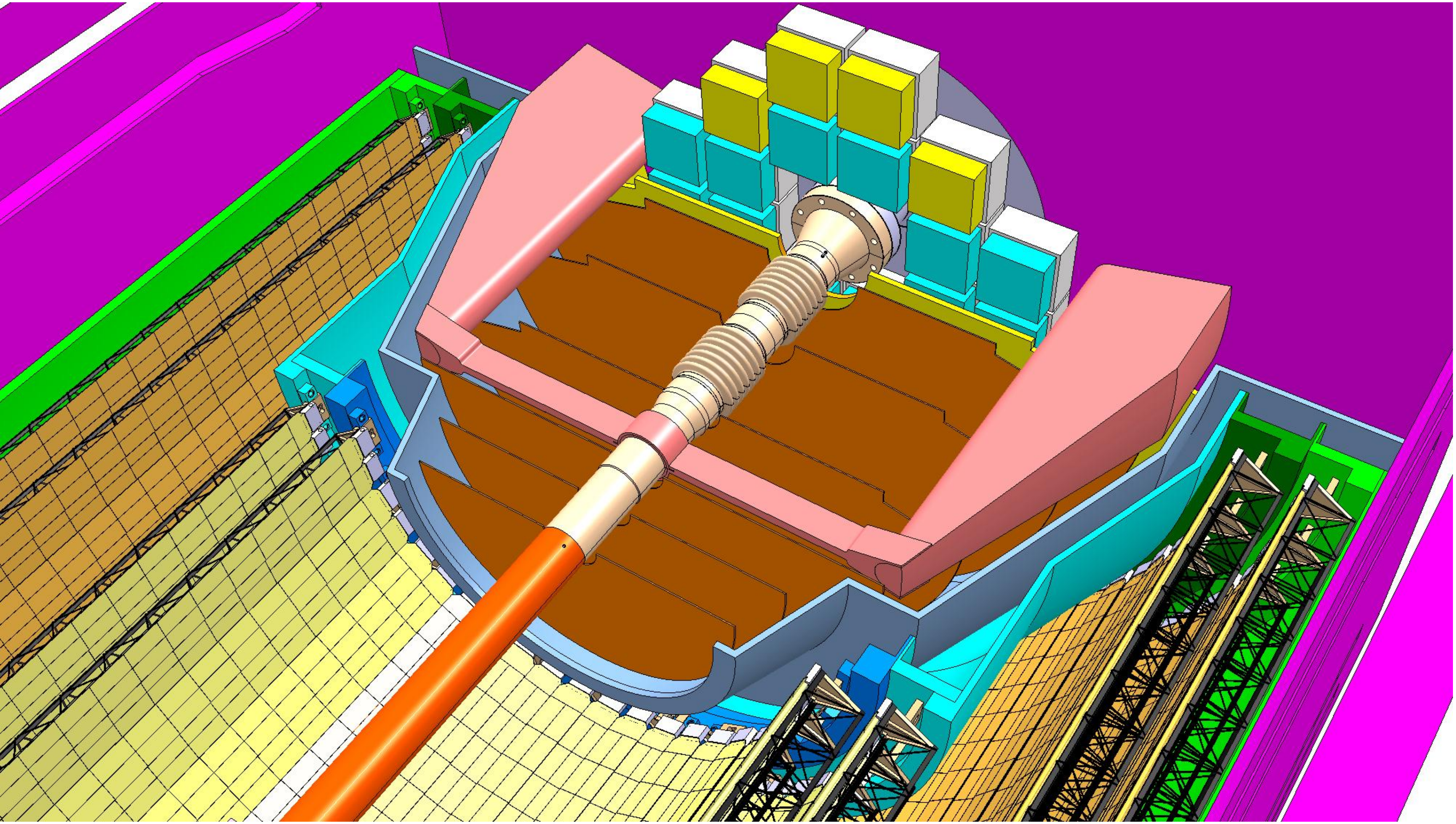
LUMINOSITY

$L_{PbPb} = 70\ \mu b^{-1}, L_{pp} \leq 100\ nb^{-1}, L_{Pbp} = 52\ \mu b^{-1}$

V0[1] scintillator horoscopes, **SPD**[2] silicon pixel detector, **MTR**[3] muon trigger, **EMCal**[4] electromagnetic calorimeter, **ITS**[5] inner tracking system, **TPC**[6] time projection chamber, **TRD**[7] transition radiator detector, **TOF**[8] time of flight, **MCH**[9] muon chambers, **MAGNET**[10]

E.Garsia

Integration on the C-side (ITS, MFT, FIT)



Corrado Gargiulo

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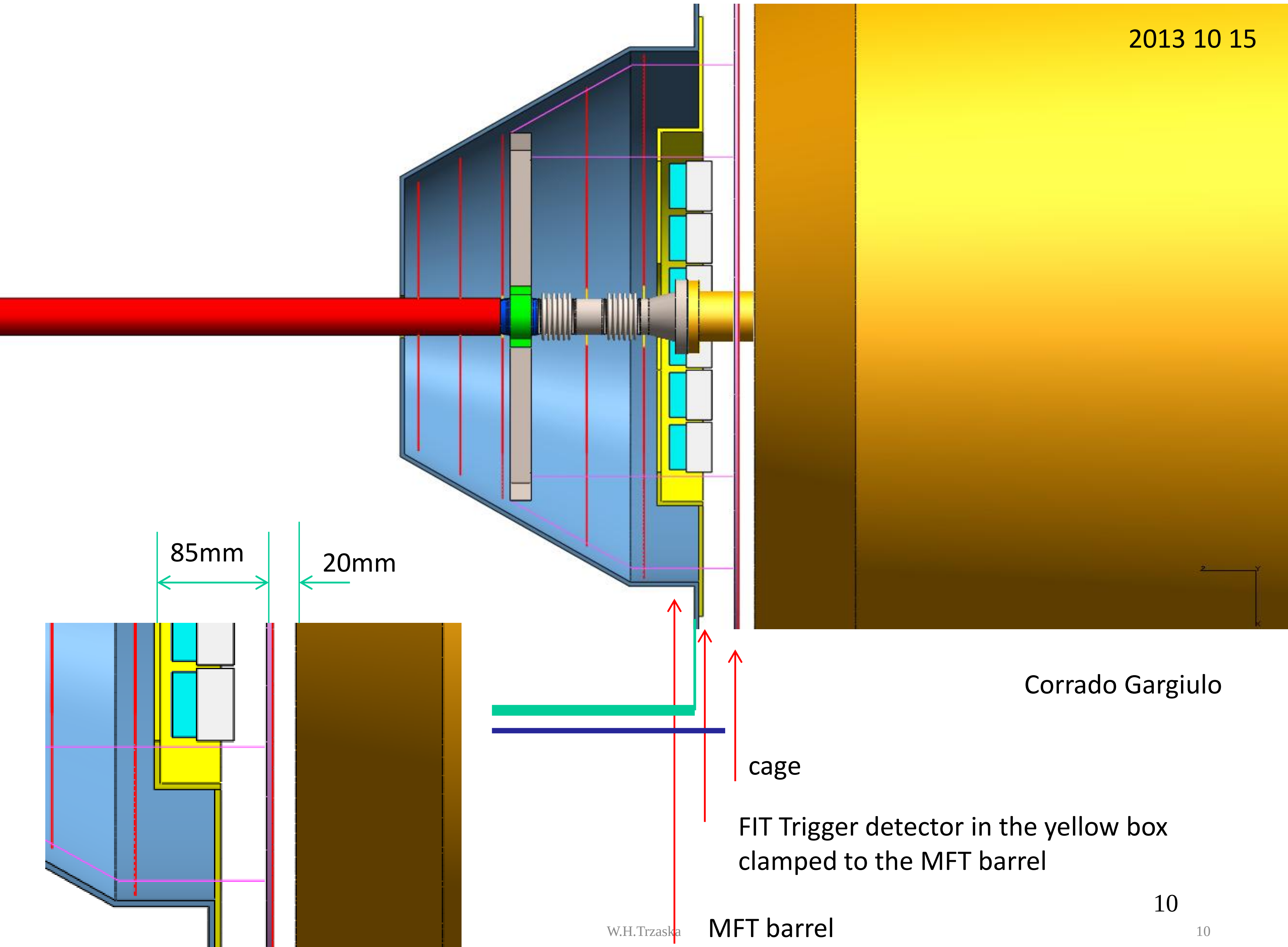

2013 10 15
85mm
20mm
cage
FIT Trigger detector in the yellow box
clamped to the MFT barrel
MFT barrel
Corrado Gargiulo

In the frame of AliRoot fast simulation we calculated the geometrical acceptances for the J/ψ production at LHC (ALICE for testing) and RHIC and at known fixed target experiments (NA50, HERA-B) .
In the same framework we calculated geometrical acceptances for fixed target experiment at LHC for charmonium production at the energy range between SPS and RHIC in p-A and A-A collisions with planning proton beam at T=7 TeV ($\sqrt{s}$ = 114.6 GeV) and
Pb beam at 2.75 TeV ($\sqrt{s}$ = 71.8 GeV).

Then - luminosity and counting rate estimation for comparison.

Geometrical acceptances for J/ψ at ALICE

Pb-Pb, √s=5.5 TeV

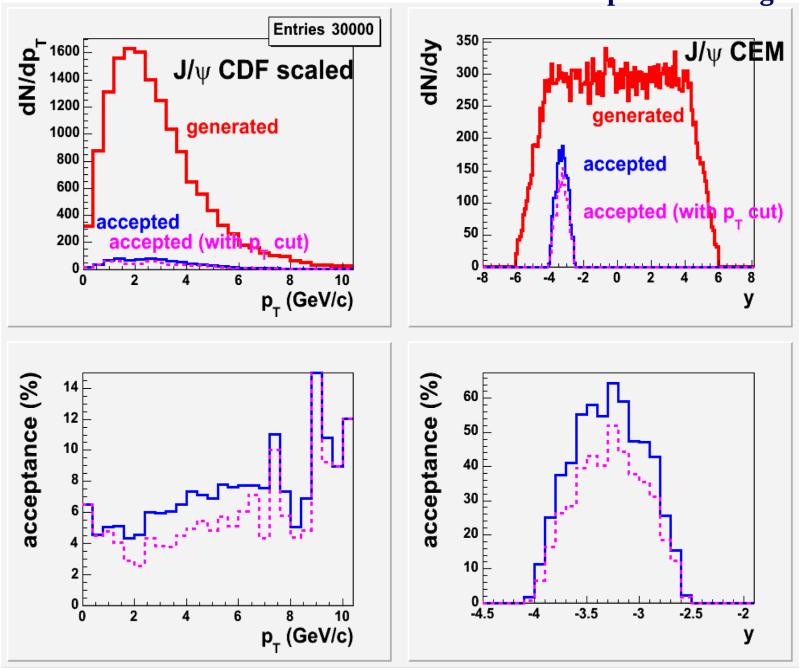
J/ψ are generated using CEM y-spectra and CDF scaled p_T-spectra and including shadowing for Pb-Pb.

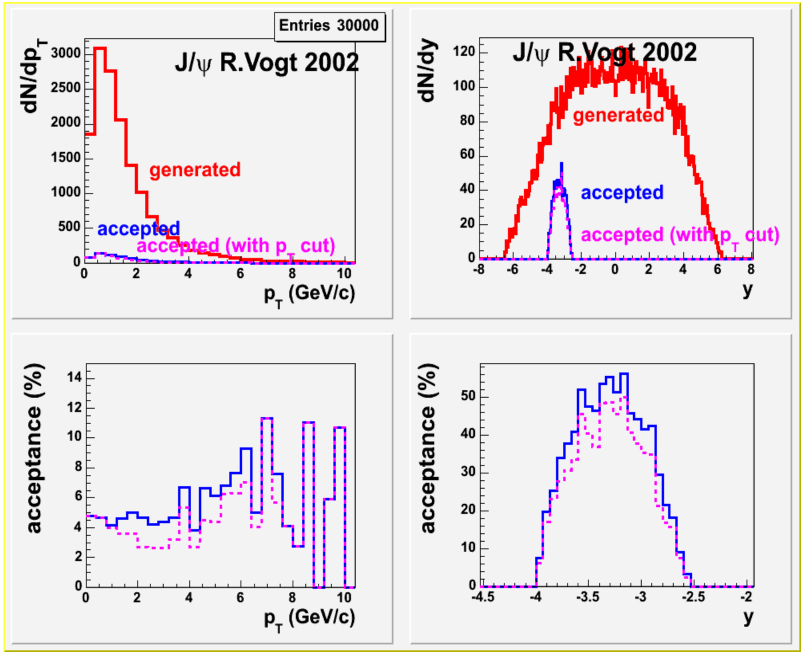
pp, √s=14 TeV

J/ψ are generated according R.Vogt 2002 approximation for p_T -spectra and y - distribution.

I_{acc} = Integrated acceptance = $N_{accepted}/N^{total}_{generated}$

$N_{gen}(J/\psi)=30000$





I_{acc}= 5.76%-w/o p_T cut
4.26%- with cut p_T >1 GeV/c

I_{acc}= 4.71%-w/o p_T cut
4.01%- with cut p_T >1 GeV/c

Fixed target experiment

Pb-Pb, T=2750 GeV, $\sqrt{s}$=71.8 GeV.

J/ψ are generated at z=0 and outside of ITS at z=+50 cm.

J/ψ are generated using p_T-spectra with HERA and PHENIX form, consistent with COM model, but parameters are energy scaled: $dN/dp_T \sim p_T[1+(35\pi \cdot p_T/256 \cdot \langle p_T \rangle)^2]^{-6}$ with $\langle p_T \rangle$= 1.4, and using y-spectra as Gaussian with mean value y_{cm}=0 and σ=1.1

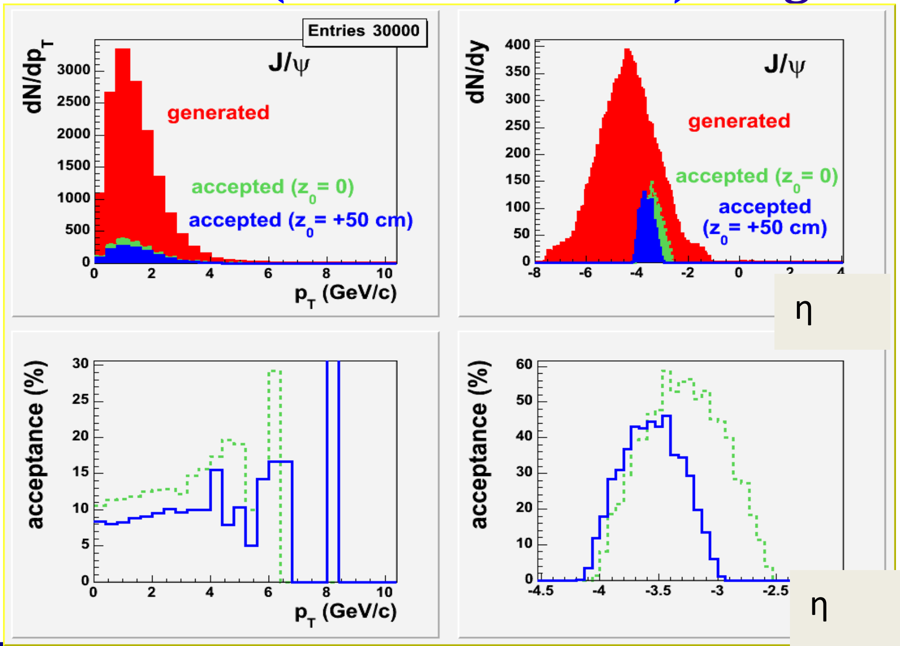
J/ψ are accepted in the rapidity range -4.0<η<-2.5 (-4.09<η<-2.97), and each of 2 muons in the degree range $171^0 < \theta < 178^0$ ($174.2^0 < \theta < 178.2^0$) for generation J/ψ at z=0 (z=+50 cm).

z=0

I_{acc} = 12.0%

z=+50 cm

I_{acc} = 7.97%

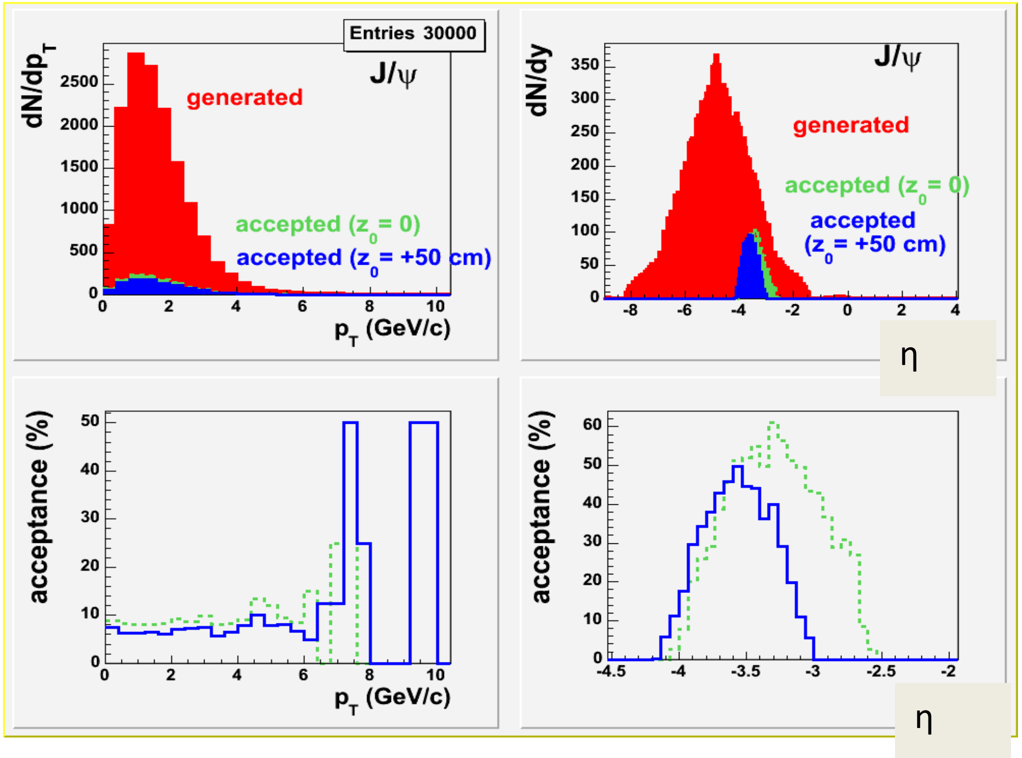


Fixed target experiment

pA, T=7000 GeV, √s=114.6 GeV.

J/ψ are generated at z=0 and outside ITS at z=+50 cm.

J/ψ are generated using p_T-spectra with the same parametrization with energy scaled parameter: $dN/dp_T \sim p_T[1+(35\pi \cdot p_T/256 \cdot \langle p_T \rangle)^2]^{-6}$ where $\langle p_T \rangle = 1.6$, and using y-spectra as Gaussian with mean value $y_{cm}=0$ and $\sigma=1.25$.



z=0

$I_{acc} = 8.54\%$

z=+50 cm

$I_{acc} = 5.98\%$

Geometrical acceptances

System pPb_{fixed}

pt cut	√s (TeV)	z = 0	z = +50 cm	z = -50 cm
no cut	0.1146	8.54	5.98	5.07
pt > 1 GeV/c	0.1146	6.77	4.89	4.11
no cut	0.0718	12.0	7.97	7.44
pt > 1 GeV/c	0.0718	9.79	6.62	6.20
η range		-2.5 ↔ -4.0	-2.97↔ -4.09	-2.5 ↔ -3.76

As it was already used for the experiment on collider with a fixed target at HERA-B K.Ehret, Nucl. Instr. Meth. A 446 (2000) 190, the target in the form of thin ribbon could be placed around the main orbit of LHC. The life time of the beam is determined by the beam-beam and beam-gas interactions. Therefore after some time the particles will leave the main orbit and interact with the target ribbon. So for fixed target measurements only loss of the beam will be used. Therefore no deterioration of the main beam will be introduced. The experiments at different interaction points will not feel any presence of the fixed target.

Luminocity, cross sections(x_F>0) , counting rates

System	$\sqrt{s}$ (TeV)	σ_{nn} (μb)	$\sigma_{pA}=\sigma_{nn}\cdot A^{0.92}$ (μb)	I (%)	$I\cdot B\cdot\sigma_{pA}$ (μb)	L ($cm^{-2}s^{-1}$)	Rate ($hour^{-1}$)
pp	14	54.1	54.1	4.71	0.150	$3\cdot10^{30}$	1620
pp_{RHIC}	0.200	2.7	2.7	3.59	0.0057	$1\cdot10^{31}$	205
pPb_{fixed}	0.1146	0.65	88.2	5.98	0.310	$3\cdot10^{30}$(*)	3360
pPb_{fixed}	0.0718	0.55	74.6	7.97	0.349	$1\cdot10^{29}$	126
pPb_{NA50}	0.0274	0.19	25.8	14.0	0.212	$7\cdot10^{29}$	535
$PbPb_{fixed}$	0.0718	0.55	11970	7.97	47.9	$1.7\cdot10^{27}$(**)	292

(*) pPb_{fixed}, 500 μ wire, $3.1\cdot10^9$ protons/s

(**) $PbPb_{fixed}$, 500 μ wire, $1.4\cdot10^6$ ions/s

Now (*) from experimental ALICE 2011 year pp data we got $1.2\cdot 10^{11}$ protons per bunch, 1380 bunches and life time 14.5 hours. We get particle loss of $1.1\cdot 10^{13}$ p/hour ($3.1\cdot 10^{9}$ p/s) and luminosity about $5\cdot 10^{30}$ $cm^{-2}\, s^{-1}$ for 500 micron lead ribbon

Mean luminosity ~ $3\cdot 10^{30}$ $cm^{-2}\, s^{-1}$ (3 $\mu b^{-1}\, s^{-1}$).

$\int Ldt$ = 30 $pb^{-1}\, yr^{-1}$). Yr (p)= 10^{7} s.

For PbPb (**) we got $1\cdot 10^{8}$ protons per bunch, 358 bunches and life time 6.5 hours. We get particle loss of $5.1\cdot 10^{9}$ Pb/hour ($1.4\cdot 10^{6}$ Pb/s) and luminosity about $2.4\cdot 10^{27}$ $cm^{-2}\, s^{-1}$ for 500 micron lead ribbon. Mean L ~$1.7\cdot 10^{27}$ $cm^{-2}\, s^{-1}$ (1.7 $mb^{-1}\, s^{-1}$).

$\int Ldt$ = 1.7 $nb^{-1}\, yr^{-1}$. Yr (Pb) = 10^{6} s.

Conclusions

1. The integrated geometrical acceptances for charmonium measurement by dimuon spectrometer of ALICE are 5.76% for $\sqrt{s}$=5.5 TeV Pb-Pb and 4.71% for $\sqrt{s}$=14 TeV pp collisions.
2. For fixed target charmonium measurement in $2.5<y<4$ range the geometrical acceptances are of the same order and even larger: 7.97% for $\sqrt{s}$=71.8 GeV Pb-Pb and 5.98% for $\sqrt{s}$=114.6 GeV pA at z=+50 cm. The acceptances are compartible with the acceptances from other experiments.
3. The energy range for fixed target experiment with high statistic between SPS and RHIC gives important additional information.

Comparison with AFTER

AFTER has advantages:

- Offers a wide physical program.
- Possibility to use different targets with high thickness – higher luminosity (20 times more for 1 cm target vs 500 μm)
- Possibility to use 1 meter-long liquid H_2 and D_2 targets: extremely high luminosity . But – high cost.

Fixed target experiment with the target in the form of thin ribbon:

- Only after beam tuning with the aid of rotation system-put in the working position
- Used only loss of the beam (and may be used as extra collimator)
- May be placed at existing experimental installation (for example, ALICE, LHCb?)
- Possibility to measure charmonium production with rather high statistics on different targets in pA and PbA.

  First step to AFTER?

Backup

In the ALICE reference frame the muon spectrometer covers a negative η range. And we presented our results in a negative η range.

But often in presentation and publication ALICE data are presented with a positive η notation.

The luminosity that was shown in the publication was obtained from the LHC proton parameters for the Commissioning Version 3

http://bruening.home.cern.ch/bruening/lcc/WWW-pages/commissioning_parameter.htm

It gives $1.15 \cdot 10^{11}$ protons per bunch, 44 bunches and life time 15.4 hours. From these parameters we get particle loss of $3.2 \cdot 10^{11}$ during one hour and luminosity about $1.5 \cdot 10^{29}$ cm^{-2} s^{-1} for 500 micron lead ribbon.

Mean luminosity ~ $1 \cdot 10^{29}$ cm^{-2} s^{-1} ($0.1 \mu b^{-1}$ s^{-1}). Integrated $\int L dt$ = 1 pb^{-1} yr^{-1}.