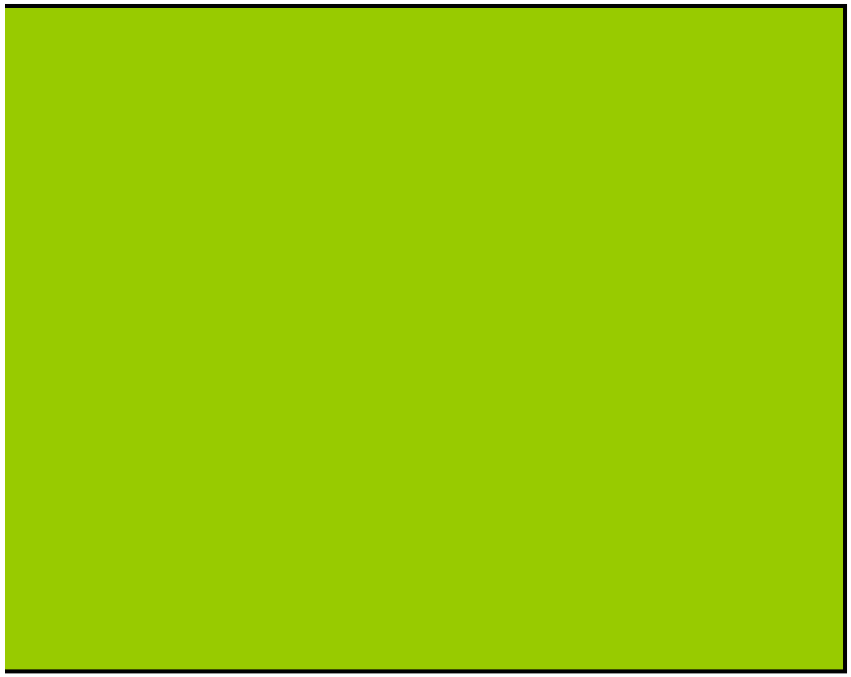
The Future of Hard and Electromagnetic Probes at the SPS

Hard Probes 2004
Ericeira/Portugal November 4 – 10, 2004

- **Villars 2004** — **Official CERN Workshop**
- **Physics** — **Photons**, **Lepton Pairs**, **Open Charm**, **Charmonia**, **(Jets)**
- **Boundary Conditions** — **SPS**, **FAIR, RHIC, LHC**
- **Conclusions** — **The CERN View**, **My View**

Hans J. Specht



Wednesday 22 September 2004 09:00->19:00	Wednesday 22 September	
Wednesday 22 September 2004 09:00->09:45	Opening Session	John B. Dainton
Wednesday 22 September 2004 09:45->16:00	CERN accelerators, performance and outlook	John B. Dainton
Wednesday 22 September 2004 16:30->18:45	[redacted]	Louis Kluberg
Thursday 23 September 2004 09:00->19:20	Thursday, 23 September	
Thursday 23 September 2004 09:00->12:15	[redacted]	Louis Kluberg
Thursday 23 September 2004 14:00->19:30	Neutrinos - Session 1	David L. Wark
Friday 24 September 2004 09:00->22:00	Friday 24 September	
Friday 24 September 2004 09:00->12:15	Neutrinos - Session 2	David L. Wark
Friday 24 September 2004 14:00->22:00	Soft and hard hadrons - Session 1	Uta Stoesslein
Saturday 25 September 2004 09:00->12:00	Soft and hard hadrons - Session 2	Uta Stoesslein
Saturday 25 September 2004 14:00->19:20	Anti-protons - Session 1	Helena Bialkowska
Sunday 26 September 2004 09:00->19:00	Sunday 26 September	
Sunday 26 September 2004 09:00->12:20	Anti-protons - Session 2	Helena Bialkowska
Sunday 26 September 2004 14:00->19:30	Heavy flavour - Session 1	Gautier Hamel de Monchenault
Monday 27 September 2004 09:00->17:15	Monday 27 September	
Monday 27 September 2004 09:00->12:00	Heavy flavour - Session 2	Gautier Hamel de Monchenault
Monday 27 September 2004 13:30->16:50	Other topics	John B. Dainton
Monday 27 September 2004 16:50->19:30	Meeting conclusions -	John B. Dainton

[redacted]

Chairperson: Louis Kluberg

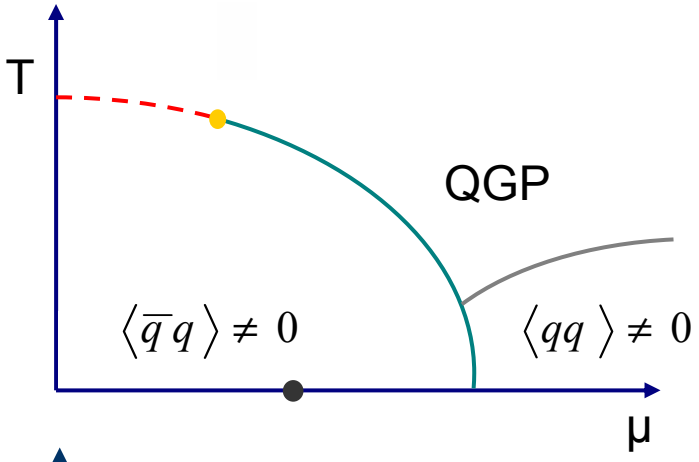
16:30	**Experimental overview** (1h00') (transparencies)	**Itzhak Tserruya**
17:30	**Discussion** (15')	
17:45	**Theoretical overview** (1h00') (transparencies)	**Bernd Mueller**
18:45	**Discussion** (15')	

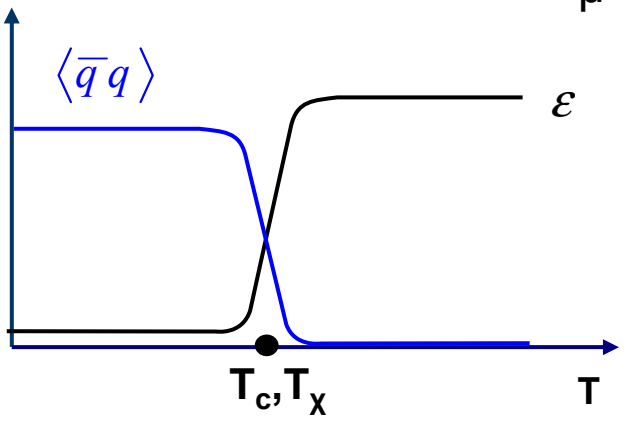
[redacted]

Chairperson: Louis Kluberg

09:00	**NA49 prime - ions programme** (35') (document transparencies)	**Marek Gazdzicki**
09:35	**Discussion** (10')	
09:45	**NA49 prime, astroparticle physics programme** (10') (transparencies)	**Andreas Haungs**
09:55	**Discussion** (05')	
10:00	**NA60:Study of dimuon and heavy-flavour production in proton-nucleus and heavy-ion collisions** (45') (document transparencies)	**Carlos Lourenco**
10:45	**Discussion** (15')	
11:00	**Critical behaviour in QCD** (30') (transparencies)	**Helmut Satz**
11:30	**Availability of ions at the SPS** (05') (transparencies)	**Jean-Pierre Riunaud**

What did we want to learn from em and $c\bar{c}$ probes?





Goals

- existence and properties of deconfined state
- nature of parameters of transition

  new: critical point
- existence and parameters of chiral transition

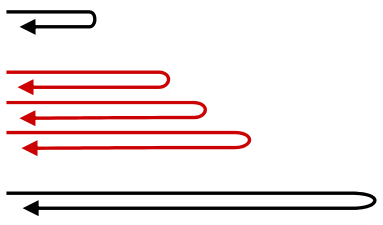
Tools

- measure ε, measure T → get ν from $\varepsilon = \nu T^4$

  ($T<T_c$, $T>T_c$)
- measure ρ meson behaviour → disappearance for $T>T_\chi$

  ($T<T_\chi$, $T>T_\chi$)
- measure J/ψ suppression → disappearance for $T>T_c$

  ($T<T_c$, $T>T_c$)



AGS

SPS

RHIC

Parameters

- CM energy √s → vary ε,T,μ
- nuclear size A → vary V +….
- impact parameter b → vary ε,T,μ,V +….

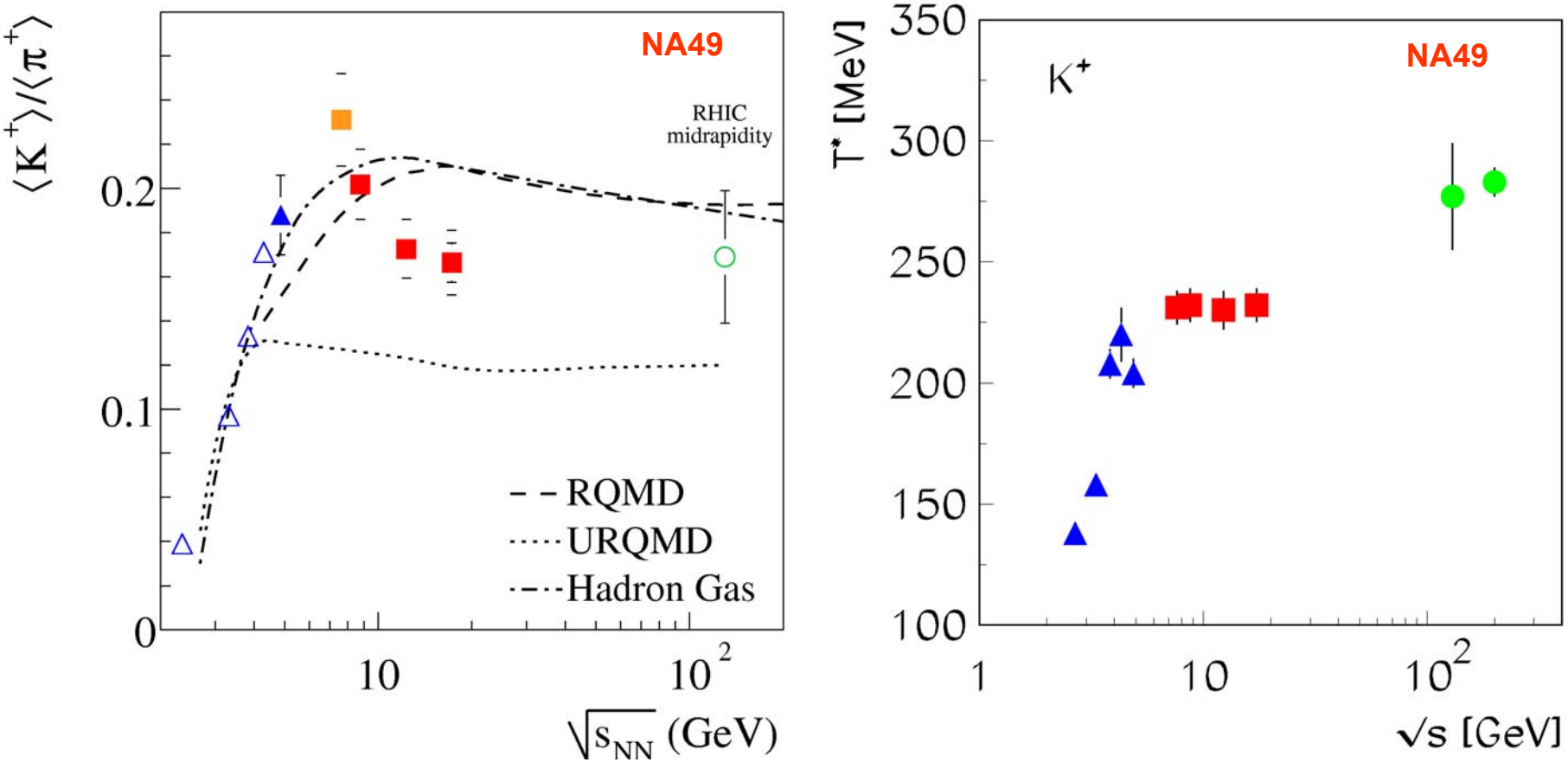
SPS unique in terms of excitation functions

Possible Evidence for the Critical Point

Importance of excitation functions in narrow steps:

so far illustrated only for soft probes: particle yields, v_2, HBT….

Most interesting result: K^+/π^+,T_{K+}; first "discontinuity"?

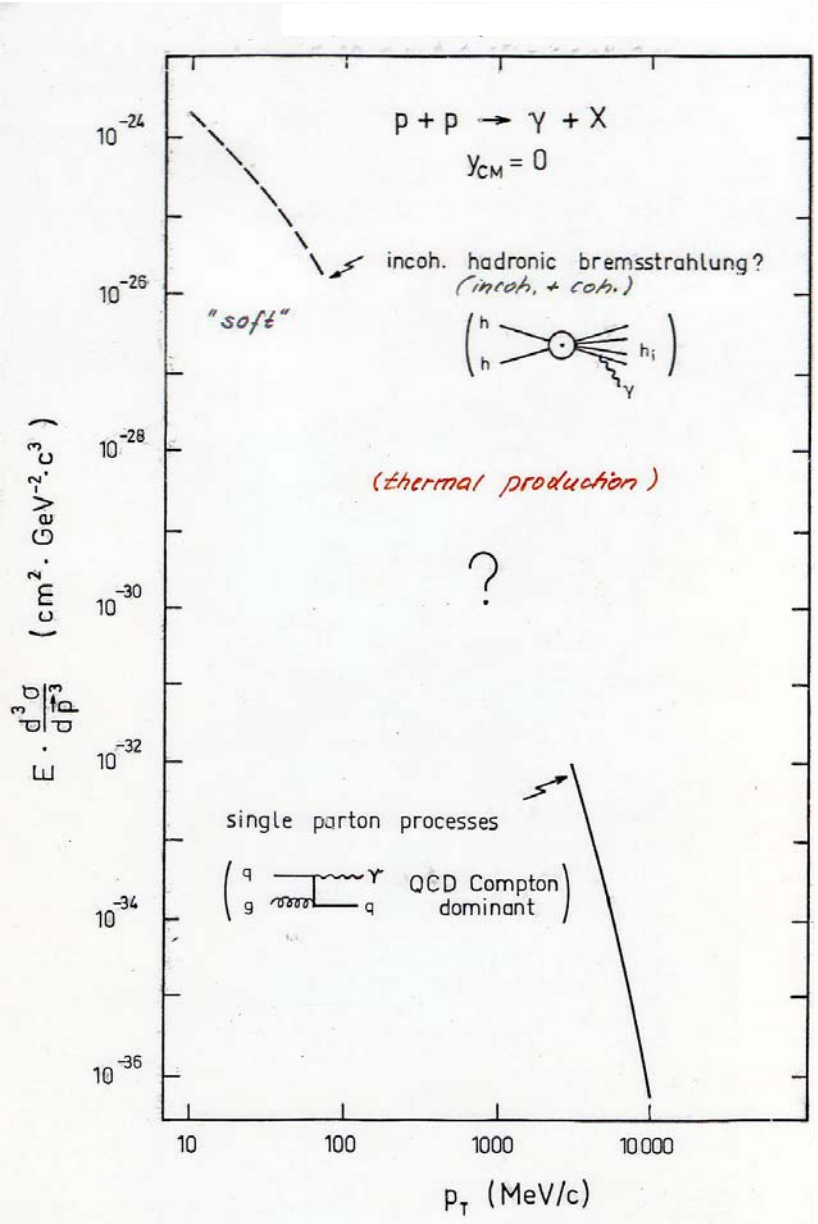


What did we achieve?

Probe	Range	Full energy 158 AGeV/c		Excitation function 80/40/30/20 AGeV/c	
		AA PbPb	Comparison pp,pA	AA PbPb	Comparison pp,pA
Photons	p_t<0.1 (GeV/c)	-	+	-	-
	0.1<p_T<1.5	-	-	-	-
	p_T>1.5	(+)	-	-	-
Lepton Pairs	m<0.2 (GeV/c^2)	-	(+)	-	-
	0.2<m<1.2	(+)	+	(+)	-
	m>1.2	(+)	(+)	-	-
Open charm	Identif. comb. l^+l^-	-	-	-	-
	Identif. D-decays	-	(+)	-	-
Charmonia	J/ψ, ψ'	(+)	(+)	-	-

No usable temperature measurement yet
No solid proof of ρ change yet
No measurement of charm level yet
No clear understanding of J/ψ suppression yet

Dynamic range of photon measurements



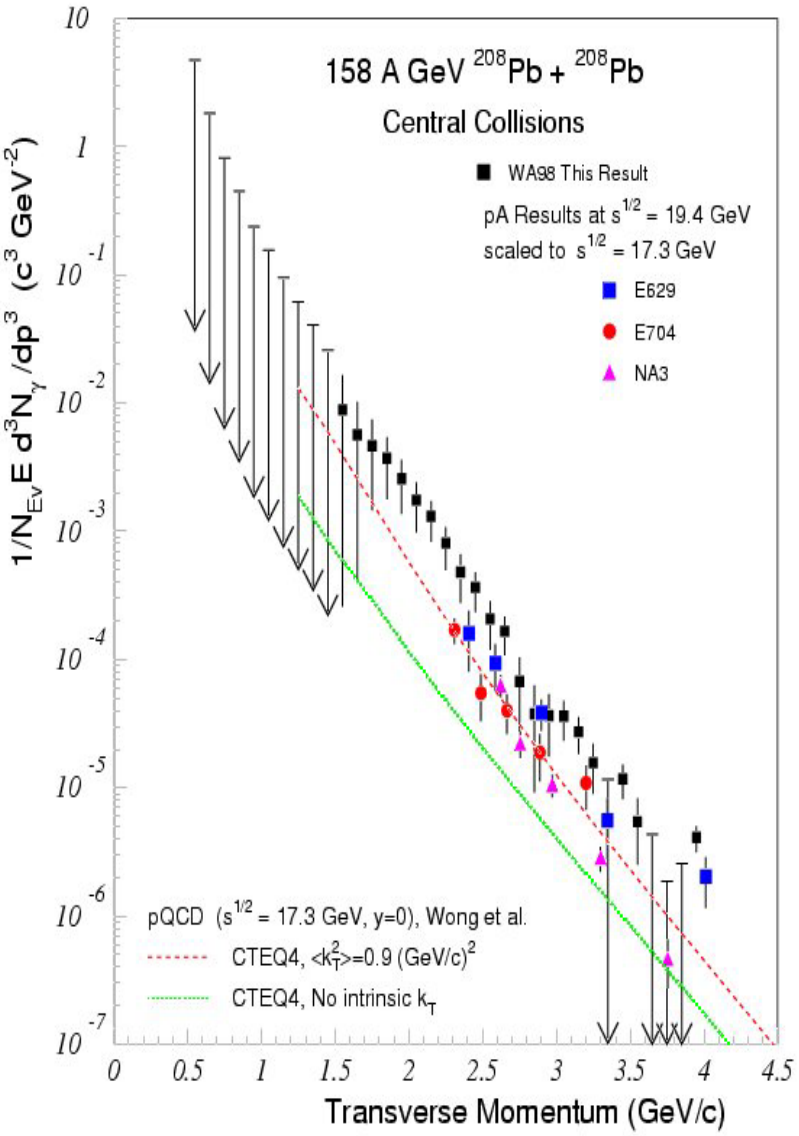
- **Bremsstrahlung** **$0.001<p_T<0.1$ (GeV/c)**
- **thermal radiation** **$0.1<p_T<5$**
- **hard parton processes** **$p_T>3$**

→ potential dynamic range $>10^3$

compare to em radiation in astronomy today

→ radio, IR, visible, UV, X, γ….

Photon reality in AA



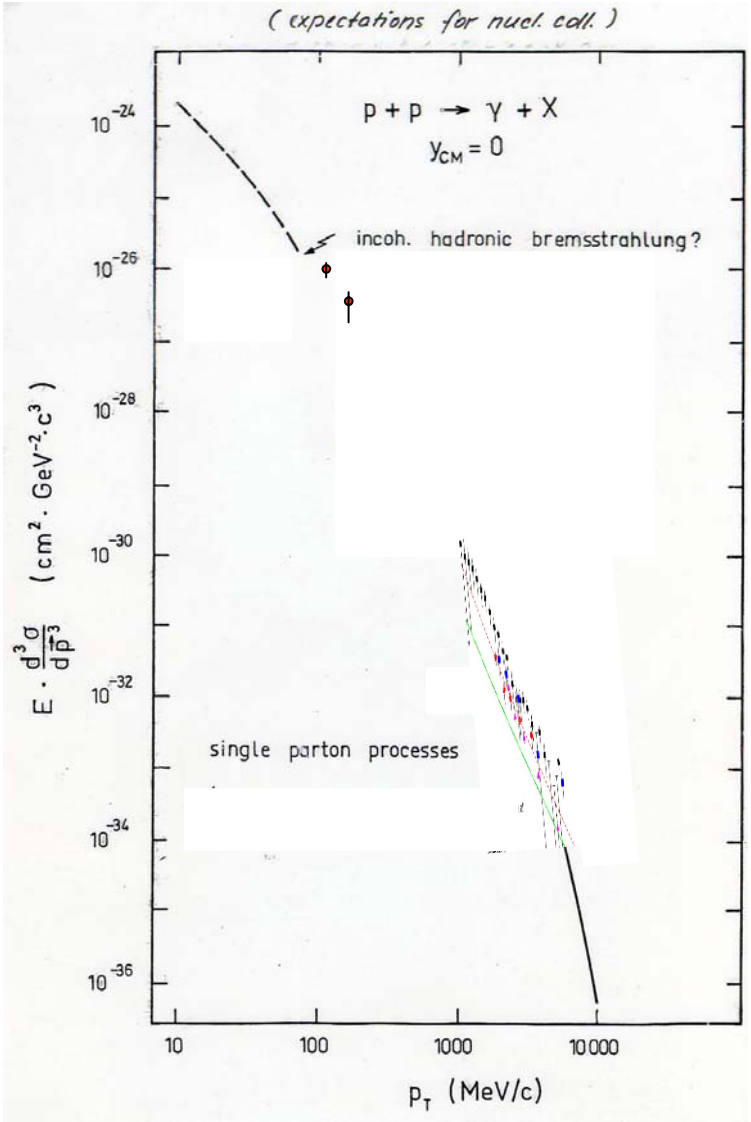
problems

- **usable dynamic range <2**
- **no pA comparison data**
- **model ambiguities**

→ large ambiguities in extraction of T_i

- **Gale (HP2004) 205 MeV**
- **Rapp and Shuryak (2000) 210 MeV**
- **Gale (HP2004) 270 MeV**
- **Srivastava (2001) 330 MeV**

Dynamic range of photons and present reality



Usable dynamic range <2

→ just the "visible light"

of astronomy

but 2 new points

Can we do better?

p_T<1.5 GeV/c:

precision instrumentation

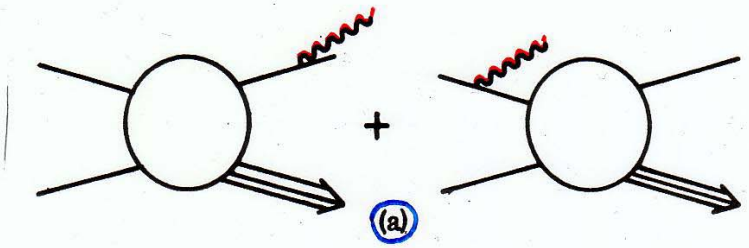
p_T<0.1 GeV/c:

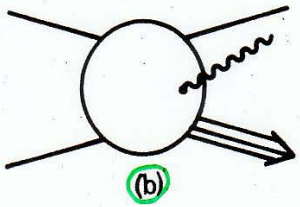
definitely feasible

Soft Photon Bremsstrahlung

Low, Phys. Rev. 110 (1958) 974

$$\sigma_f = \underbrace{\frac{\sigma_0}{k}}_{(a)} + \sigma_1 + \sigma_2 \cdot k + \ldots$$





photons from virtual particles

in the soft photon limit $k \to 0$

unique values for σ_0 and σ_1; calculable from scattering amplitudes without photon radiation

↳ bremsstrahlung determined by "outer particle lines"

pp, pA

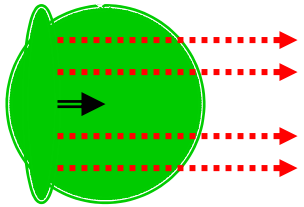
incoherent Bremsstrahlung:

hadrons radiate independently

"coherence":

hadrons radiate, not partons inside

AA



coherent Bremsstrahlung:

nuclei radiate, not hadrons inside

→ $\sigma \sim Z^2$! → collision dynamics

other sources of soft photons

"(first) window to chiral symmetry?"

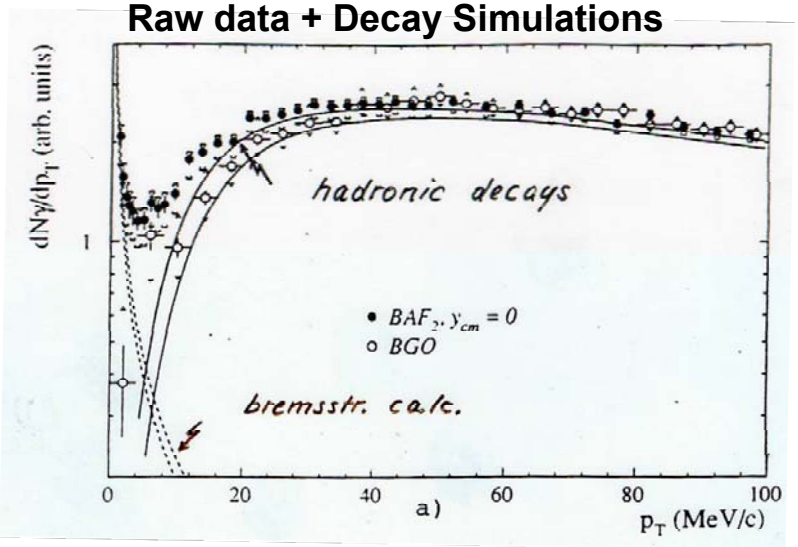
C.Gale, HP2004

Soft Photon Bremsstrahlung

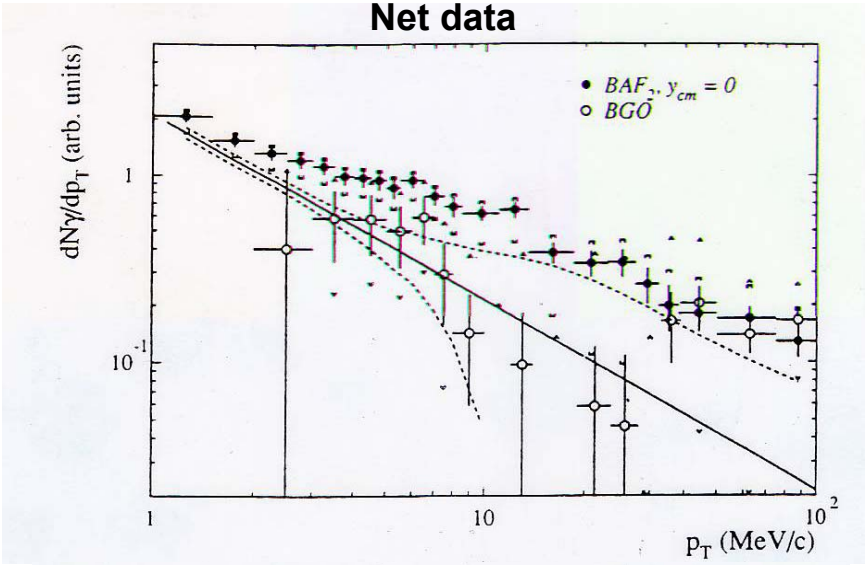
pBe at 450 GeV/c SOPHY/BACY within HELIOS/NA34

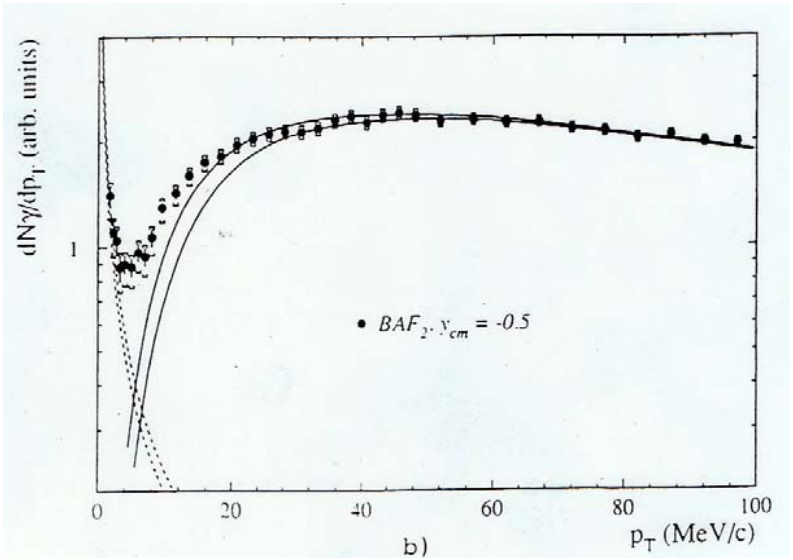
Anthos et al., Z.Phys. C59 (1993) 547

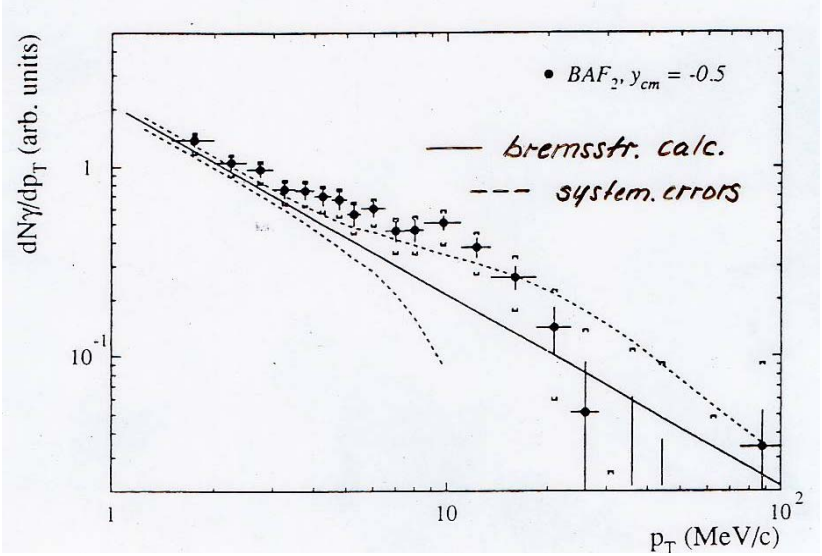
Raw data + Decay Simulations



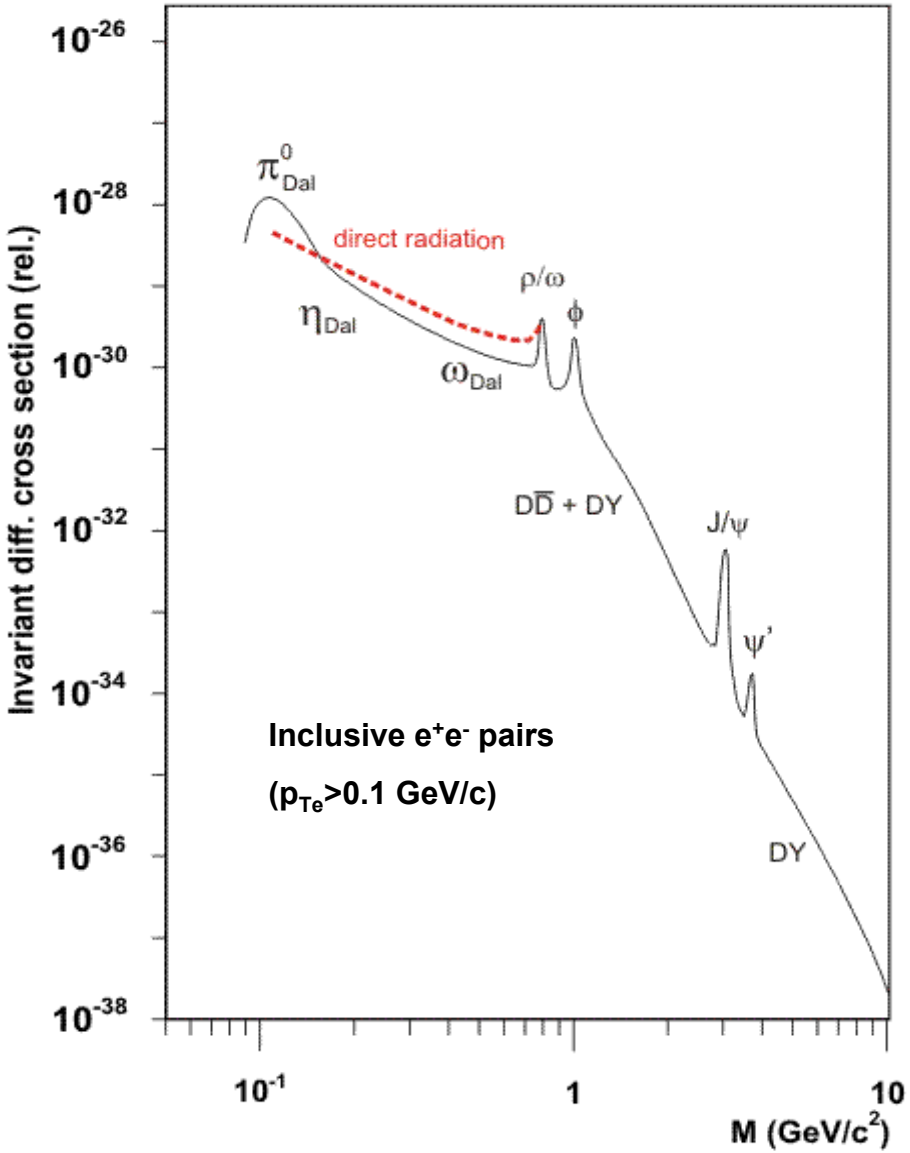
Net data







Dynamic range of lepton pair measuremens



- **Bremsstrahlung $0.001<m<0.1$ GeV/c^2**

  (plot m>0.02, but pp data!)

- **thermal radiation $0.1<m<1.2$**

  (light vector meson spectral densities)

- **thermal radiation $1.2<m<3$**

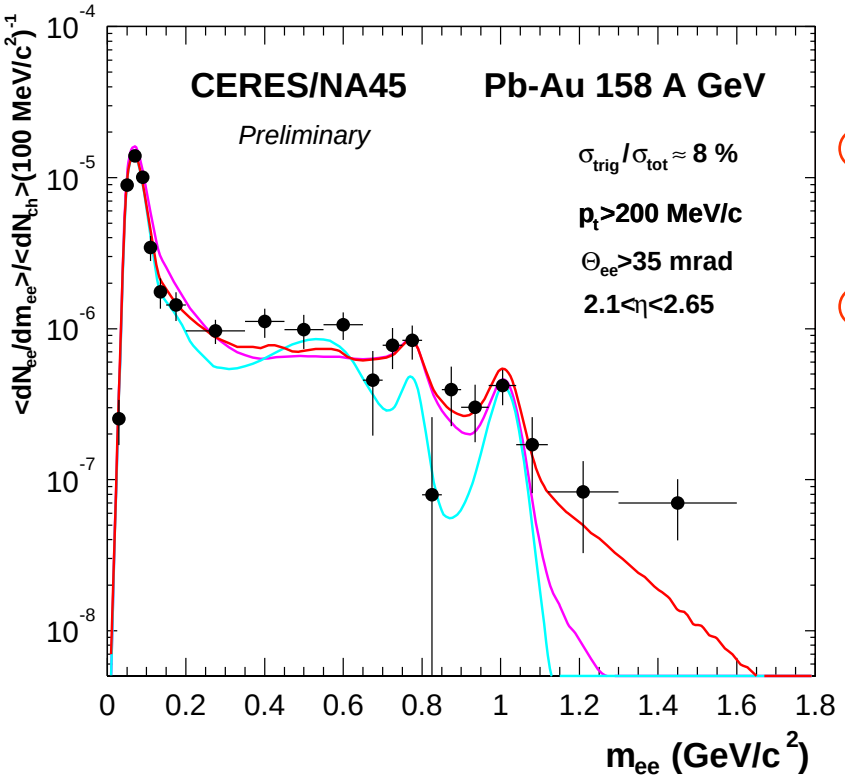
  (continuum regime)

- **hard parton process (DY) $p_T>1.2$**

  (dominant for $p_T>3$)

→ potential dynamic range of $>10^3$

Low Mass Electron Pairs/CERES



⊕ existence of strong excess above hadron decays

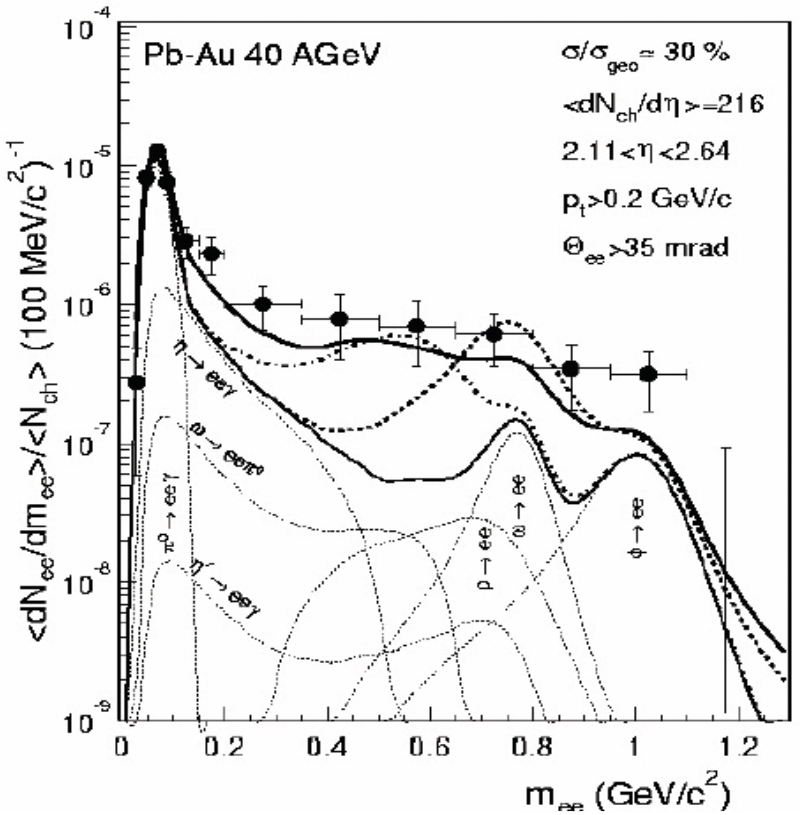
⊖ limited in statistics and resolution

1995/96	(30%)	(2600) 220	7%
2000	(8%)	(2200) 160	4%

⊕ excess = rate * space-time volume * medium influence

⊖ mechanism open: disappearance of vacuum ρ?
ρ melting à la Brown-Rho scaling?
ρ melting à la Rapp/Wambach?
qq annihilation?

Low Mass Lepton Pairs/ CERES



only example for a measurement of an electromagnetic/hard probe at a lower SPS energy!

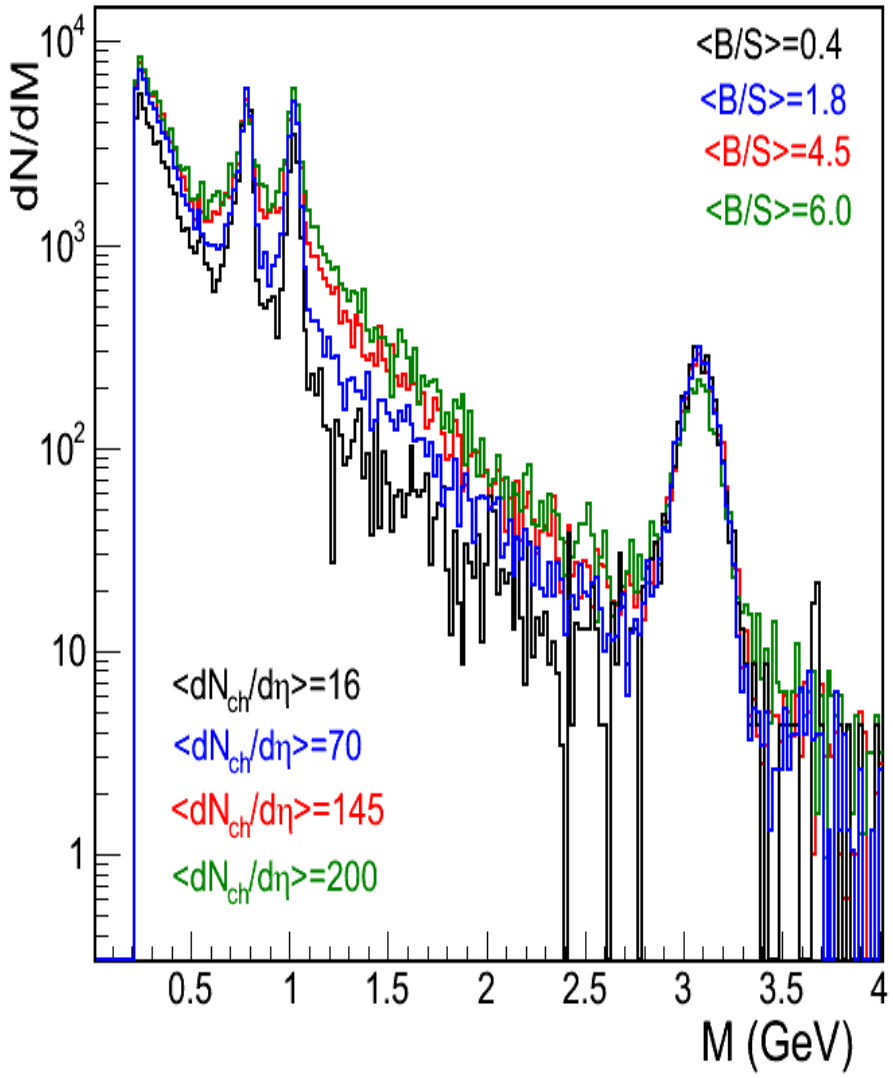
statistics (180) 30 pairs

enhancement (40 AGeV) > enhancement (160 AGeV)

→ baryons driving ρ melting?

→ precision measurements of low mass lepton pairs at lower SPS energies absolutely vital (will never come from RHIC)

Low Mass Lepton Pairs/NA60

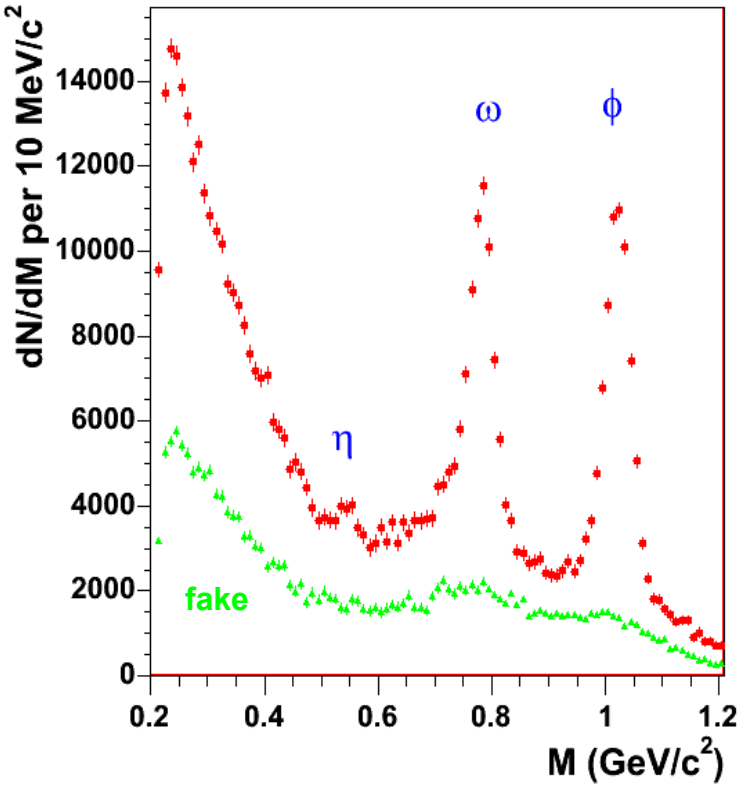


sample size (35%) 370000

final sample 10^6 → 200000

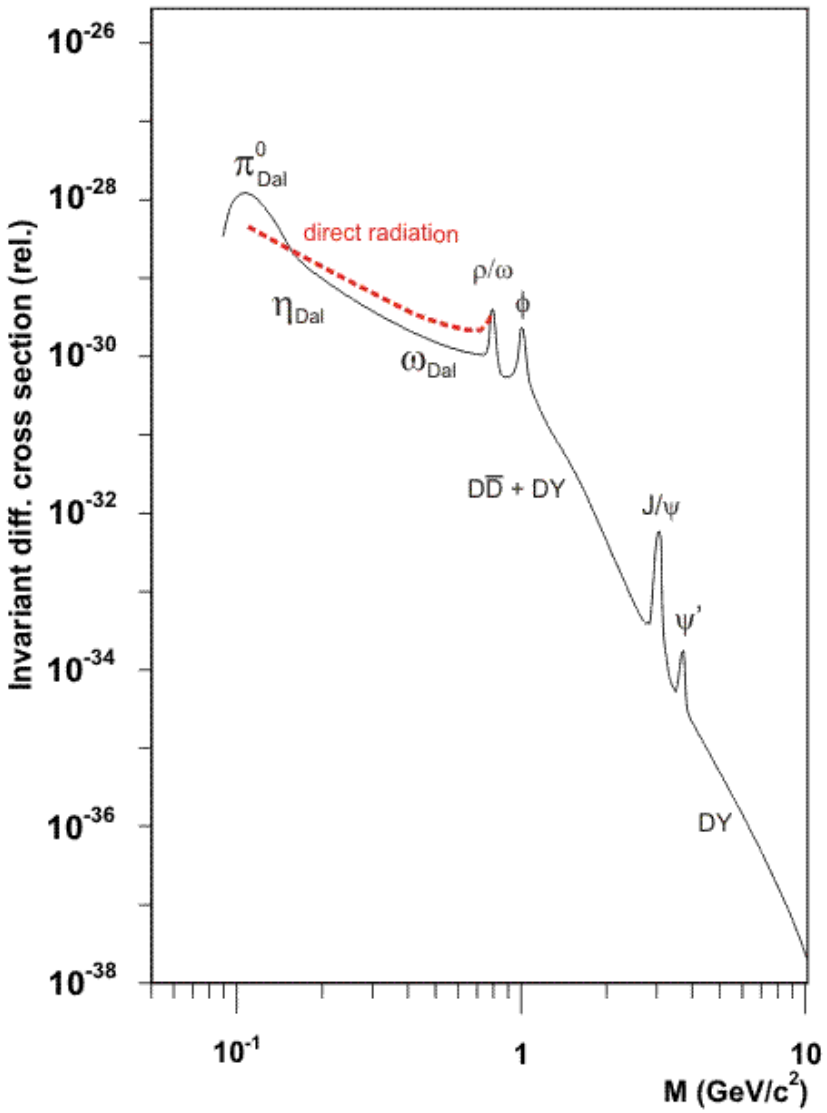
mass resolution

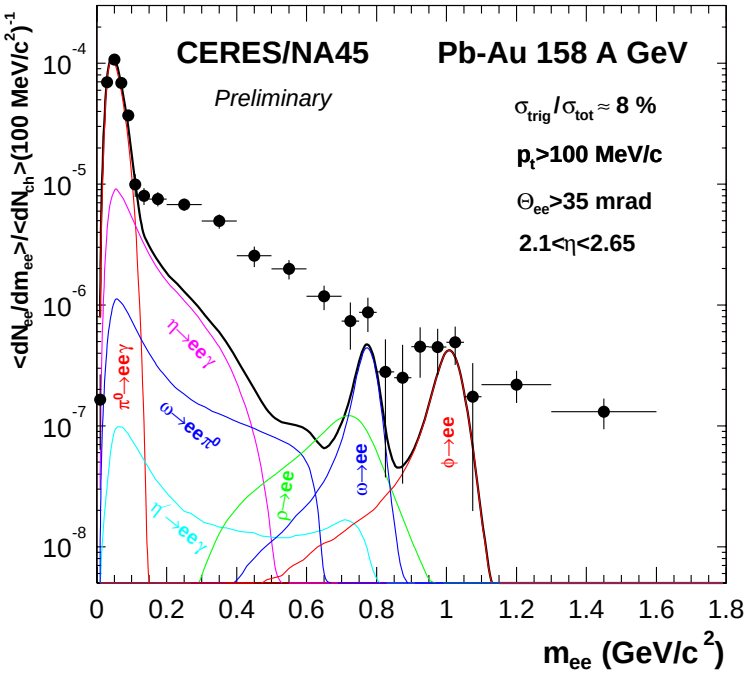
at the ϕ(1.02GeV) 23 MeV



Statistics, mass resolution and multiplicity dependence should bring a major advance in the understanding of low mass lepton pair production

Soft Electron Pairs





cuts p_T<50, m_T<100

→ explore π^0 Dalitz region

(absolute normalization required)

S/B ratio may stay >1.2

Soft electron pairs have analogous information to soft photons

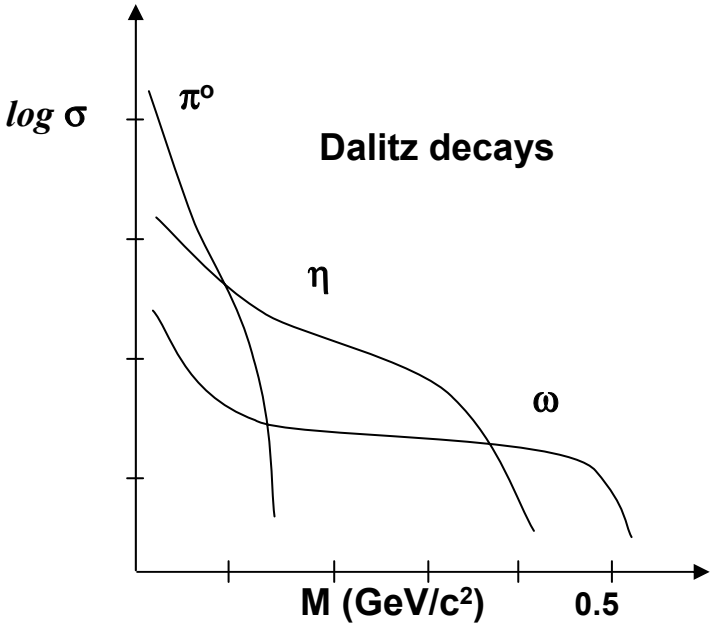
"Quasi Real" Photons?

basic idea: use lepton pairs with small mass m

select $p_T >> m$

→virtual photons close to the pole

problem:



relative to $\pi^0, \eta \rightarrow \gamma\gamma$

Dalitz suppressed by factor α

relative to γ

$\gamma^* \rightarrow l^+l^-$ suppressed by factor α

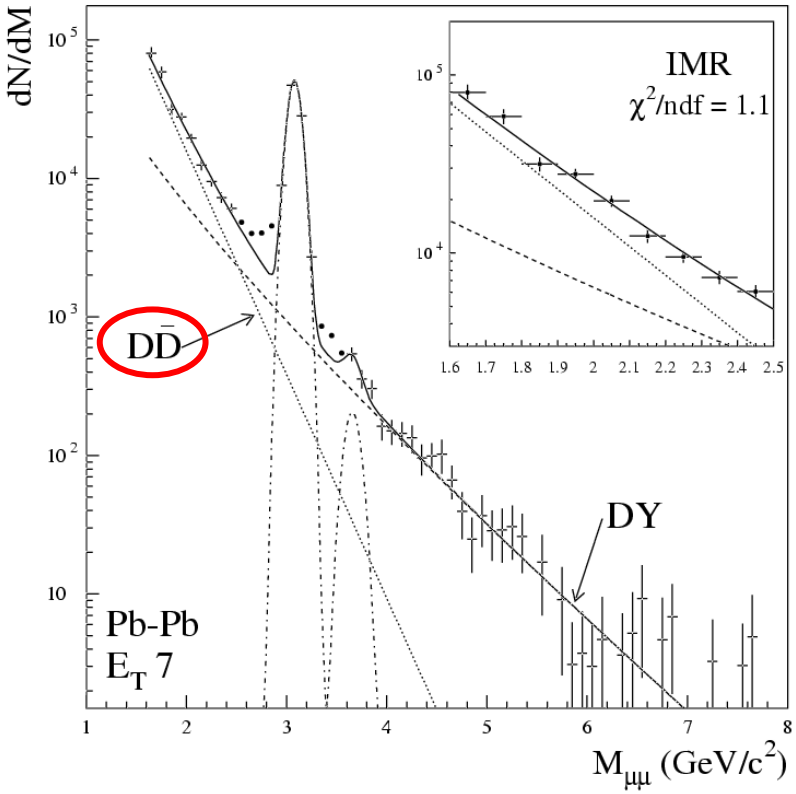
→ probably no net gain

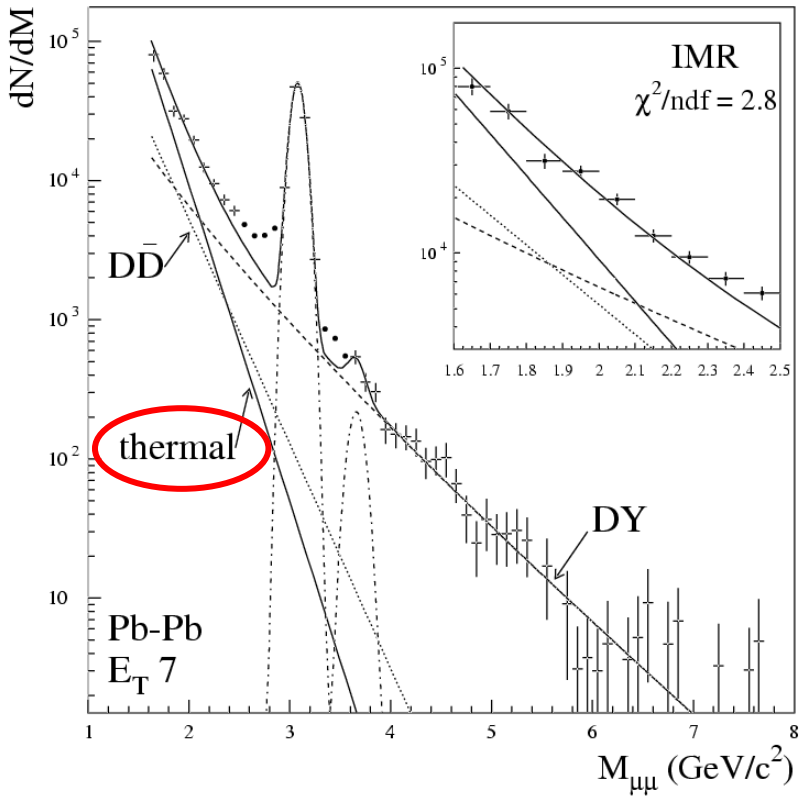
Intermediate Mass Open Pairs/NA50

Charm enhancement or thermal dimuons ?

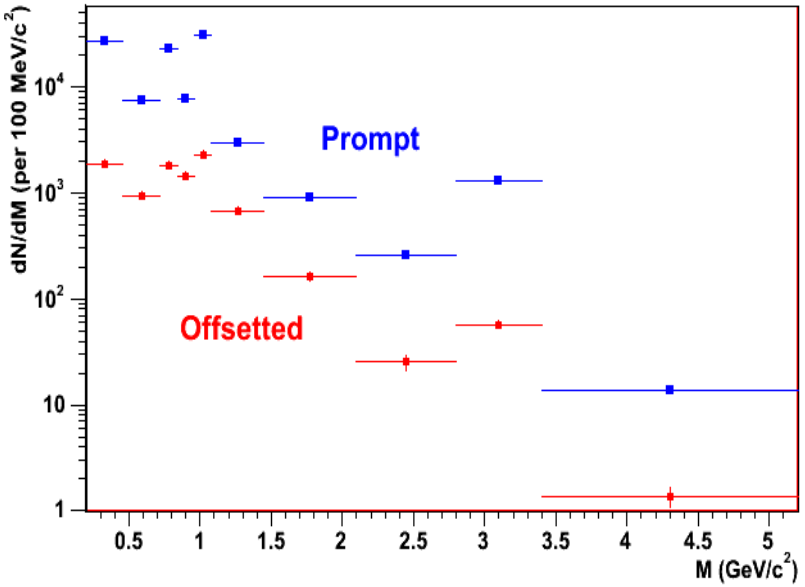
The intermediate mass dimuon yields can be reproduced :

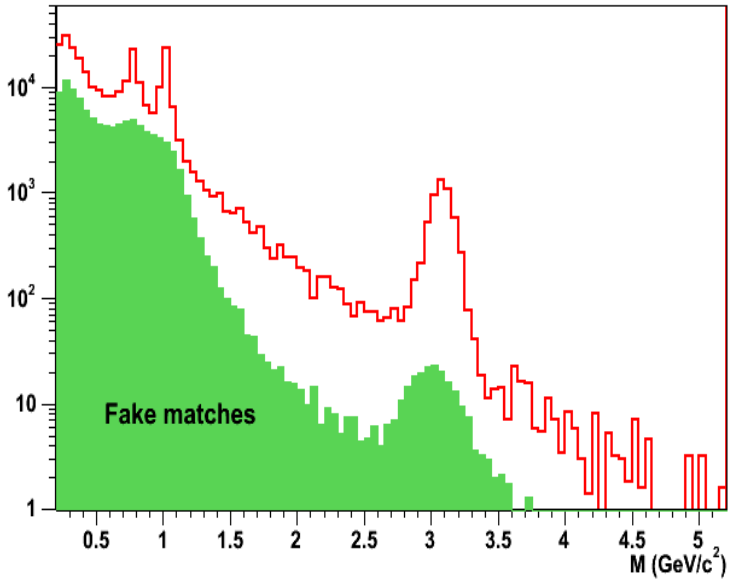
- **by scaling up the charm contribution by up to a factor of 3 (!)**
- **or by adding thermal radiation to the DY and open charm**

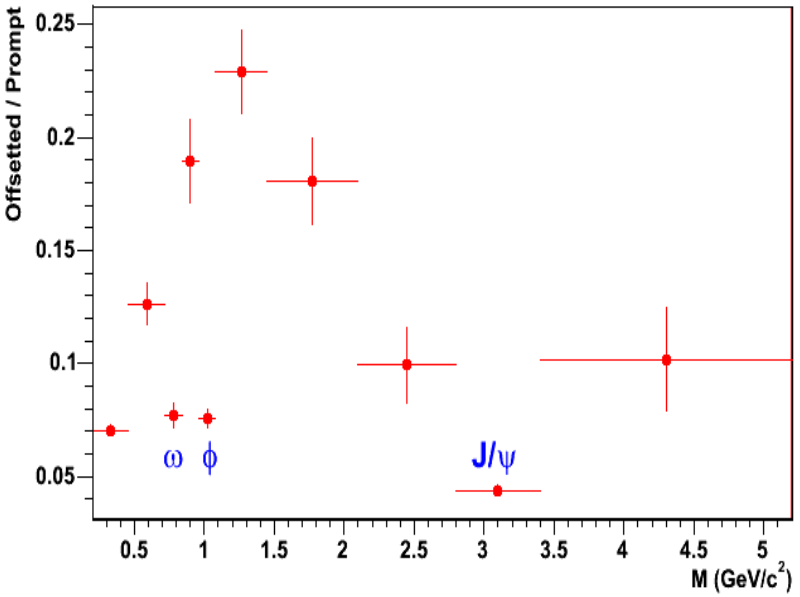




Evidence for Open Charm/NA60







Significant offset yield in the mass region $1.2<m<3$ GeV/c^2, but also between the ω and the ϕ and below the ω

D-decays

RHIC: **at least in d+Au:**

several D-decays (2 and > 2-body) identified

SPS: **great history in pp**

(the experimental revolution of Si-strip detectors)

no transfer of that culture to the initial AA program

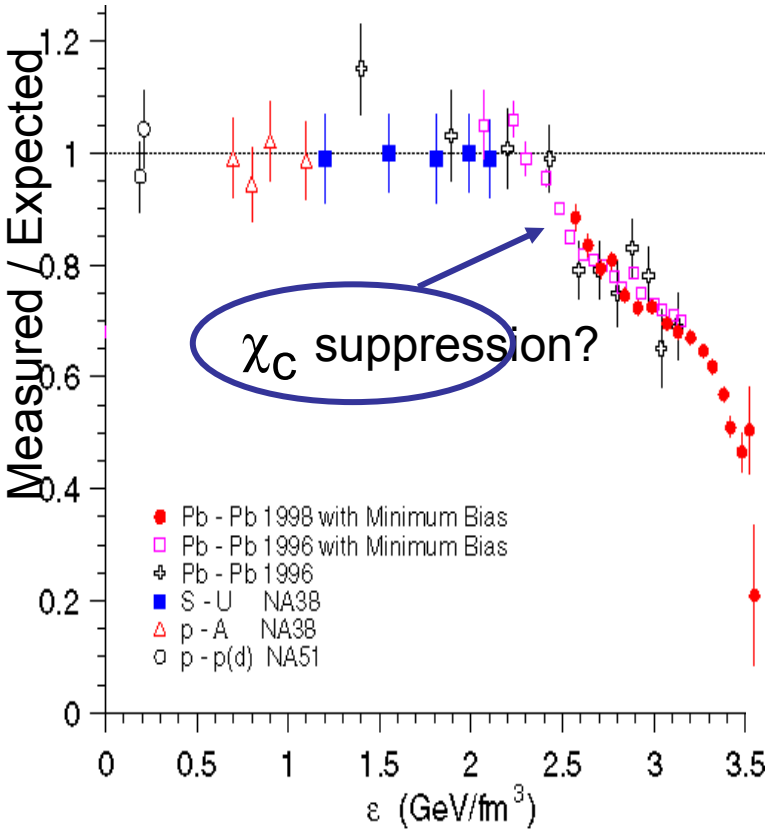
CERES ?

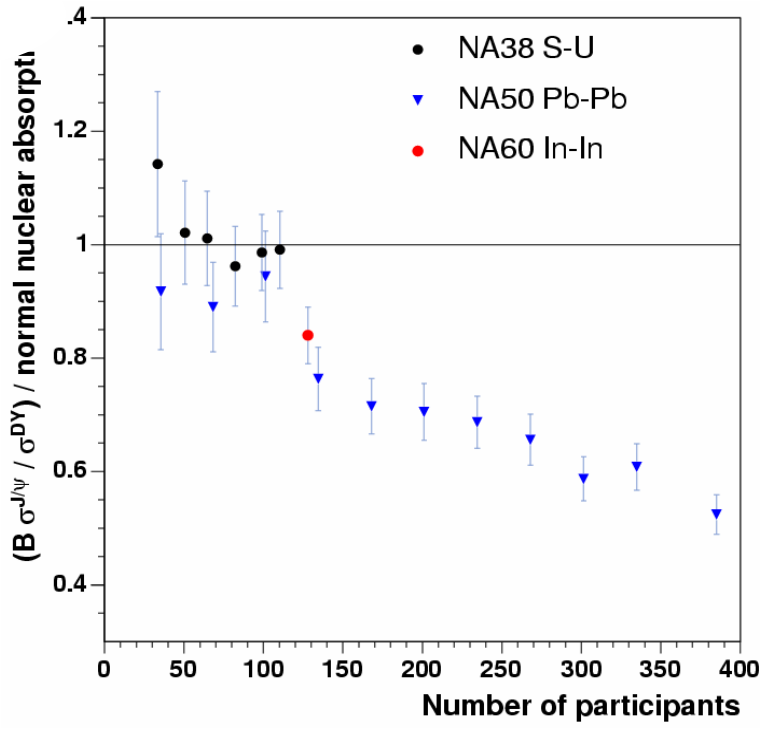
NA60 ?

A dedicated new effort ?

J/ψ suppression/NA50 +NA60

Anomalous J/ψ suppression: evidence for deconfinement?

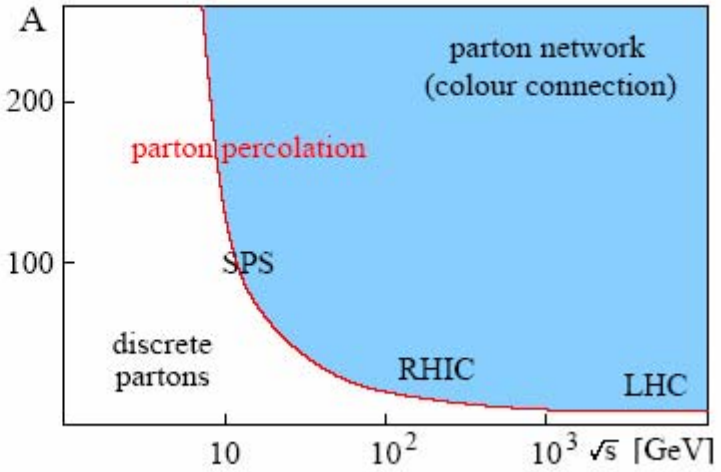




- **Is the deconfined phase reached through a geometrical transition (percolation) or through a thermal transition (QGP) ?**
- **does the J/ψ melt through initial-state parton density (structure functions) or final state-parton density (QGP)?**

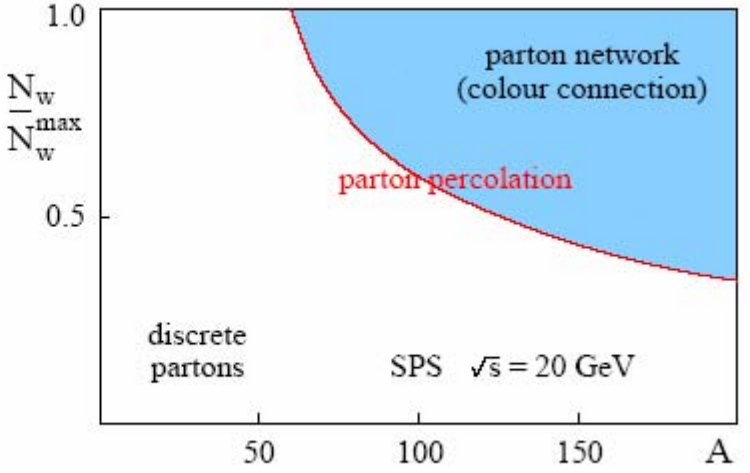
Percolation at SPS Energies/H.Satz

schematic:
central $A-A$ collisions
vs. A and $\sqrt{s}$

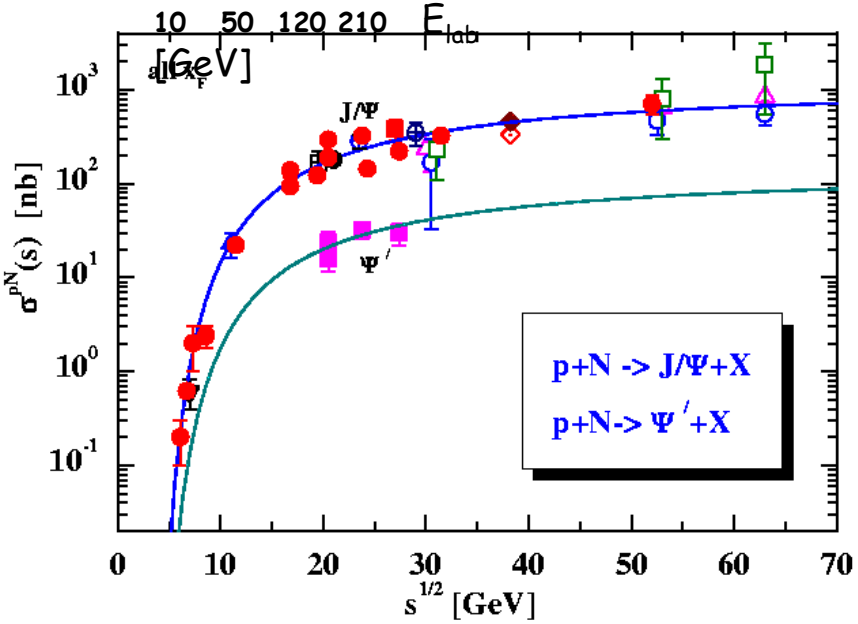


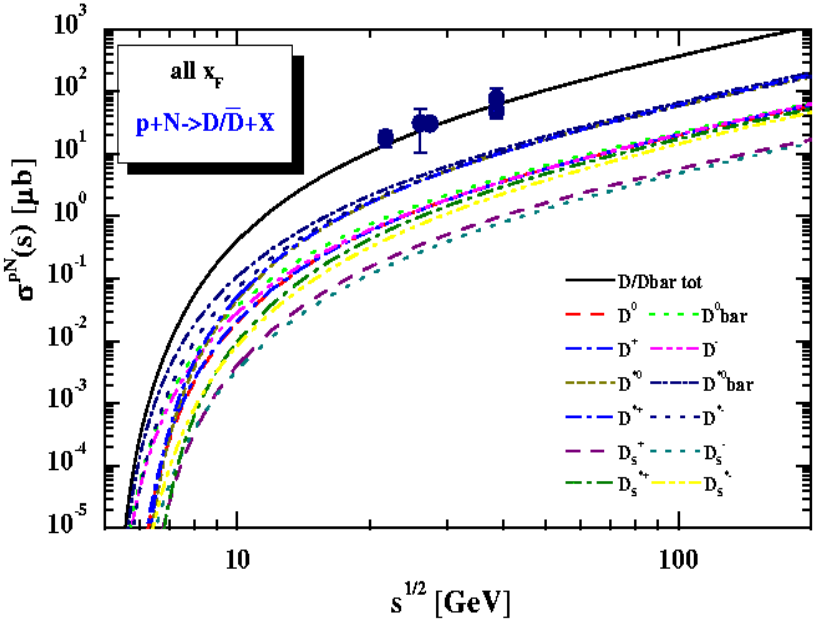
$\Rightarrow$ onset of percolation
best accessible at SPS

schematic:
$Pb-Pb$ collisions
vs.centrality
SPS, $\sqrt{s} = 20$ GeV



Excitation Function of Charm and Charmonia Production





Can the physics of J/ψ, ψ' and open charm be done at lower energy than 158 AGeV?

energy (AGeV)	158	40	
σ_{rel}	1	0.08	0.08
<y>	3.5	3.5	2.2
rel. loss	1	0.2	1
rel. total	1	0.016	0.08
J/ψ's	100000	1600	8000

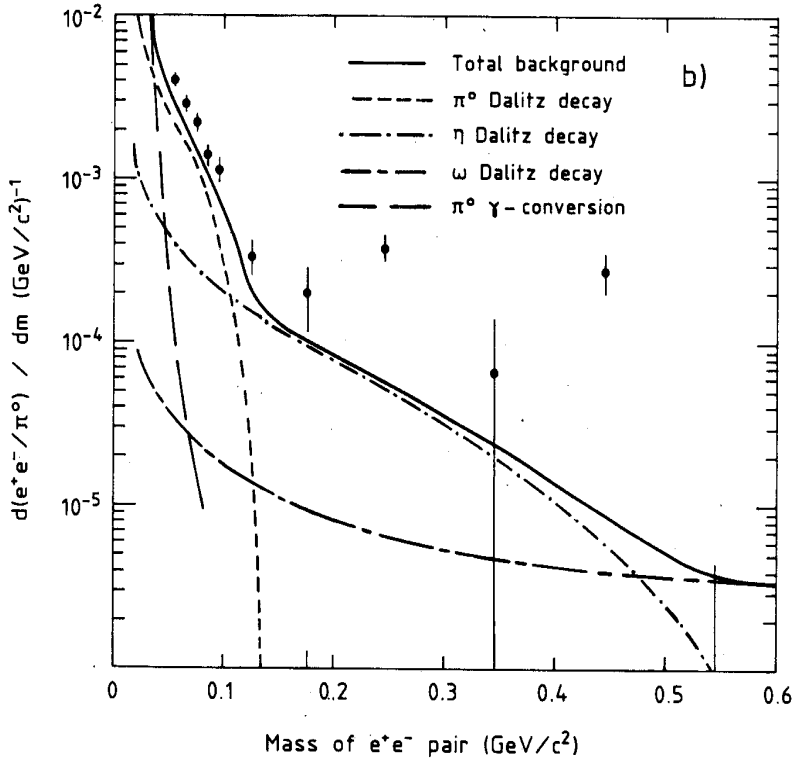
GSI quotation:

10^5 J/ψ /week at 25 AGeV !

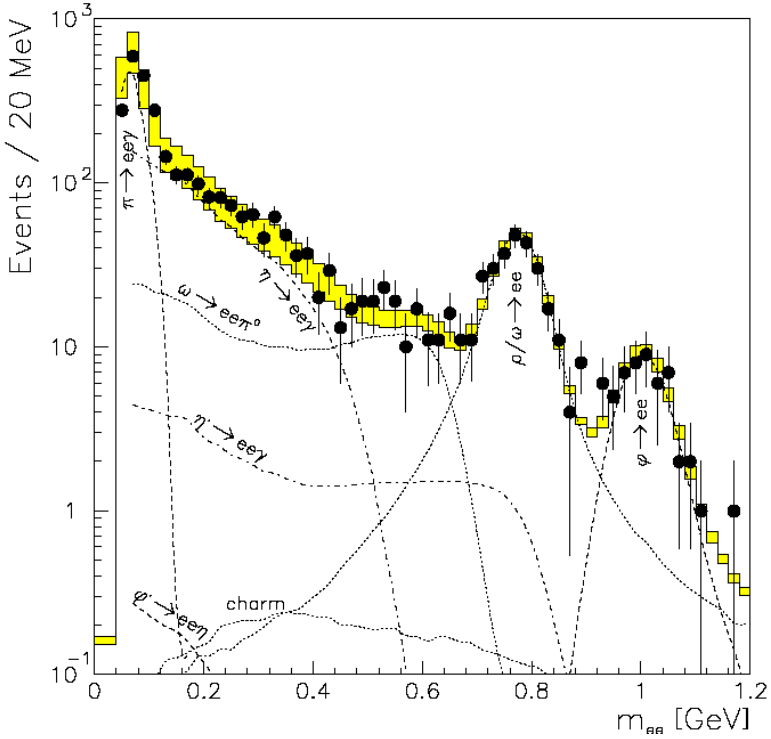
Luminosity

Luminosity, Luminosity, Luminosity!

R807/ ISR (1985)



HELIOS N34/I (1993)



Availability of Heavy Ions for SPS Fixed Target Physics

Until Nov. 2003, Heavy Ions for Fixed Target physics were produced via :

Ions source – Linac 3 - PS Booster – PS - SPS

Since then, the production of Lead Ions for LHC has started via :

(new) Ions source – Linac 3 - LEIR – PS - SPS

⇨ The previous Heavy Ions route via the PSB is not available anymore as synchronisation PSB/Linac3 has been disactivated and converted into a synchronisation LEIR/Linac3

J.P.Riunaud Villars 2004

Availability of Heavy Ions for SPS Fixed Target Physics

Planning of the Lead Ions for LHC :

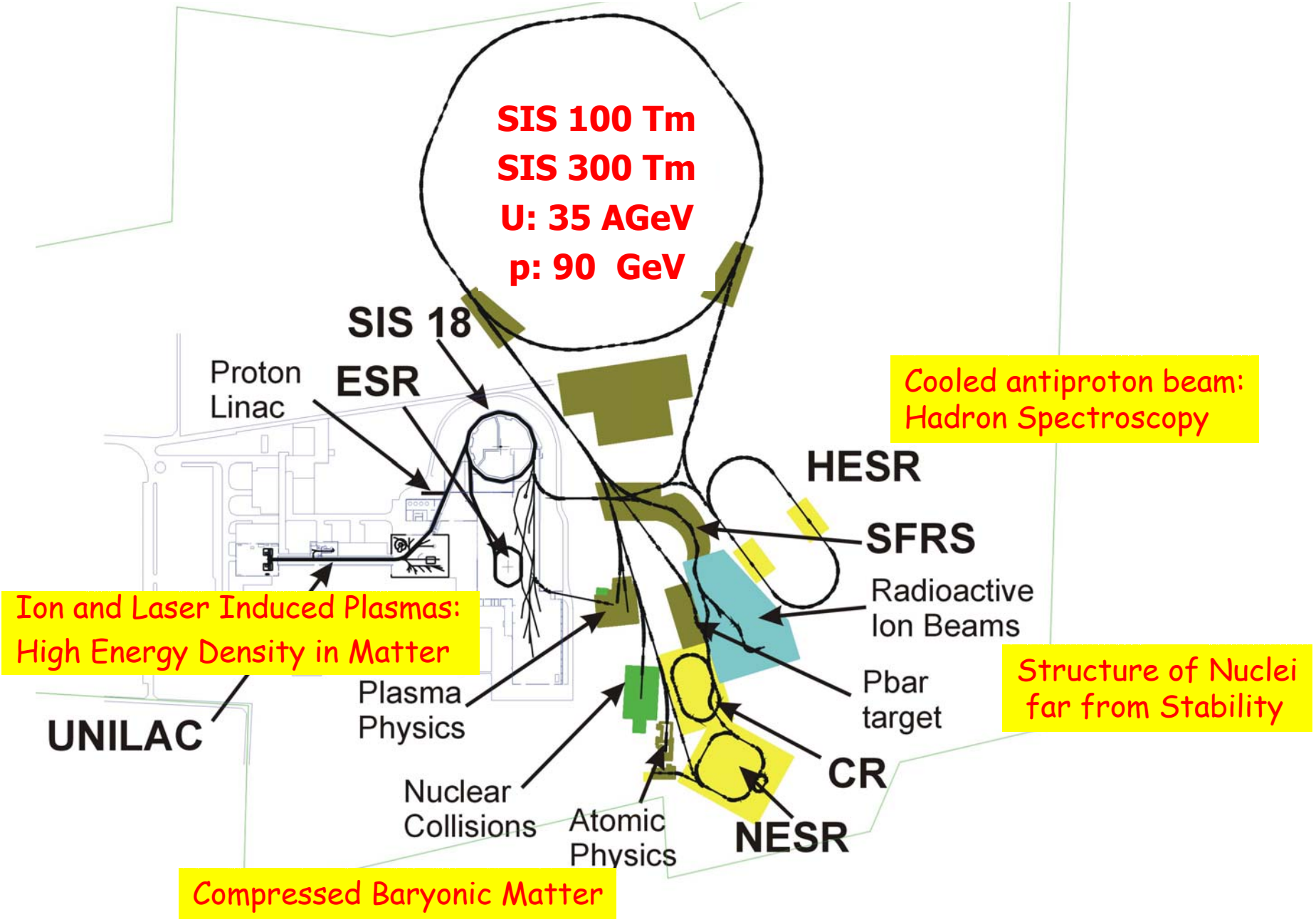
- **Linac3 start up with Pb ions 02/2005**
- **Linac3 to LEIR injection line commissioning 06/2005 to 08/2005**
- **LEIR commissioning 08/2005 to 03/2006**
- **PS commissioning : 25 shifts in 2006 (6 dedicated MDs)**
- **SPS commissioning : 34 shifts in 2007 (24 dedicated MDs)**
- **LHC commissioning and physics with "early beam" : 2008**

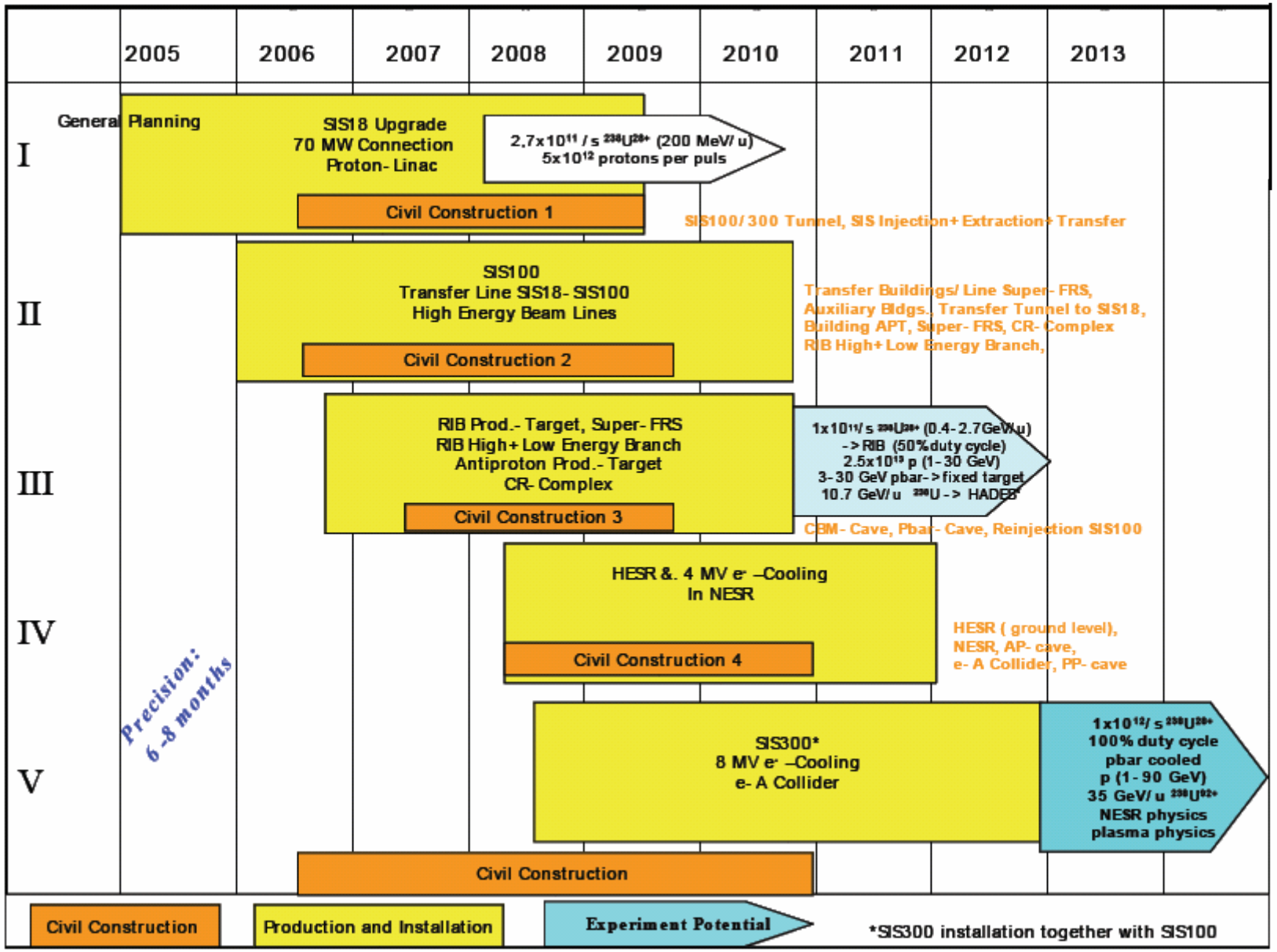
⇨ Lead ions can only be available for Fixed Target physics
- when they are available in the SPS and
- when they have been tuned for Fixed Target operation
(different beam in SPS than for LHC)

⇨ **With the present I-LHC schedule, Lead ions can only be available after the ion LHC commissioning in 2008**

J.P.Riunaud Villars 2004

The future Facility for Antiproton an Ion Research (FAIR)




2005
2006
2007
2008
2009
2010
2011
2012
2013
I
II
III
IV
V
General Planning
SIS18 Upgrade
70 MW Connection
Proton- Linac
2,7x10¹¹ / s ²³⁸U²⁸⁺ (200 MeV/ u)
5x10¹² protons per puls
Civil Construction 1
SIS100/ 300 Tunnel, SIS Injection+ Extraction+ Transfer
SIS100
Transfer Line SIS18- SIS100
High Energy Beam Lines
Civil Construction 2
Transfer Buildings/ Line Super- FRS,
Auxiliary Bldgs., Transfer Tunnel to SIS18,
Building APT, Super- FRS, CR- Complex
RIB High+ Low Energy Branch,
RIB Prod.- Target, Super- FRS
RIB High+ Low Energy Branch
Antiproton Prod.- Target
CR- Complex
Civil Construction 3
1x10¹¹/ s ²³⁸U²⁸⁺ (0.4- 2.7GeV/u)
-> RIB (50% duty cycle)
2.5x10¹³ p (1- 30 GeV)
3- 30 GeV pbar- > fixed target
10.7 GeV/ u ²³⁸U -> HADES
CBM- Cave, Pbar- Cave, Reinjection SIS100
HESR &. 4 MV e⁻ –Cooling
In NESR
Civil Construction 4
HESR (ground level),
NESR, AP- cave,
e- A Collider, PP- cave
Precision:
6 -8 months
SIS300*
8 MV e⁻ –Cooling
e- A Collider
1x10¹²/ s ²³⁸U²⁸⁺
100% duty cycle
pbar cooled
p (1- 90 GeV)
35 GeV/ u ²³⁸U⁹²⁺
NESR physics
plasma physics
Civil Construction
Civil Construction
Production and Installation
Experiment Potential
*SIS300 installation together with SIS100

Conclusions on future SPS Running

Full Energy

continuation of NA60 with Pb-Pb (a must !)

- **low mass pairs**
- **intermediate masses**
- **J/ψ physics**

Full and lower energies

(continuation of NA49)

continuation of NA60

- **low mass pairs**
- **intermediate masses**
- **J/ψ physics**

dedicated experiment on real photons

- **better data for all p_T**
- **soft photons (a must!)**

soft electron pairs?