How well do we understand the Drell-Yan cross sections?

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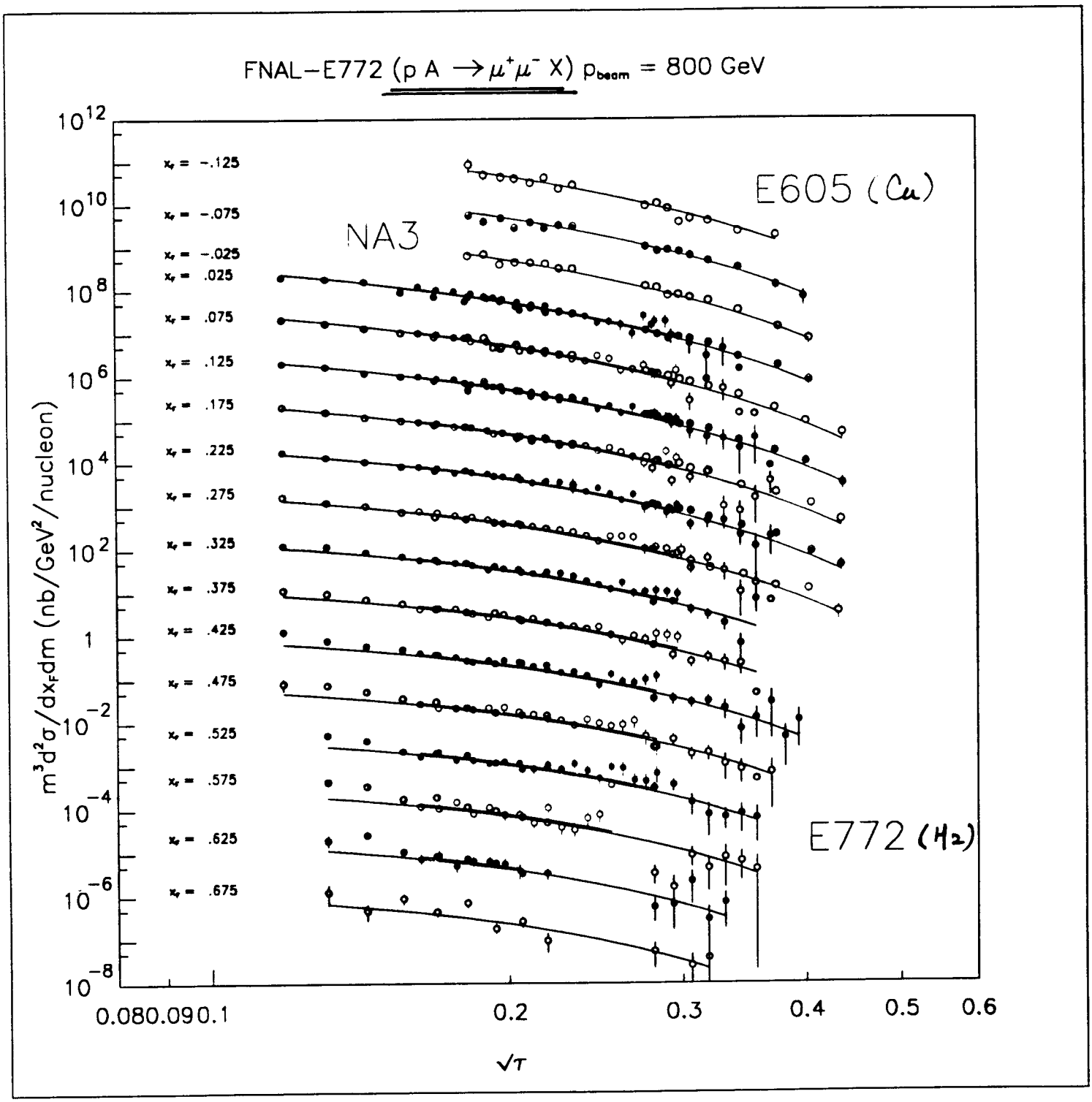
Outline:

1. Introduction
2. Proton-induced fixed target Drell-Yan (E605/E772/E789)
3. E866: sea quark distribution + ...
4. Conclusion

Journal of Phys. G 19 Data Review (1993) D1 – D102

"A compilation of Drell-Yan cross sections" W.J. Stirling & M.R. Whalley

Experiment	p_{beam} (GeV)	$\sqrt{s}$ (GeV)	Target	Reference	Measurement	Page	NLO QCD K-factor
p Nucleus → μ^+ μ^- X							
	200	19.4					
FNAL-288	300	23.7	Pt	Ito *et al*	$sd^2\sigma/d\sqrt{\tau}\,dy$	9–11	1.049
	400	27.4			$Ed^3\sigma/dp^3$ v $p_\perp$	70–77	
	200	19.4					
FNAL-325	300	23.7	Cu	Antreaysan *et al*	$d^2\sigma/dm\,dy\|_{y=0.0}$	12	1.112
	400	27.4					
			C				
FNAL-444	225	20.5	Cu	Anderson *et al*	$d\sigma/dm$	13	1.099
			W				
FNAL-439	400	27.4	W	Smith *et al*	$d^2\sigma/dm\,dx'$	14–15	1.108
					$d^2\sigma/dm\,dx'\|_{x'=0.1}$	16–19	
CERN-NA3	400	27.4	Pt	Badier *et al*	$d^2\sigma/dm\,dx$	20–25	1.105
					$sd^2\sigma/d\sqrt{\tau}\,dy$	26–28	1.071
FNAL-605	800	38.7	Cu	Moreno *et al*	$m^3d^2\sigma/dm\,dx$	28–30	
					$Ed^3\sigma/dp^3$ v $p_\perp$	78–79	
FNAL-772	800	38.7	H_2	Alde *et al*	$d\sigma/dm$	32–33	

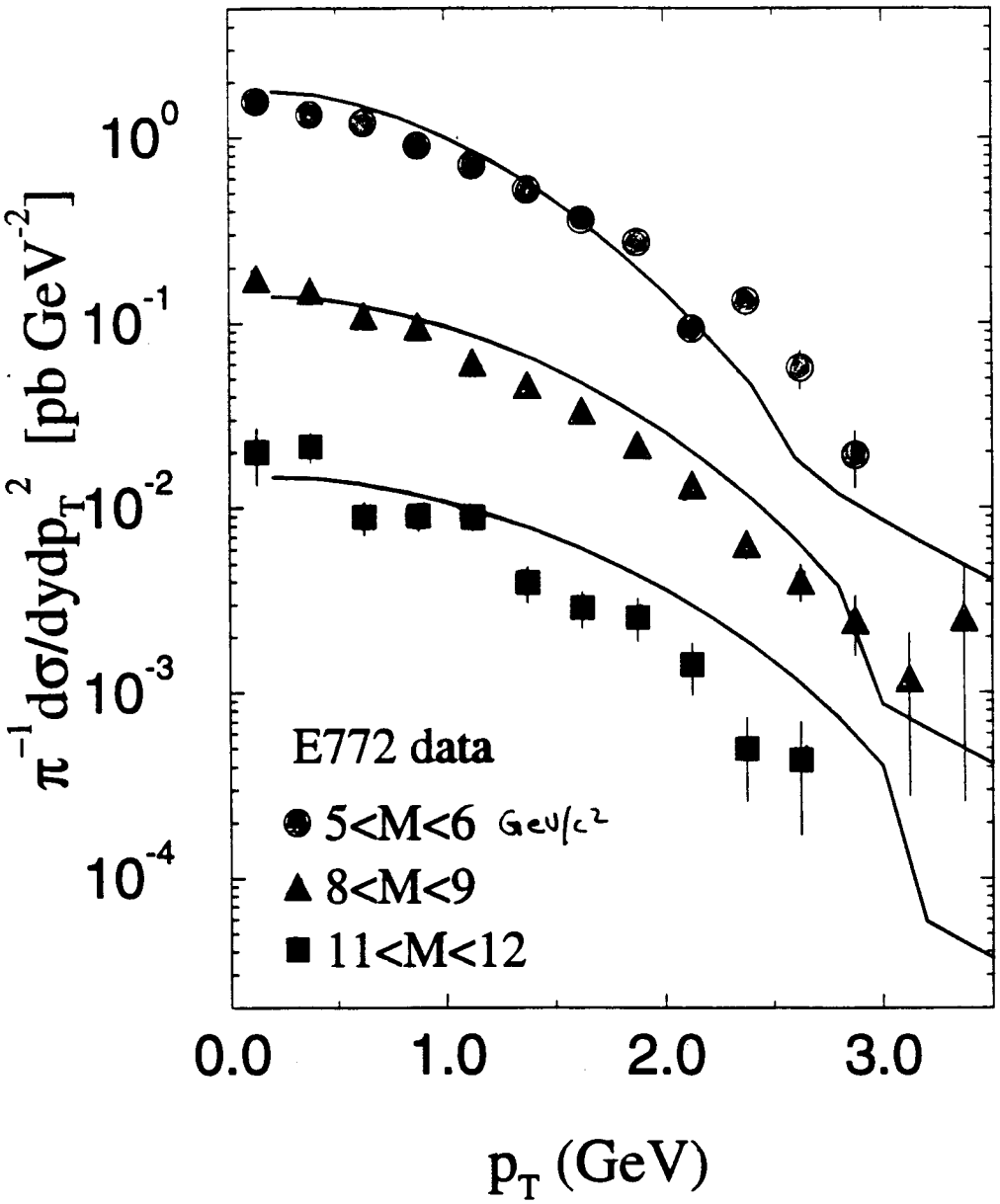


(CTEQ 2M
LO DY calculation

x_F bins have σ scaled by factor 10

800 GeV $p + A \rightarrow D\text{-}Y$

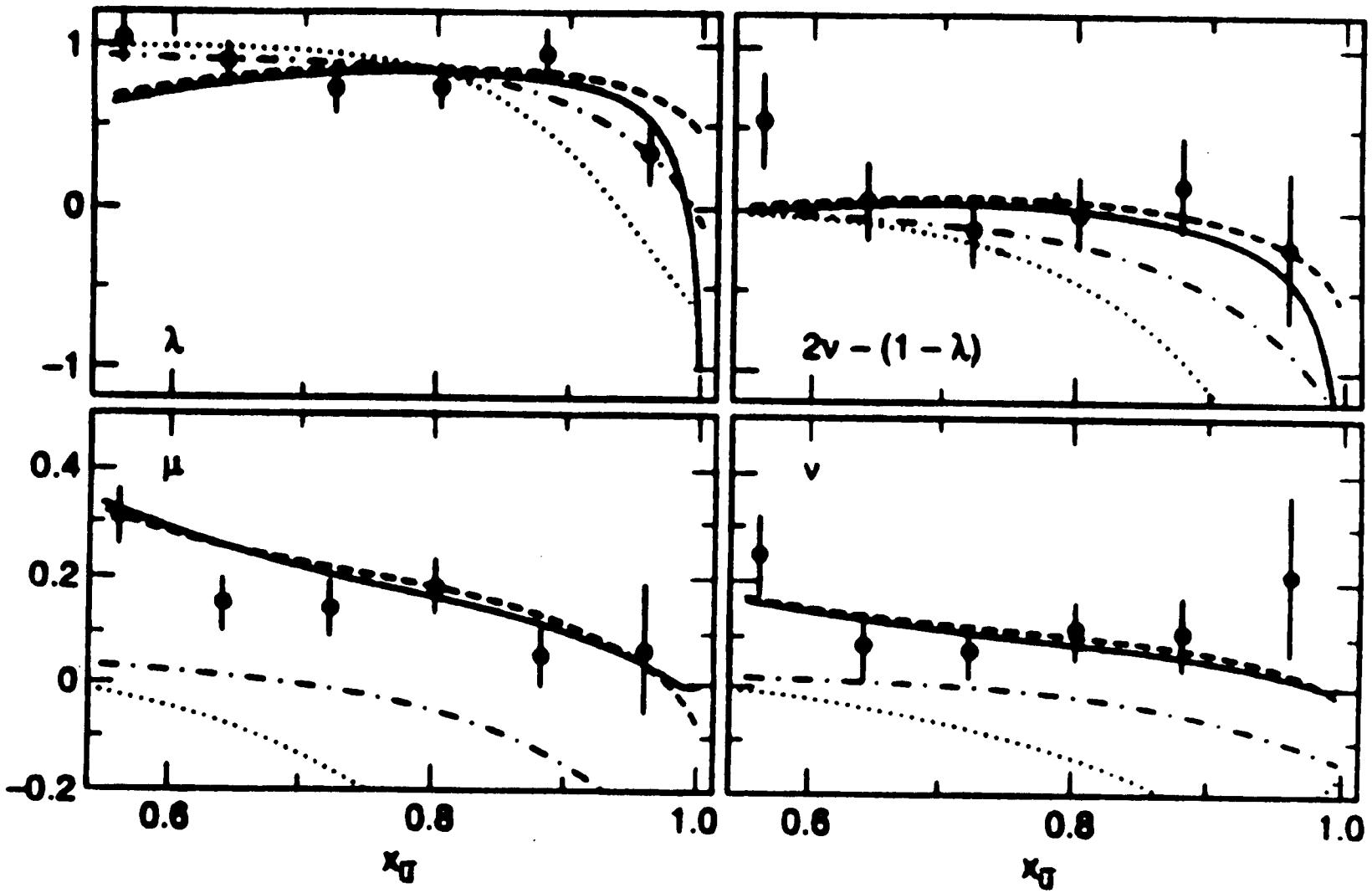
p_T dependence of cross section



Curves are NLO D-Y calculation from

S. Gavin, et.al., Int. J. Mod. Phys. A10, 2961 (95)

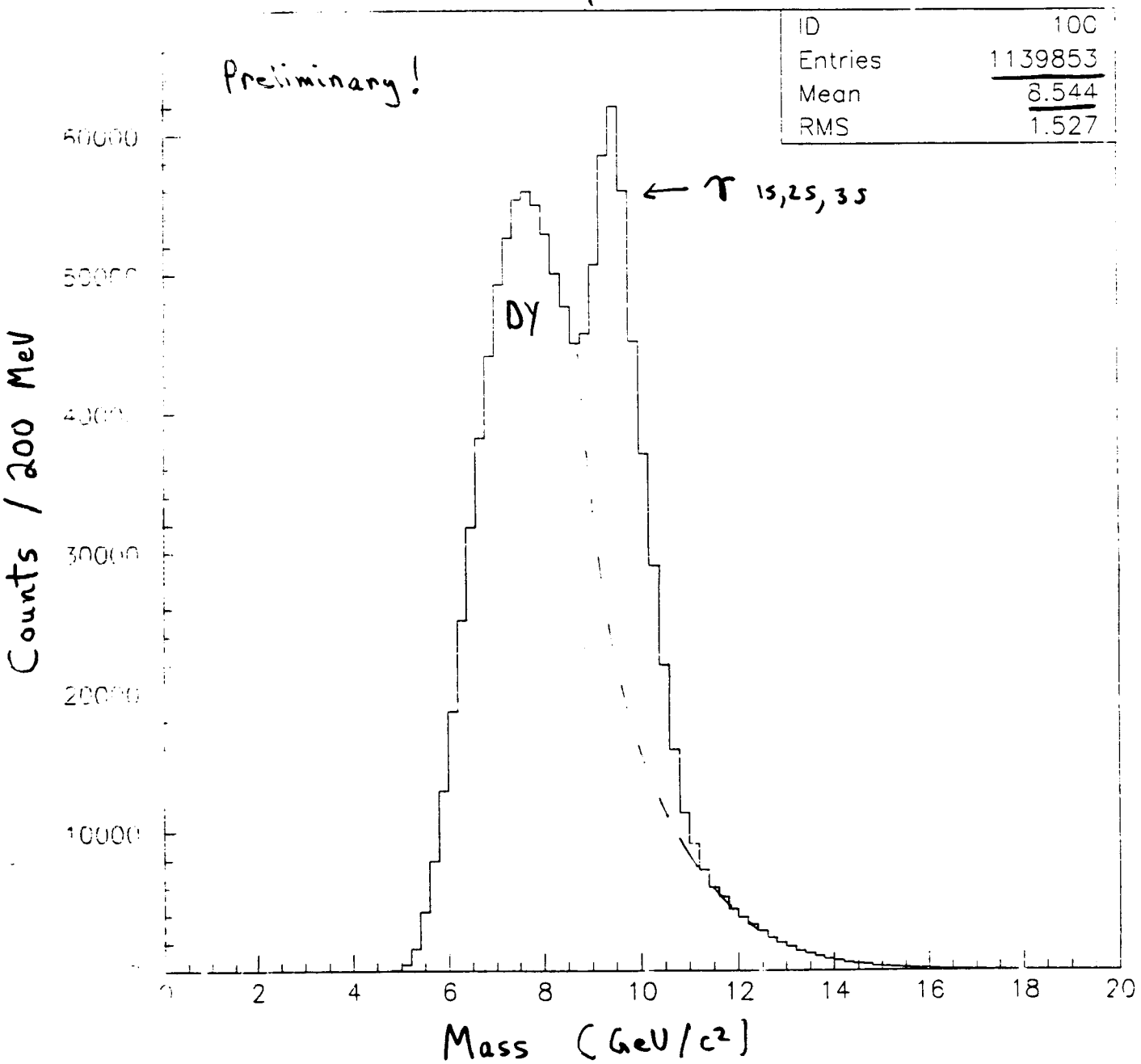
PRL 73 939 (1994) Brandenburg, Brodsky, Khoze, Müller



$$\frac{1}{\sigma}\frac{d\sigma}{d\Omega} \sim 1 + \lambda \cos^2\theta + \mu \sin^2\theta \cos\phi + \tfrac{\nu}{2} \sin^2\theta \cos 2\phi$$

New E772 beam dump data

800 GeV $p + Cu \rightarrow \mu^+\mu^-$



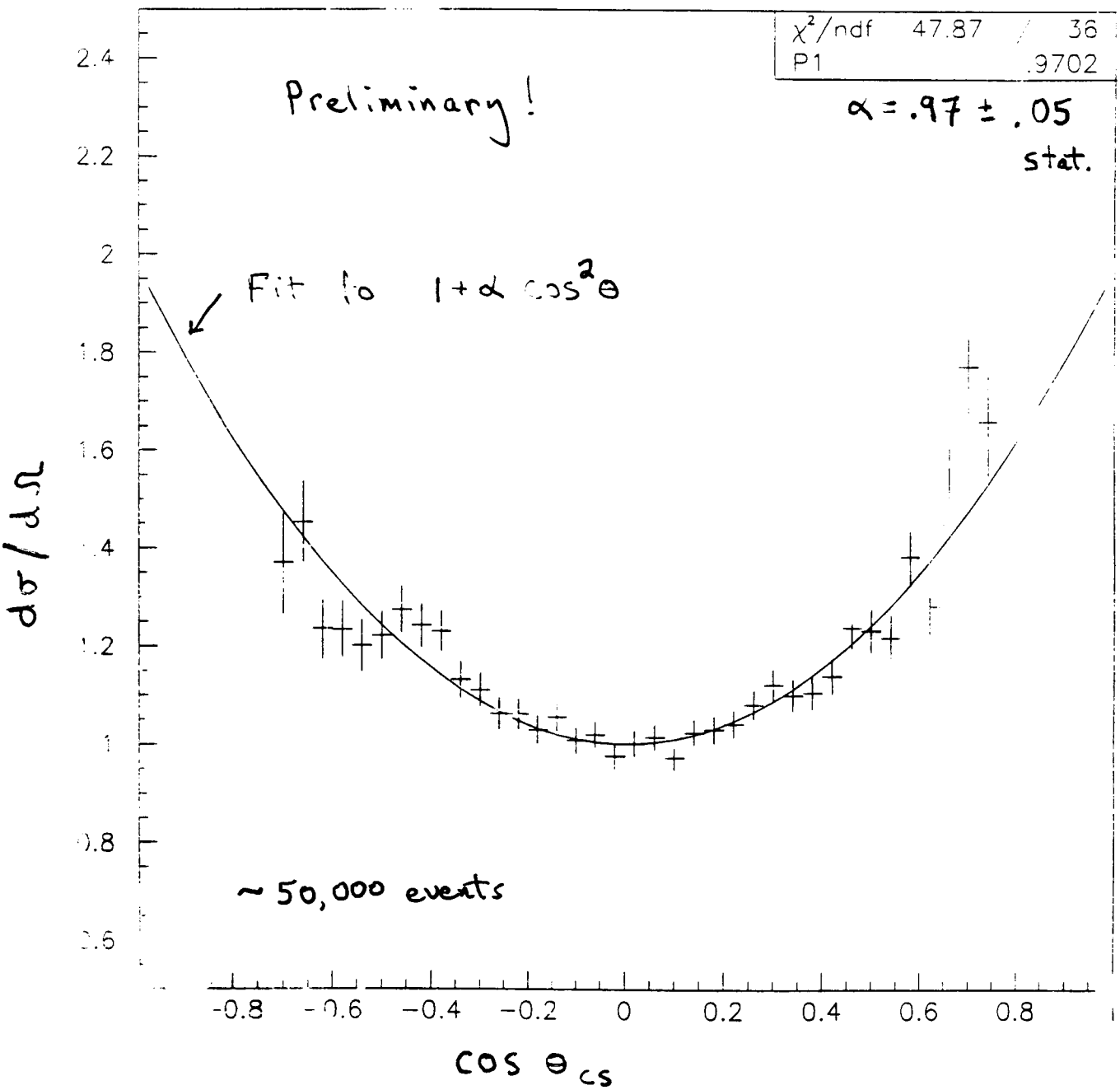
1.1×10^6 events with $M > 5$ GeV

$\sim 200{,}000$ Υ's

$\sim 50{,}000$ events with $M > 11$ GeV

E772 800 GeV p + Cu → DY

11 < Mass < 14 GeV



$\langle P_T \rangle$ = 1.4 GeV/c

$\langle \text{Mass} \rangle$ = 11.9 GeV/c^2

$\langle P_T/M \rangle$ = .12

CTEQ 604: Lai et al, CTEQ4
(preprint from CTEQ Home page)

Process	Experiment	Measurable	Data Points	Ref.	
DIS	BCDMS	$F_{2\,H}^{\mu}, F_{2\,D}^{\mu}$	324	[26]	
	NMC	$F_{2\,H}^{\mu}, F_{2\,D}^{\mu}, F_{2\,n/p}^{\mu}$	297	[18]	
	E665	$F_{2\,H}^{\mu}, F_{2\,D}^{\mu}$	70	[21]	
	H1	$F_{2\,H}^{e}$	172	[19]	
	ZEUS	$F_{2\,H}^{e}$	179	[20]	
	CCFR	$F_{2\,Fe}^{\nu}, x\,F_{3\,Fe}^{\nu}$	126	[27]	
Drell-Yan	E605	$sd\sigma/d\sqrt{\tau}dy$	119	[28]	p+Cu
	NA-51	A_{DY}	1	[29]	pp, pd.
W-prod.	CDF	Lepton asym.	9	[30]	
Direct γ	WA70	$Ed^3\sigma/d^3p$	8	[3]	
	UA6	$Ed^3\sigma/d^3p$	16	[31]	
Incl. Jet	CDF	$d\sigma/dE_t$	36	[7]	
	D0	$d\sigma/dE_t$	26	[8]	

Table 2: List of processes and experiments used in the Global analysis.

PDF set	Description	$\alpha_s(m_z)$	Q_0^2 (GeV^2)
	Standard Sets		
CTEQ4M	$\overline{MS}$ scheme	0.116	2.56
CTEQ4D	DIS scheme	0.116	2.56
CTEQ4L	Leading Order	0.132	2.56
	α_s series		
CTEQ4A1	1	0.110	2.56
CTEQ4A2	2	0.113	2.56
CTEQ4A3	Same as CTEQ4M	0.116	2.56
CTEQ4A4	4	0.119	2.56
CTEQ4A5	5	0.122	2.56
	Specials		
CTEQ4HJ	"Hi-Jet"	0.116	2.56
CTEQ4LQ	"Low Q_0"	0.114	0.49

Table 3: List of new CTEQ4 parton distributions and their characteristics.

NMC: $I_G = \frac{1}{3} + \frac{2}{3}\int_0^1 (\bar{u}(x) - \bar{d}(x))\,dx$ ∴ if $\bar{u} = \bar{d}$

$= 0.240 \pm 0.016$

$\Rightarrow \int_0^1 (\bar{d}(x) - \bar{u}(x))\,dx = 0.14 \pm 0.02$

NA51: $\sigma_{DY}(p+p) \propto \bar{u}_p(x_2)$

$\sigma_{DY}(p+n) \propto \bar{u}_n(x_2) = \bar{d}_p(x_2)$

$$A_{DY} = \frac{\sigma^{pp} - \sigma^{pn}}{\sigma^{pp} + \sigma^{pn}}$$

$\Rightarrow \bar{u}/\bar{d} = 0.51 \pm 0.04 + 0.05$

PRD 51 4763 ('95) Lai et al.

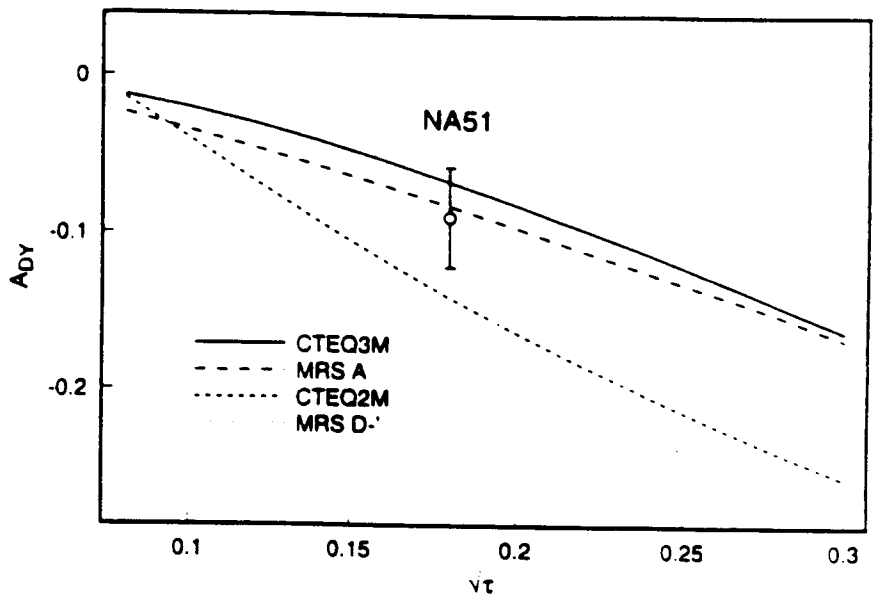


FIG. 1. A comparison of the data for A_{DY} from NA51 with NLO QCD results obtained from previous and current versions of MRS and CTEQ parton distributions.

E866: Measurement of the antiquark distributions in the proton
(Proposed 9/92, Approved 12/92, Currently taking data)
(Spokesman: Pat McGaughey)

Abilene Christian U., ANL, Fermilab,
Georgia State U., IIT, LANL, LSU, NMSU,
ORNL, Texas A&M, and Valparaiso U.

Precision measurement of Drell-Yan yields from
Hydrogen and Deuterium. (800 GeV/c proton on LH2, LD2)

The ratio of these yields can be used to infer the
$\bar{u}/\bar{d}$ in proton ($0.03 < x < 0.3$)
Measures also J/ Ψ, Ψ', Y, Y', Y''

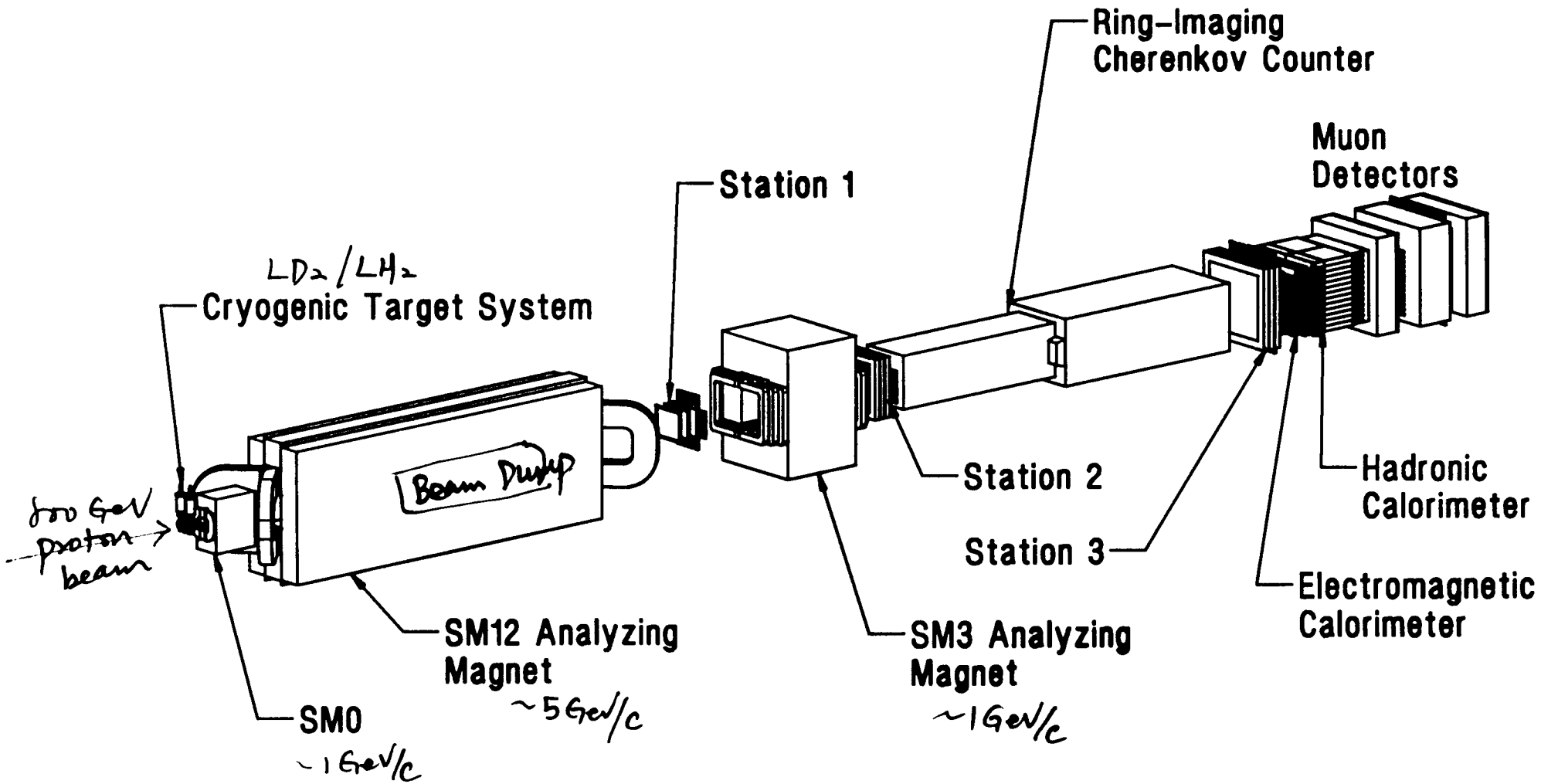
High rate capability with better than 100 MeV at the J/ Ψ
Beam produces 2E12 protons/spill

E866
300,000 events
$0.03 < x < 0.3$
$2 <$ mass (GeV) $< \sim 15$
p_t
0
⋮

NA51
~ 6,000 events
$x = 0.18$
mass < 8 GeV

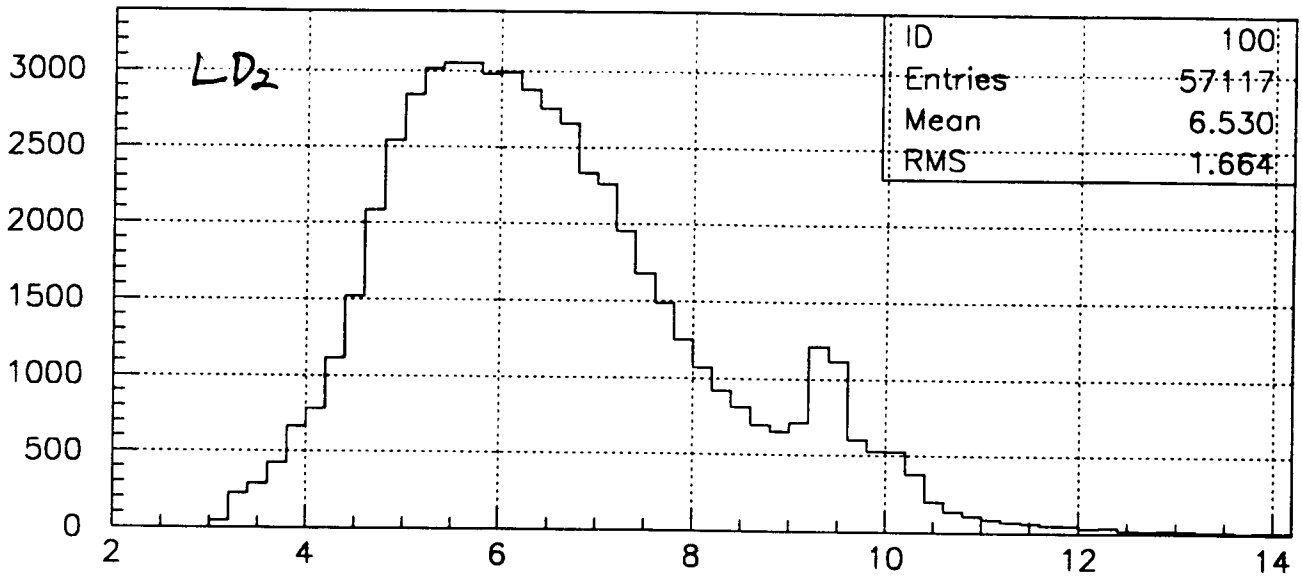
FNAL E866 (NUSEA)

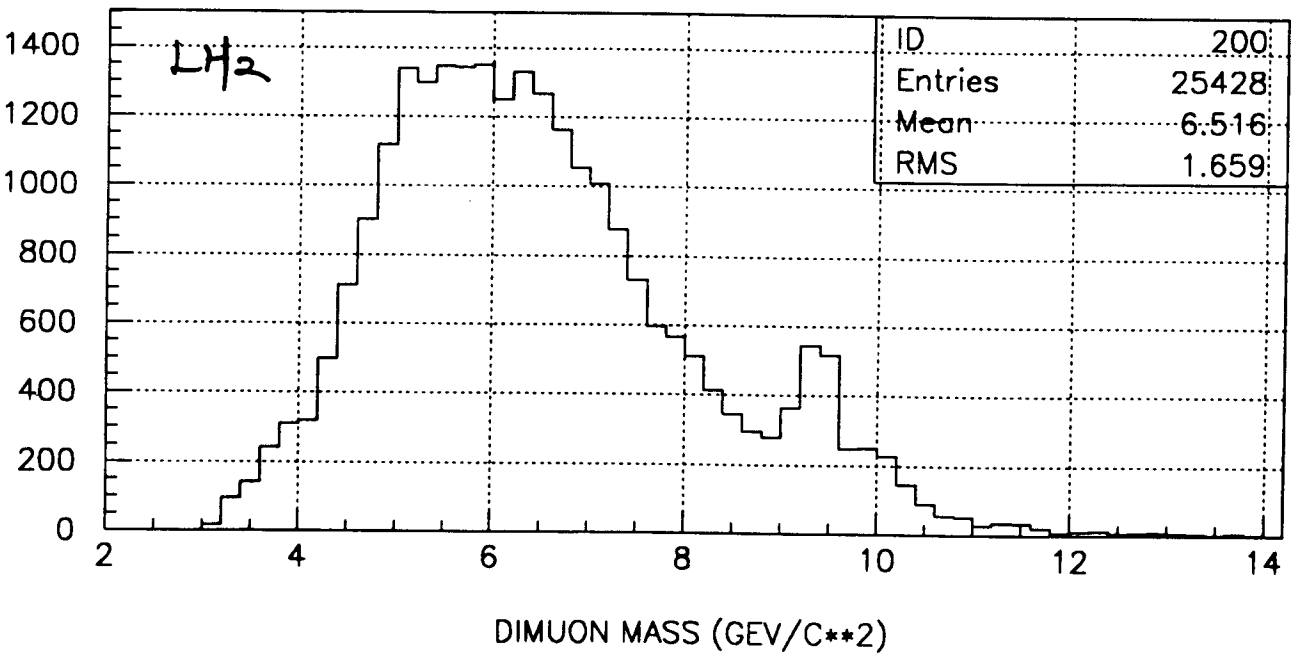
$\bar{u}/\bar{d}$ measurement



E605 / E772 / E789

E866 PRELIMINARY RESULT



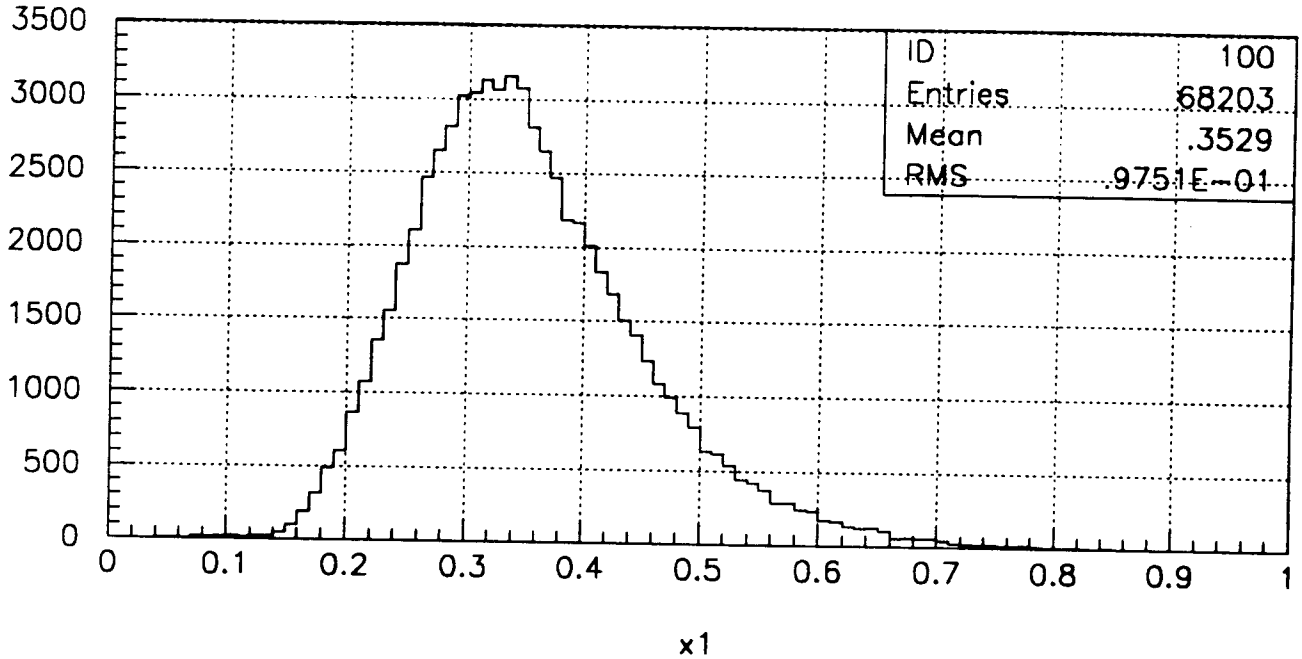


1/3 mass setting : medium mass > J/ψ

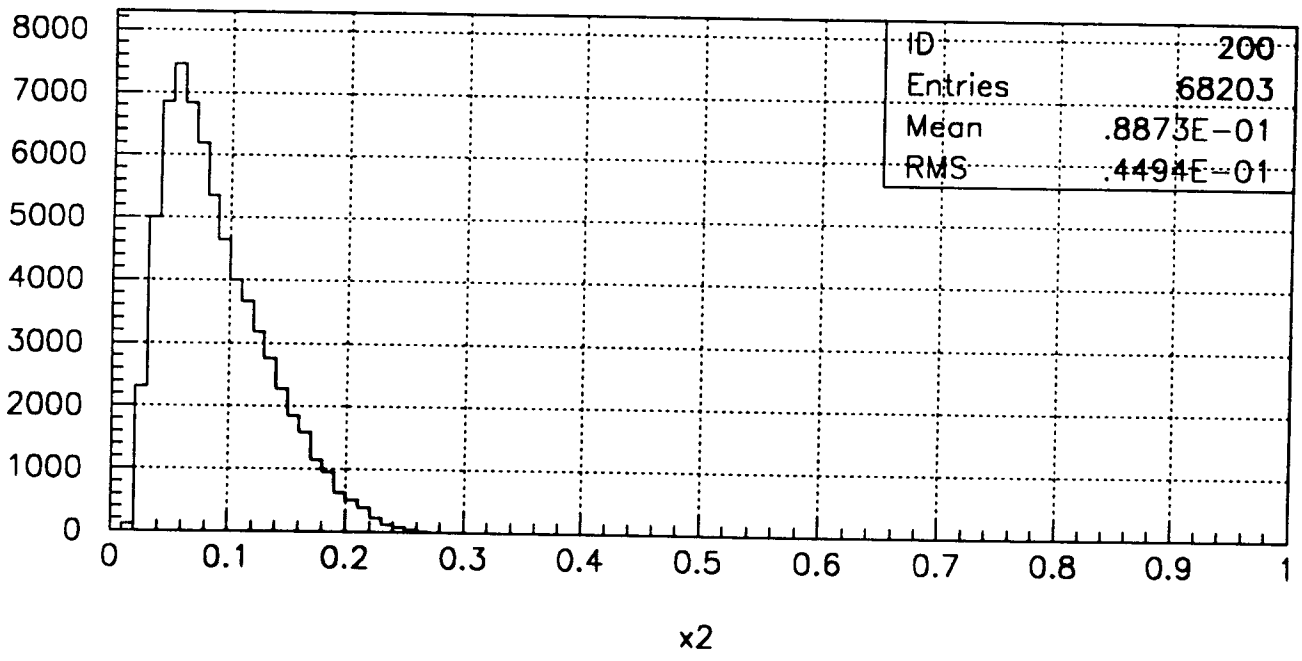
2 wks

E866 PRELIMINARY RESULT

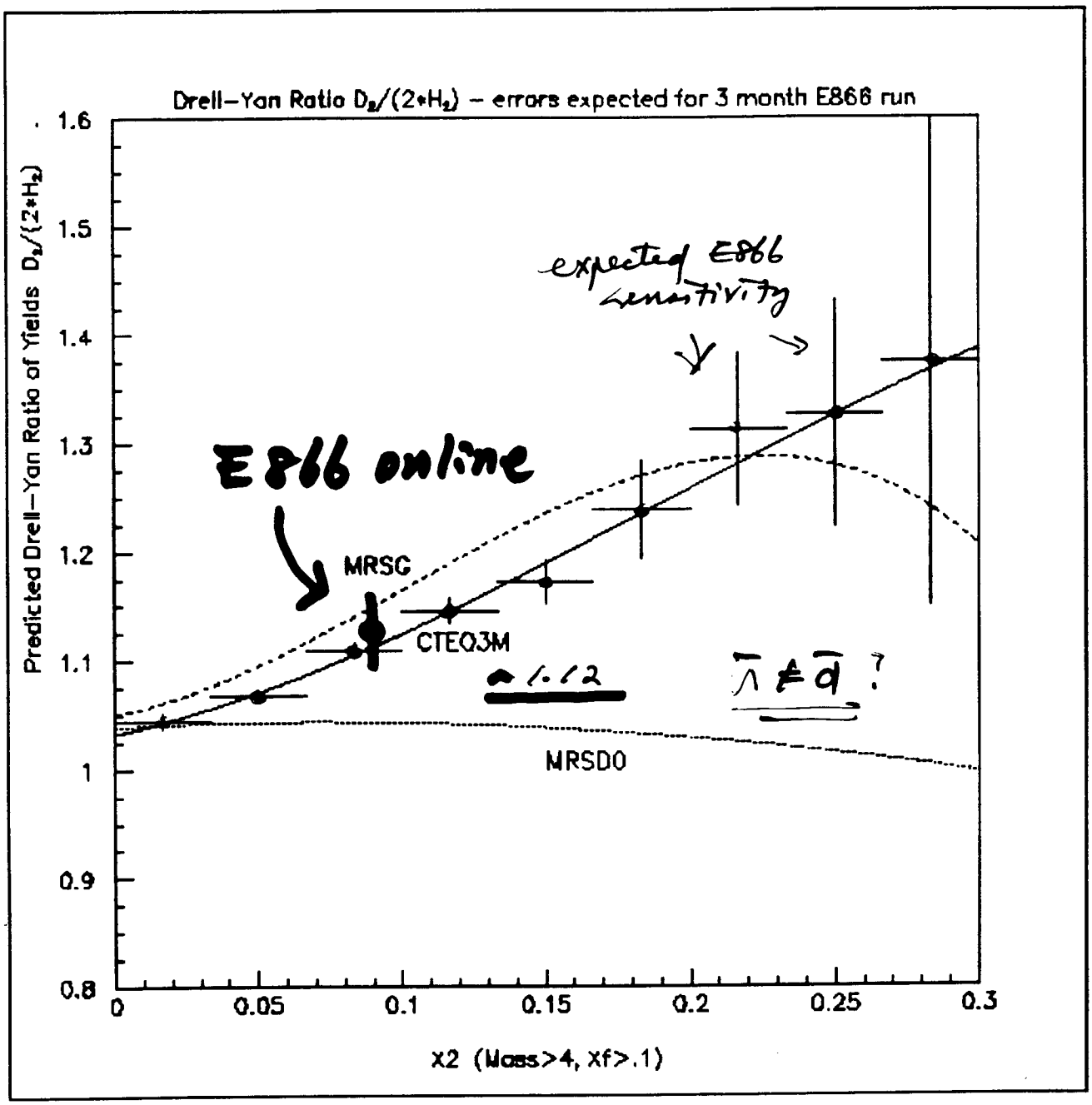
present (medium mass) setting



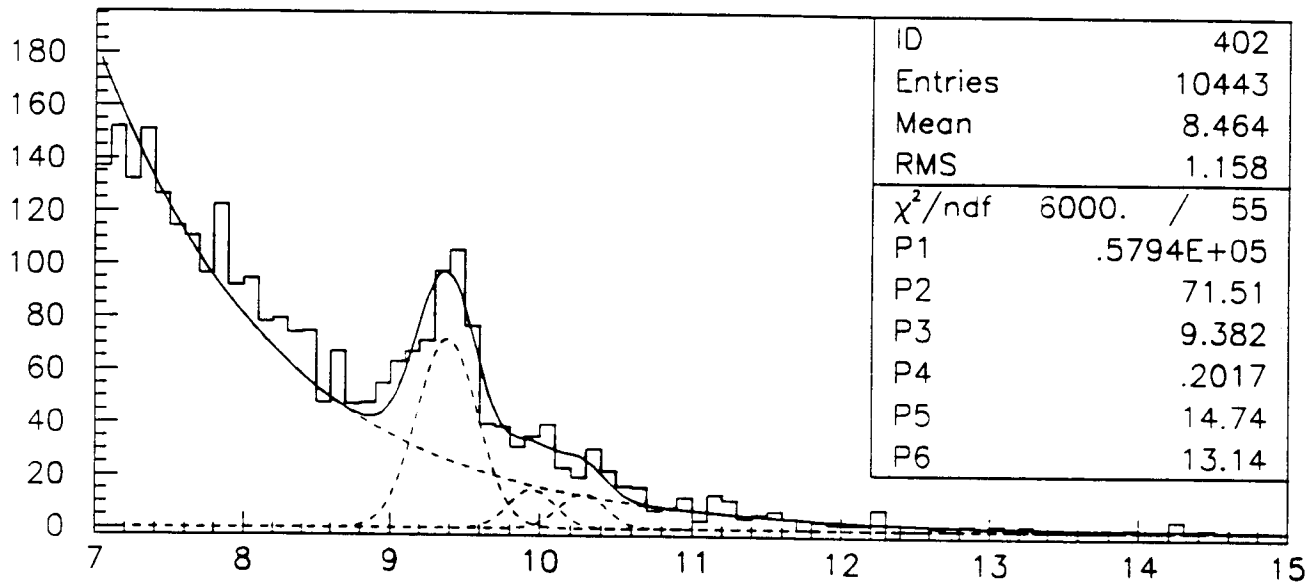
x1

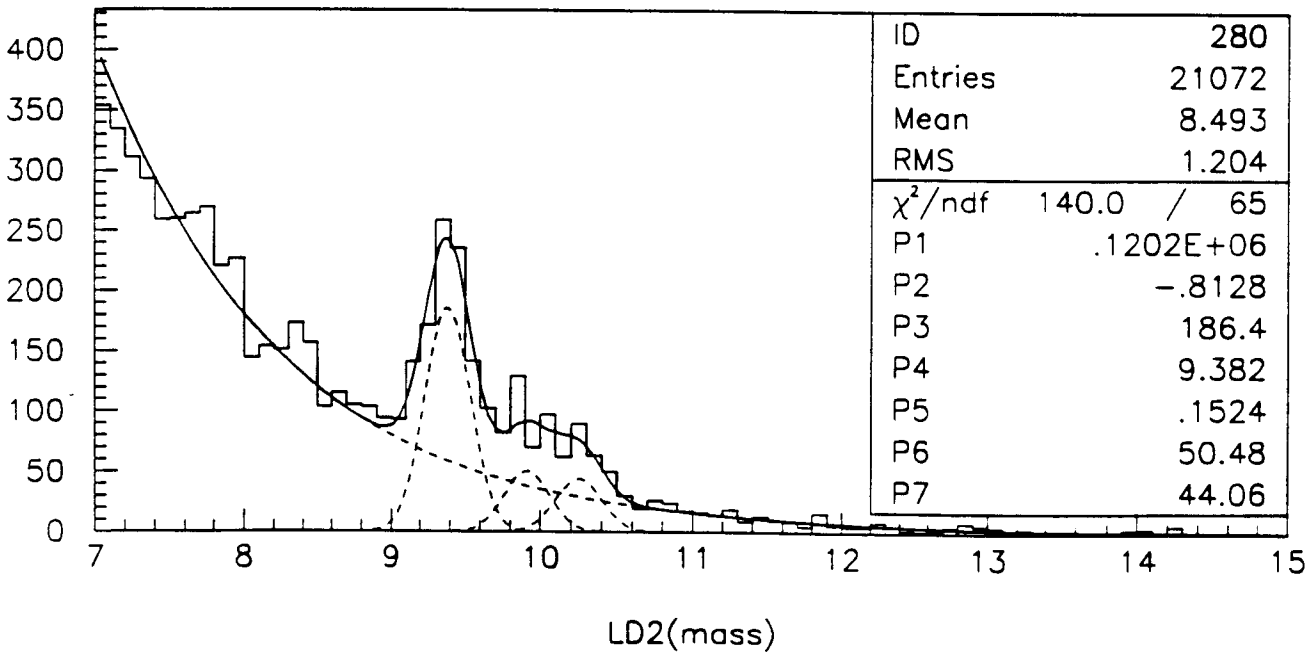


x2

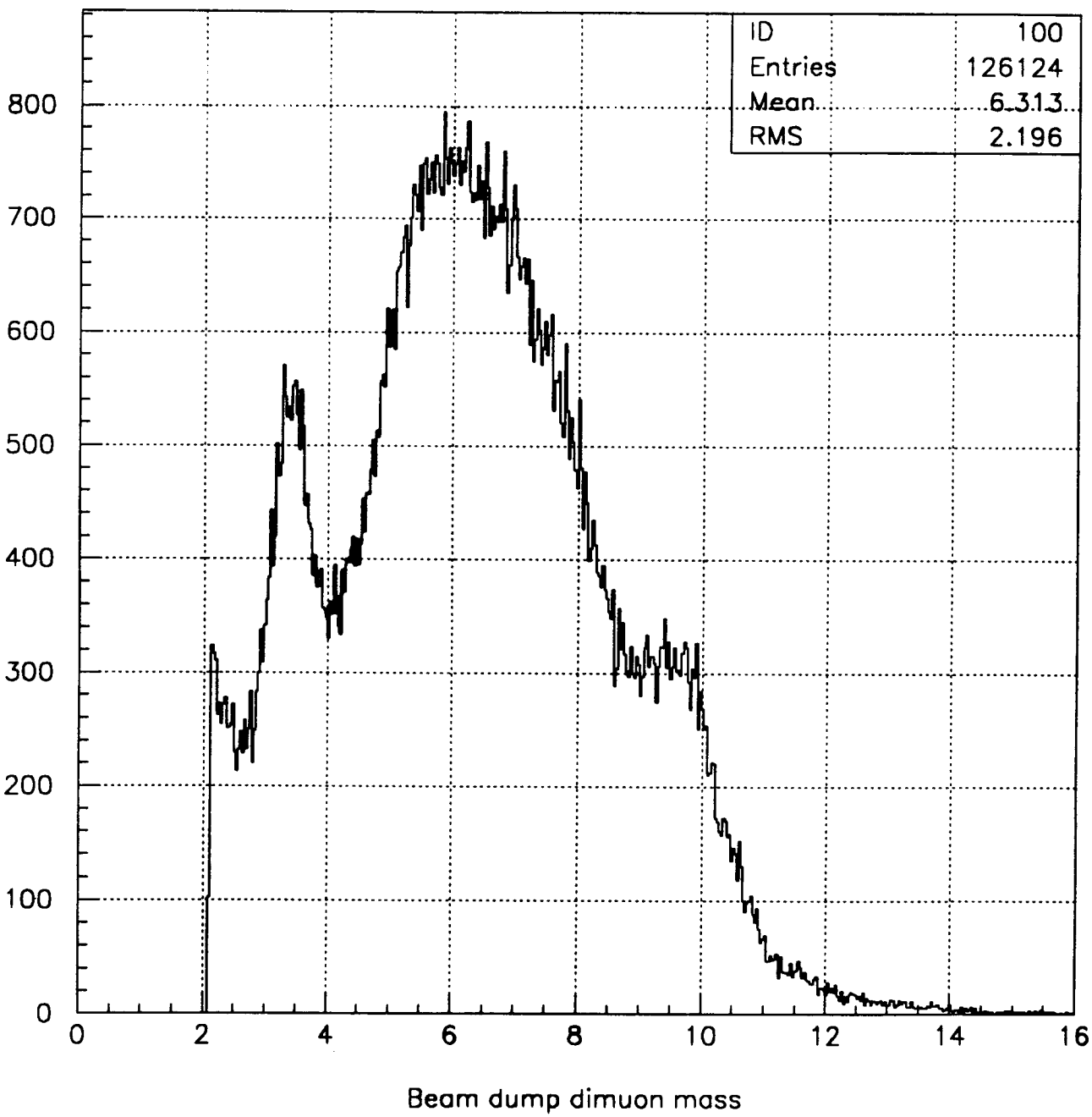

Drell–Yan Ratio $D_2/(2*H_2)$ – errors expected for 3 month E866 run
Predicted Drell–Yan Ratio of Yields $D_2/(2*H_2)$
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0
0.05
0.1
0.15
0.2
0.25
0.3
x2 (Mass>4, Xf>.1)
expected E866 sensitivity
E866 online
MRSC
CTEQ3M
≈ 1.12
$\bar{u} \neq \bar{d}$?
MRSD0

E866 PRELIMINARY RESULT

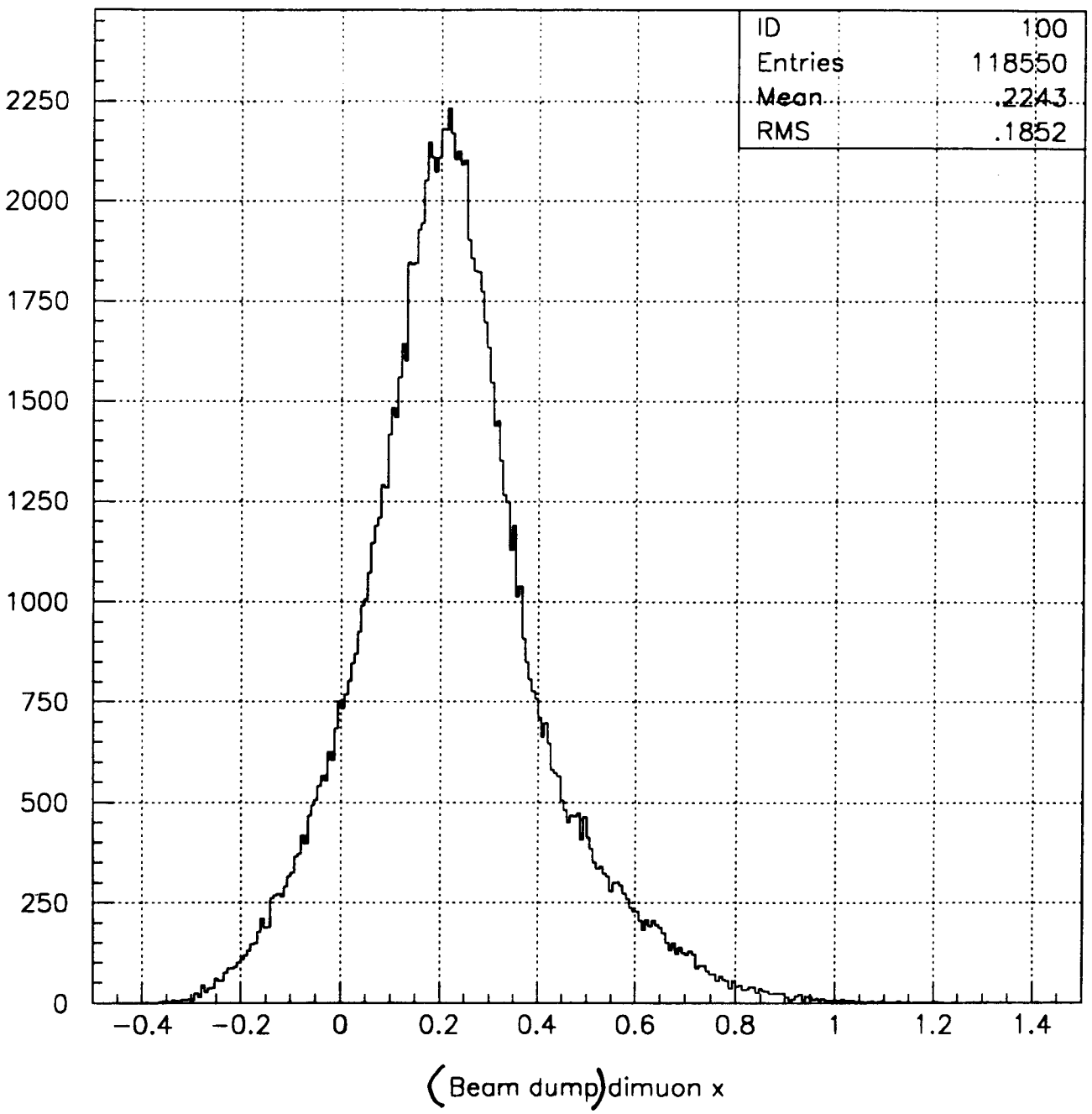


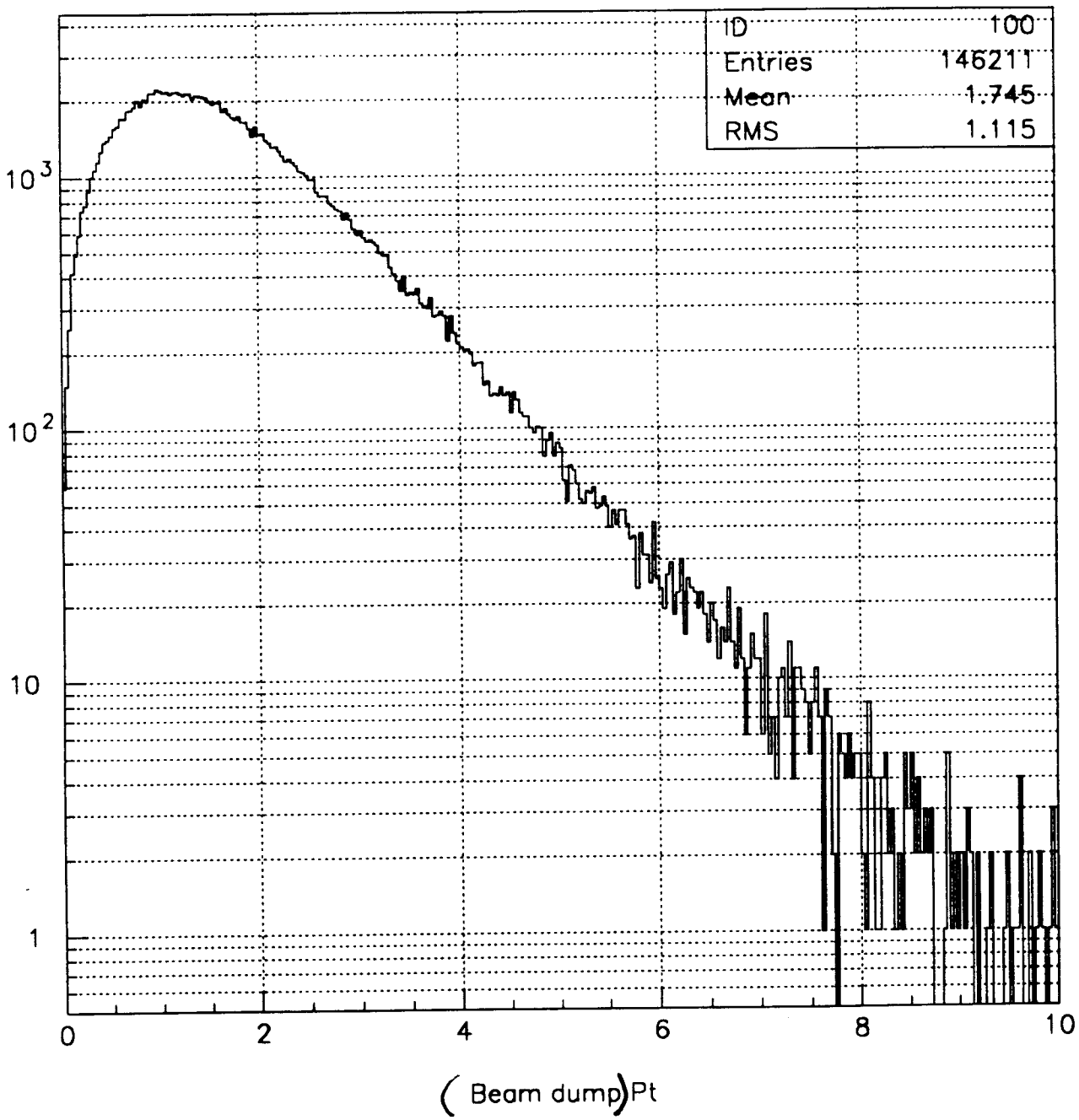


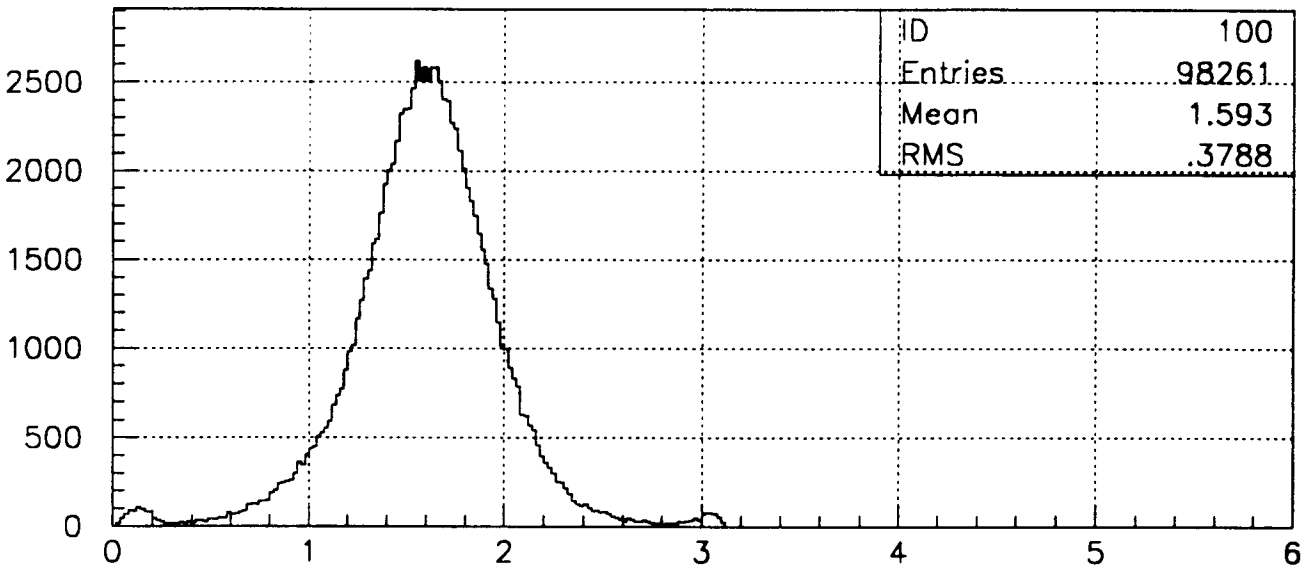
$\frac{\gamma(1S)_H}{\gamma(1S)_D} \sim 1$ different from 1.12.

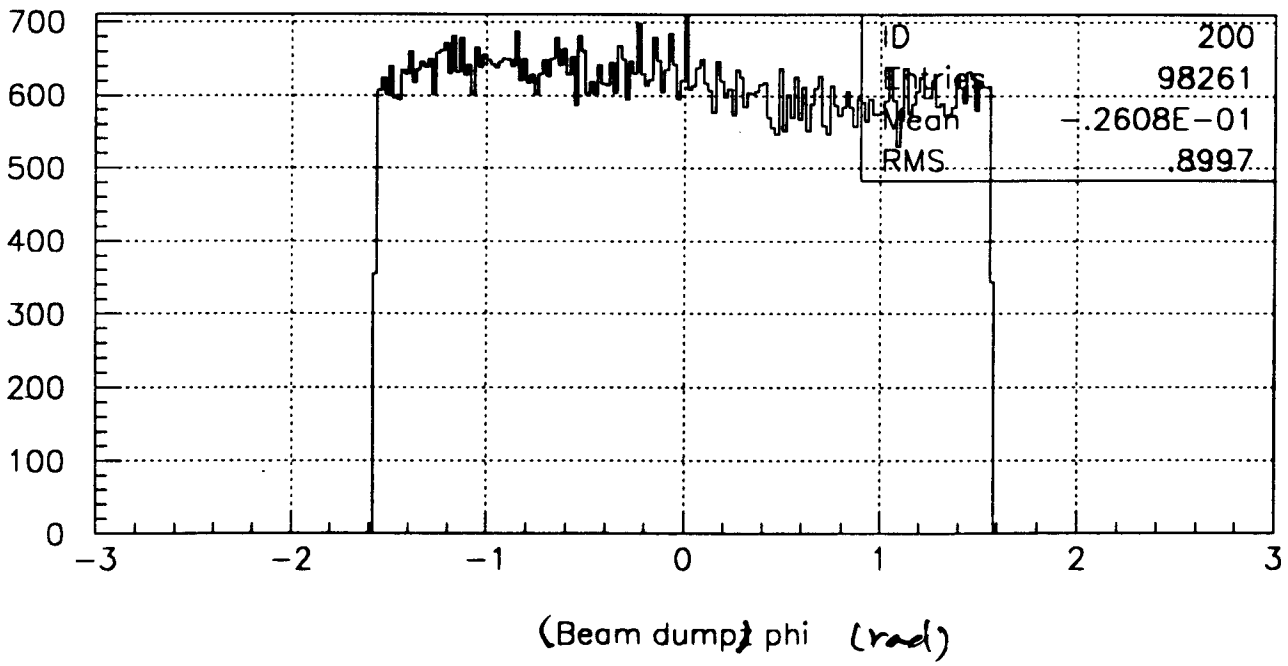

ID 100
Entries 126124
Mean 6.313
RMS 2.196
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
Beam dump dimuon mass

E866 PRELIMINARY Result
on beam dump.




1D
Entries
Mean
RMS
100
146211
1.745
1.115
10^3
10^2
10
1
0
2
4
6
8
10
(Beam dump)Pt


ID 100
Entries 98261
Mean 1.593
RMS .3788
2500
2000
1500
1000
500
0
0 1 2 3 4 5 6
(Beam dump) theta (rad)


ID 200
Entries 98261
Mean -.2608E-01
RMS .8997
700
600
500
400
300
200
100
0
−3 −2 −1 0 1 2 3
(Beam dump) phi (rad)

Conclusion

1. Existing theory describing Drell-Yan seems to work fairly well.

2. The good understanding of the Drell-Yan process allows one to use DY as a tool to study subtle effects such as the u/d asymmetry, in parton distributions.

3. E866 will measure $\bar{u}/\bar{d}$, Drell-Yan, and quarkonium production for 800 GeV/c p-p, p-d, and p-A collisions.
   E866 should provide more stringent limits in testing QCD.

4. E866 (beam dump) is expected to extend the proton-induced Drell-Yan data to kinematic regions not studied before, such as

   a) large x

   b) large Pt region

   c) detailed information on Θ/ϕ distributions