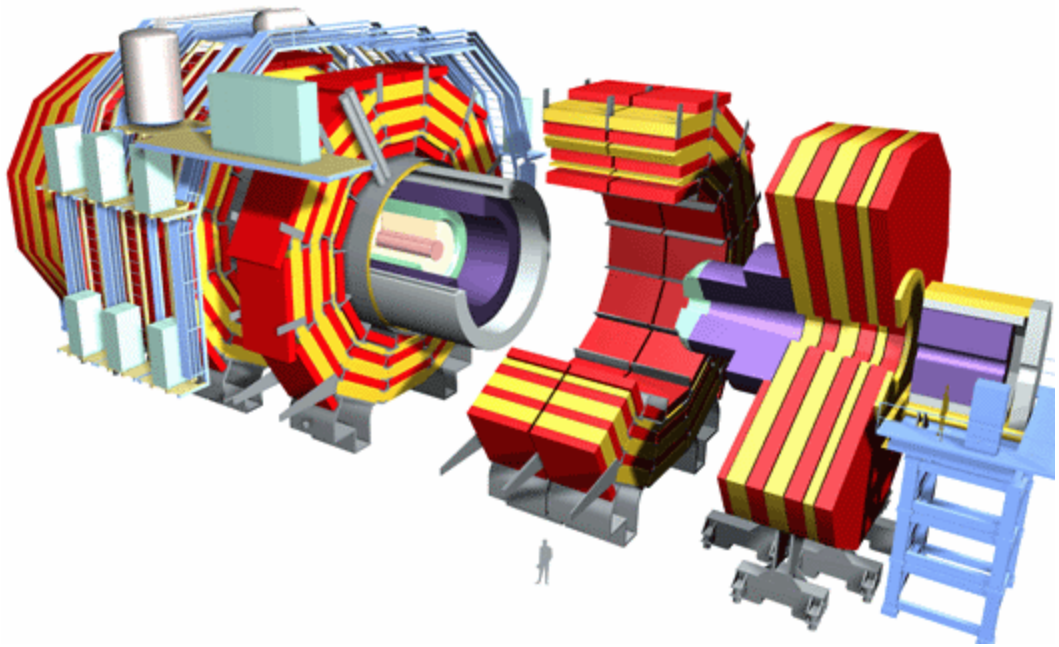
Heavy Ion Physics with CMS



Pablo Yepes, Rice University
for the CMS Collaboration
Quark Matter Jan 16, 2001

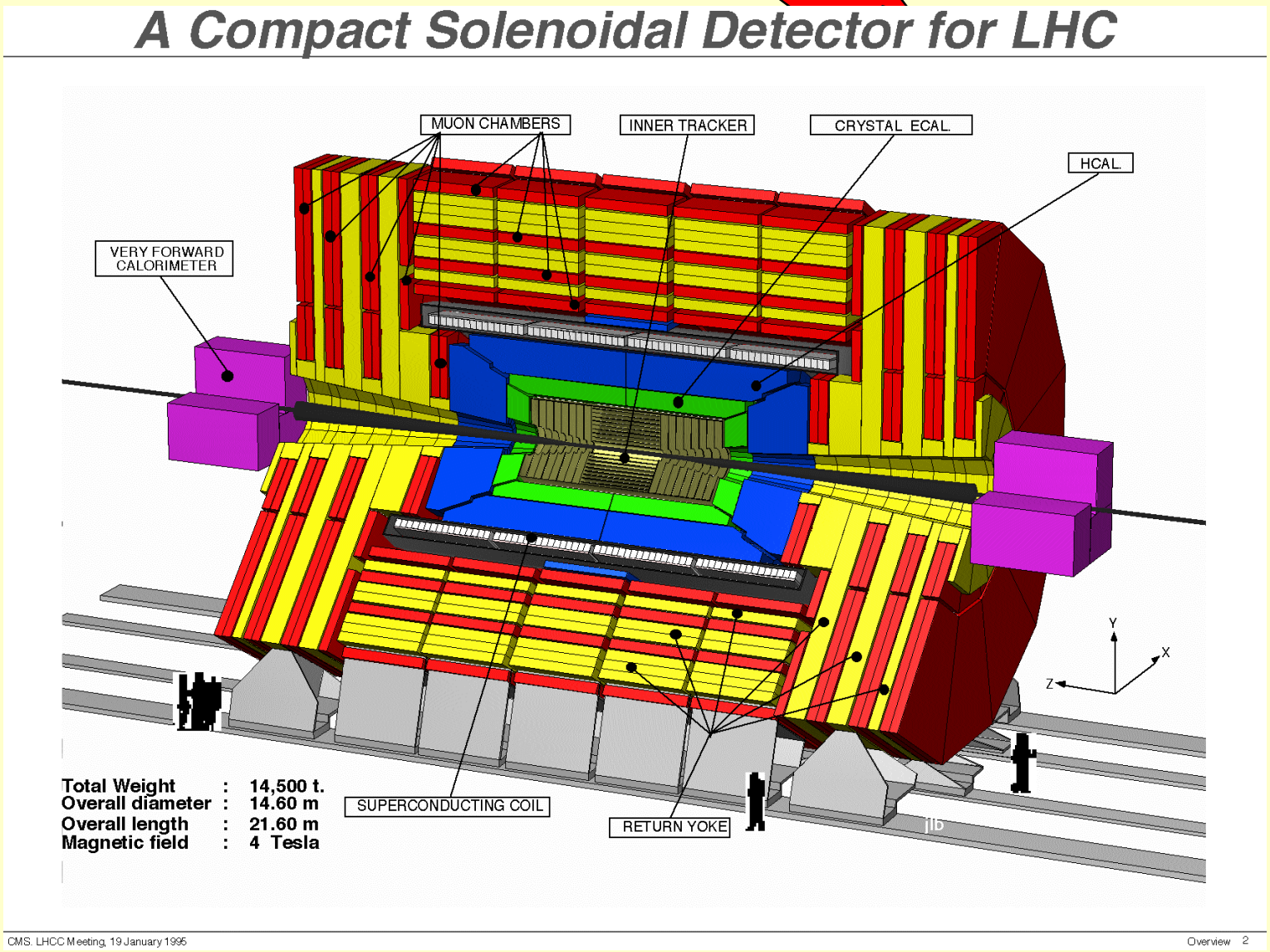
What To Expect from LHC

- LHC (Large Heavy ion Collider) is expected to provide pA and AA collisions.
- Energy: 7 TeV/charge

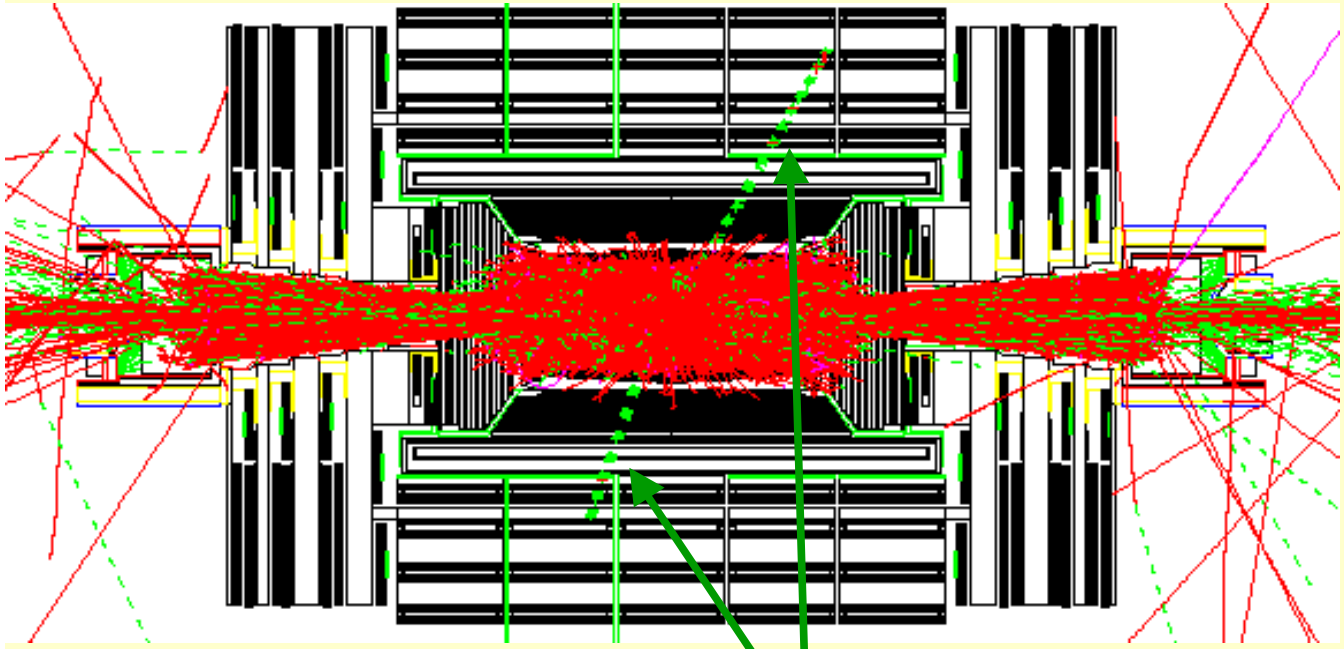
Luminosity

Ion	L_{max}	<L>
$^{208}Pb^{82}$	$1.0\ 10^{27}$	$4.2\ 10^{26}$
$^{120}Sn^{50}$	$1.7\ 10^{28}$	$7.6\ 10^{27}$
$^{84}Kr^{36}$	$6.6\ 10^{28}$	$3.2\ 10^{28}$
$^{40}Ar^{18}$	$1.0\ 10^{30}$	$5.2\ 10^{29}$
$^{16}O^{8}$	$3.1\ 10^{31}$	$1.4\ 10^{31}$

What to Expect From CMS



Stretching CMS



A minimum bias Pb-Pb event in CMS

Detector designed for pp. However due to flexible design offers unique capabilities for AA

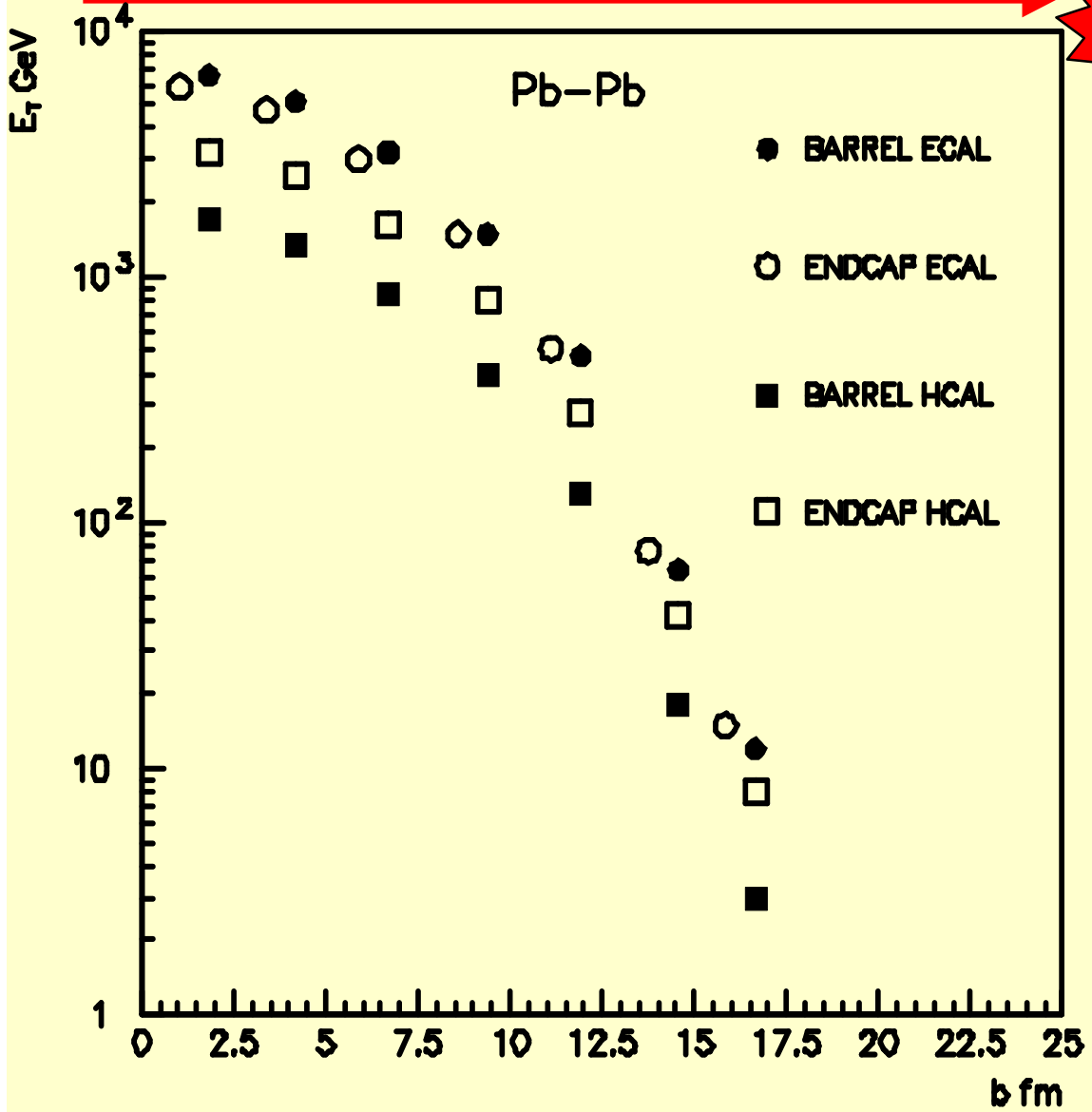
Some CMS Assets

- CMS has excellent muon detection capabilities:
  - $|\eta|<1.3$ for barrel and $|\eta|<2.4$ with endcaps.
  - Good mass resolution: 46 MeV for the Upsilon.
  - Efficient suppression of background from π/K decays:
    - Electromagnetic calorimeter at 1.3 m from beam axis.
    - P_T threshold at 3.5 GeV/c for a single muon to reach the μ-chambers.
- Large calorimeter coverage with good jet reconstruction capabilities.

Physics Topics

- Event Characterization
- Quarkonium Production: Upsilon and J/Ψ
- Z➔μμ
- Jet Production:
  - Single/Double jet ratios.
  - Z and γ tagged jets
- *Ultra-Peripheral Collisions: γγ and γ-Pomeron*

Event Characterization



In spite of very strong magnetic field (4 Tesla) there is a good correlation between centrality and transverse energy.

Quarkonia Cross Sections

- A scaling law:

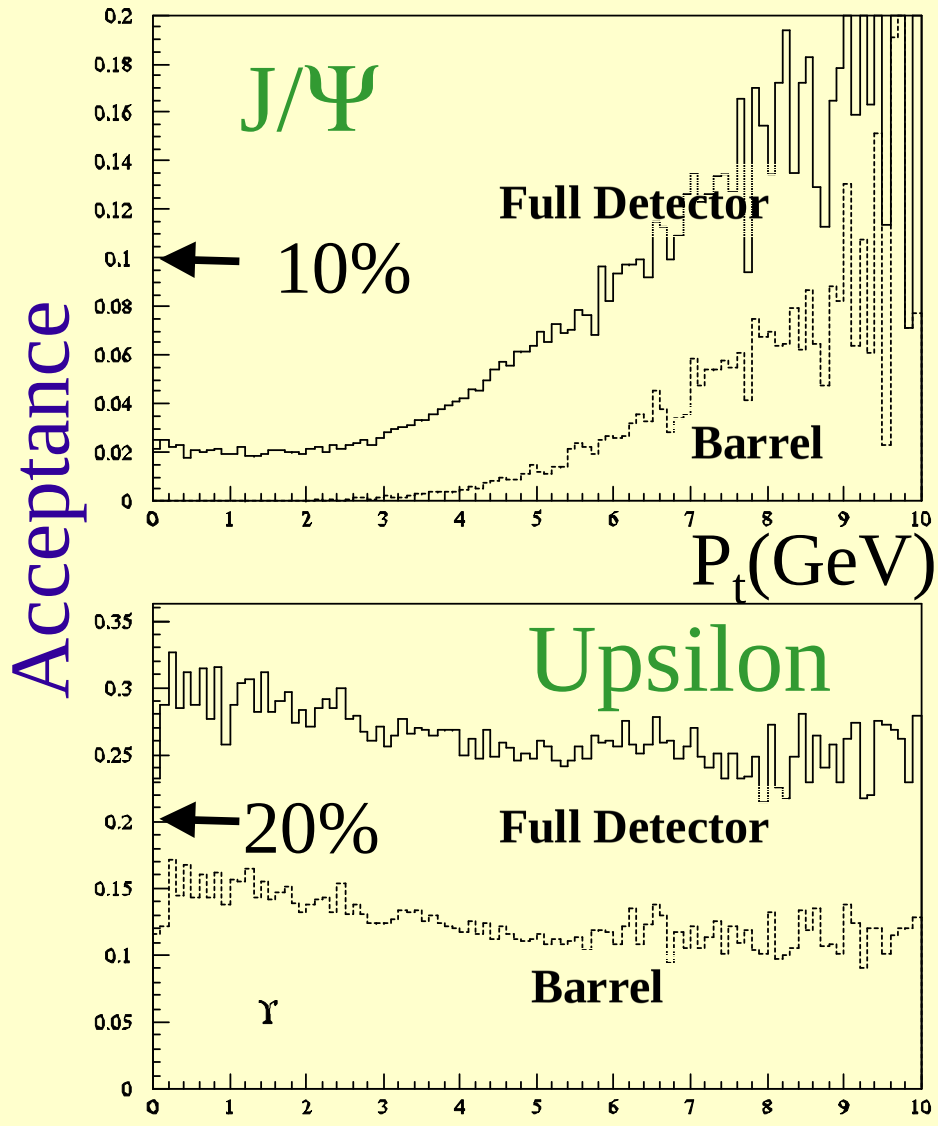
$$\sigma_{AA} = A^{2\alpha}\,\sigma_{pp}$$

- σ_{pp} from CDF @ 1.8 TeV extrapolated to 5.5(7) TeV.
- α=0.9(0.95) for J/Ψ (Upsilon).

Production Cross Sections for our studies

	Pb+Pb	*Ca+Ca*
J/Ψ (mb)	58.0	3.6
Ψ' (mb)	1.4	0.09
ϒ (μb)	410	21
ϒ' (μb)	120	6.4
ϒ'' (μb)	41	2.1

Quarkonia Acceptance in μ–Chambers



- J/Ψ with p_T>5 GeV in Barrel
- Upsilon down to low transverse momentum

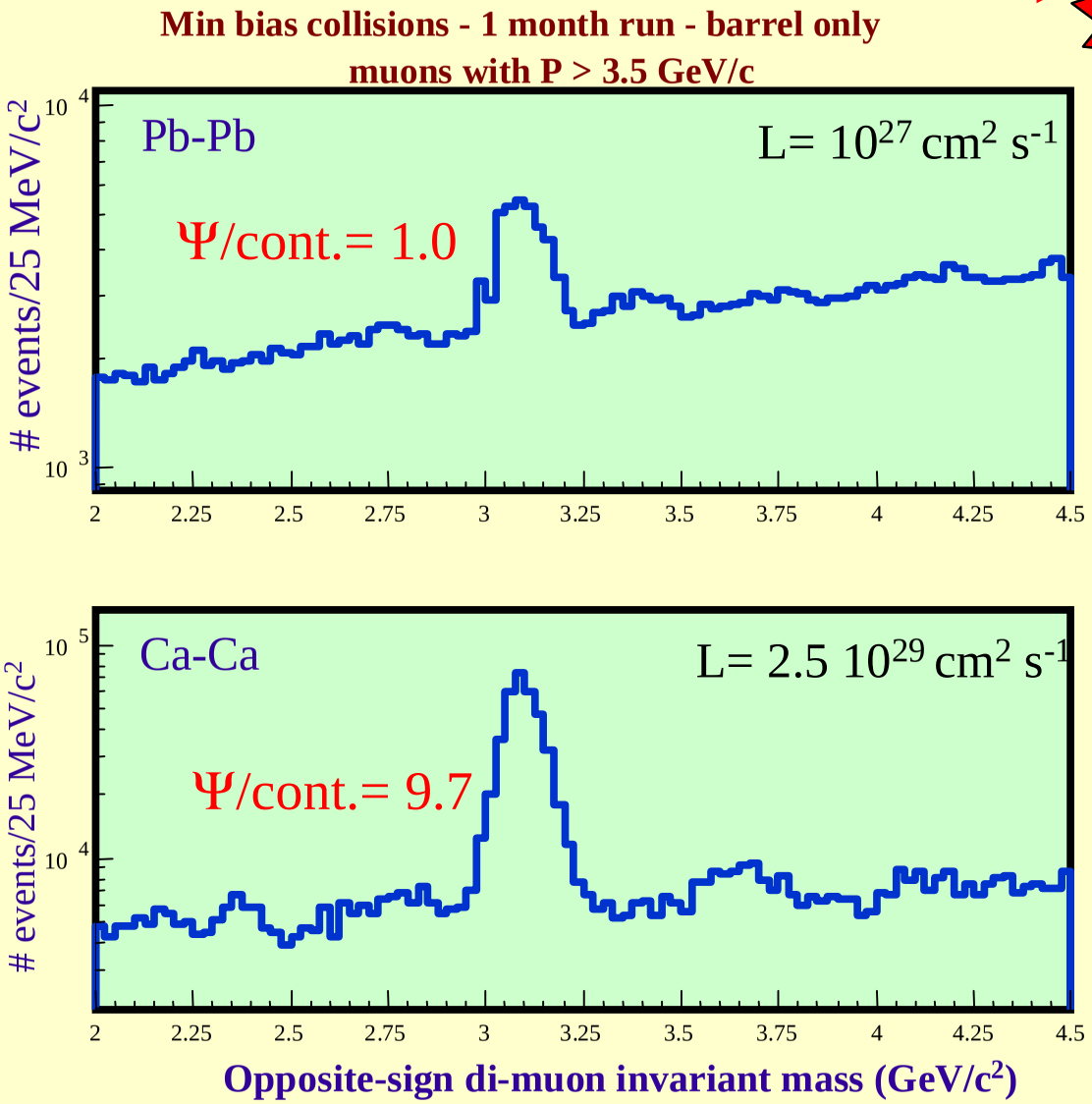
Quarkonia Reconstruction

- Essential sub-detectors:
  - Tracking devices
  - Muon system
- Pessimistic assumptions for background estimates:
  - $dN^{ch}/dy=8000$ (most generators < 5500)
  - $\langle p_t \rangle^{\pi}=0.48$ GeV/c (HIJING 0.39 GeV/c)
  - $\langle p_t \rangle^{k}=0.67$ GeV/c

Special Heavy Ion Tracking Algorithm

Significant Muon background from π and K decays

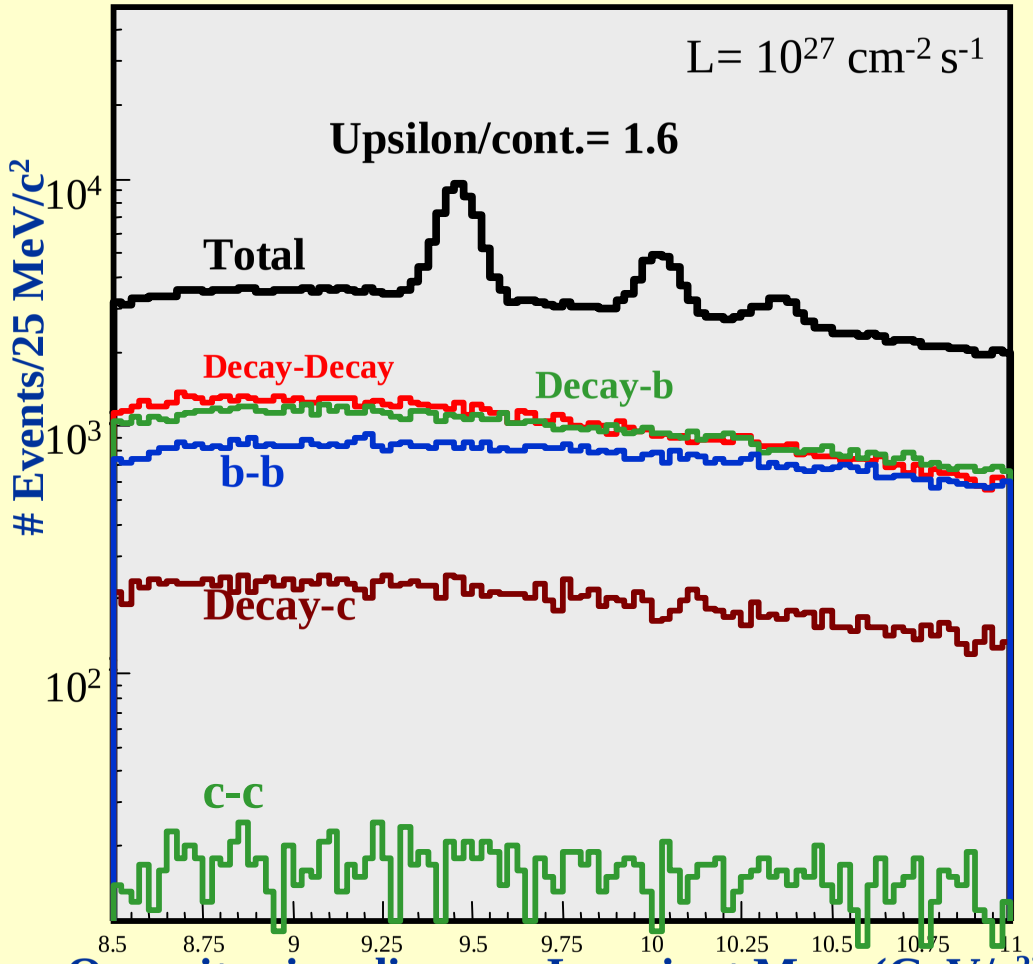
J/Ψ Signal



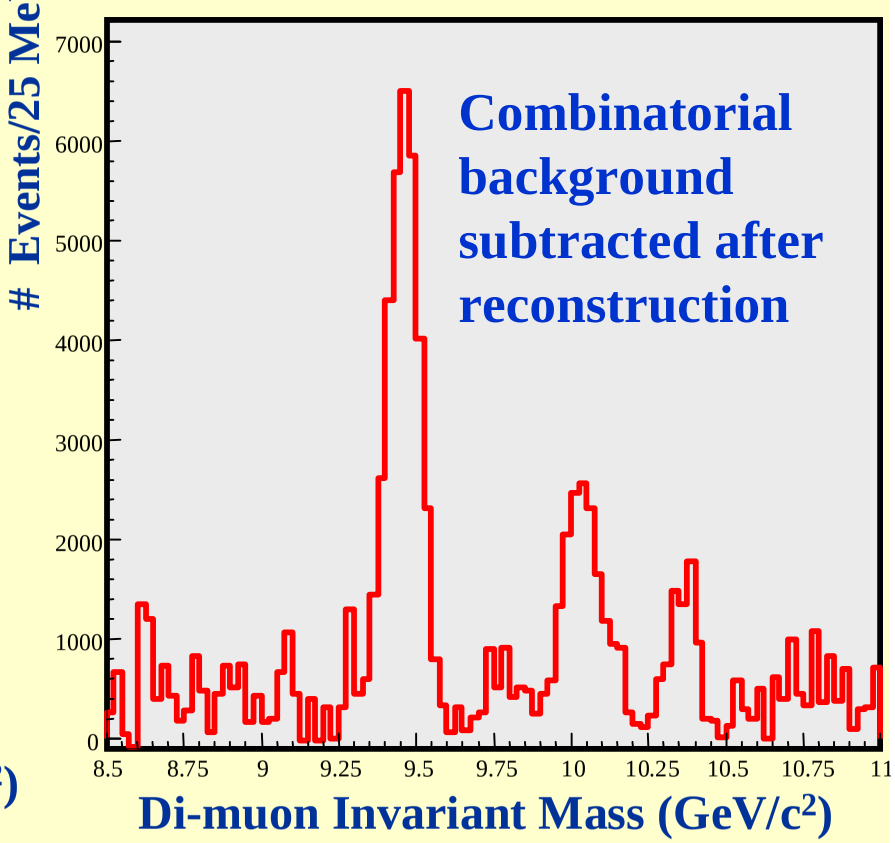
1 month running at top Luminosity:
J/Ψ's detected and reconstructed in the Barrel:

	Ca-Ca	*Pb-Pb*
# J/Ψ	2.2 10^5	10^4
S/B	9.7	1.0

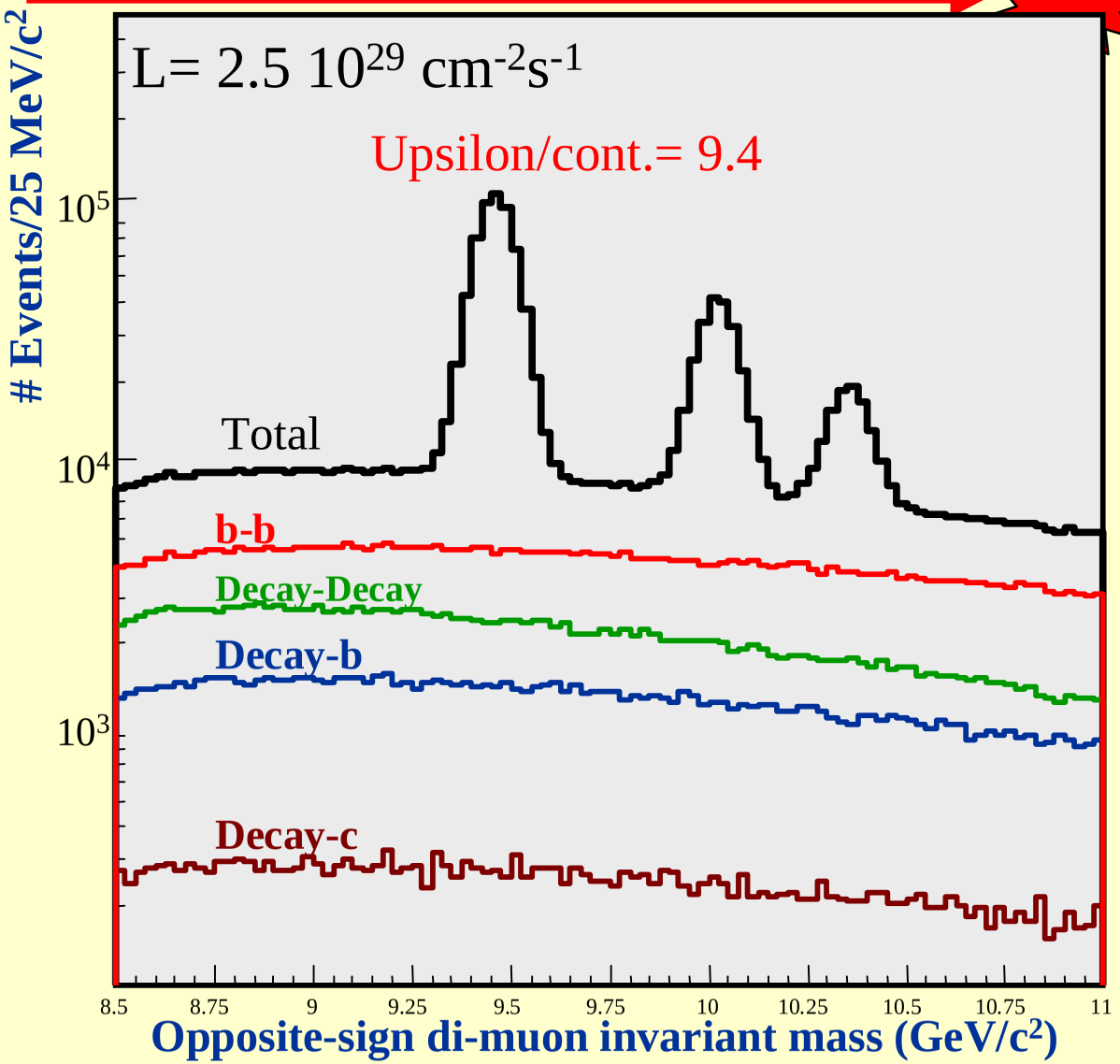
Upsilon in Pb-Pb



1 month: 22000 Υ and 7500 Υ' detected in the barrel



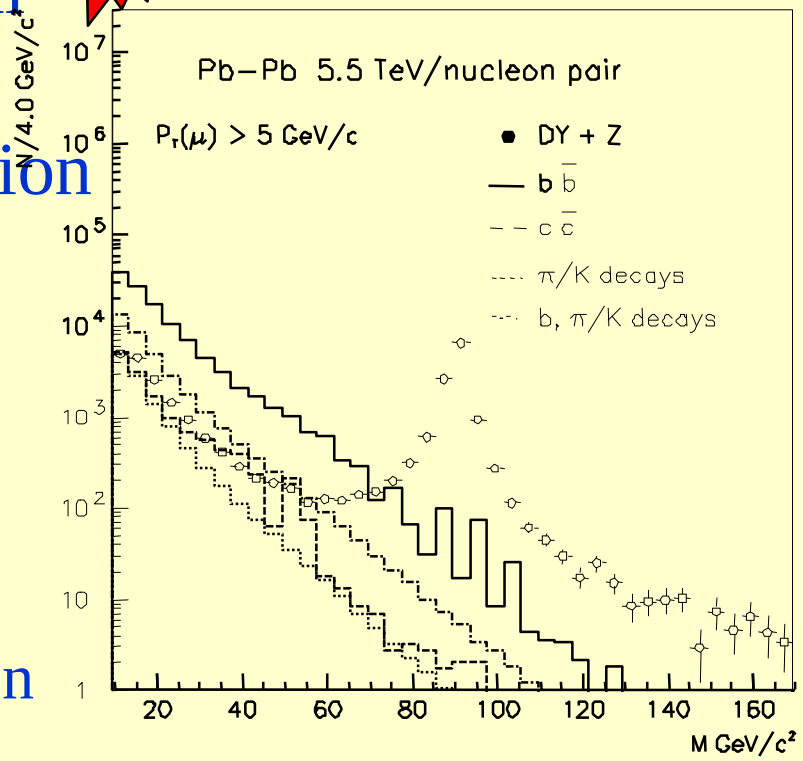
Upsilon in Ca-Ca



- 1 month:
  - 340000 Υ
  - 115000 Υ'
- Only barrel used.

Quarkonia Reference

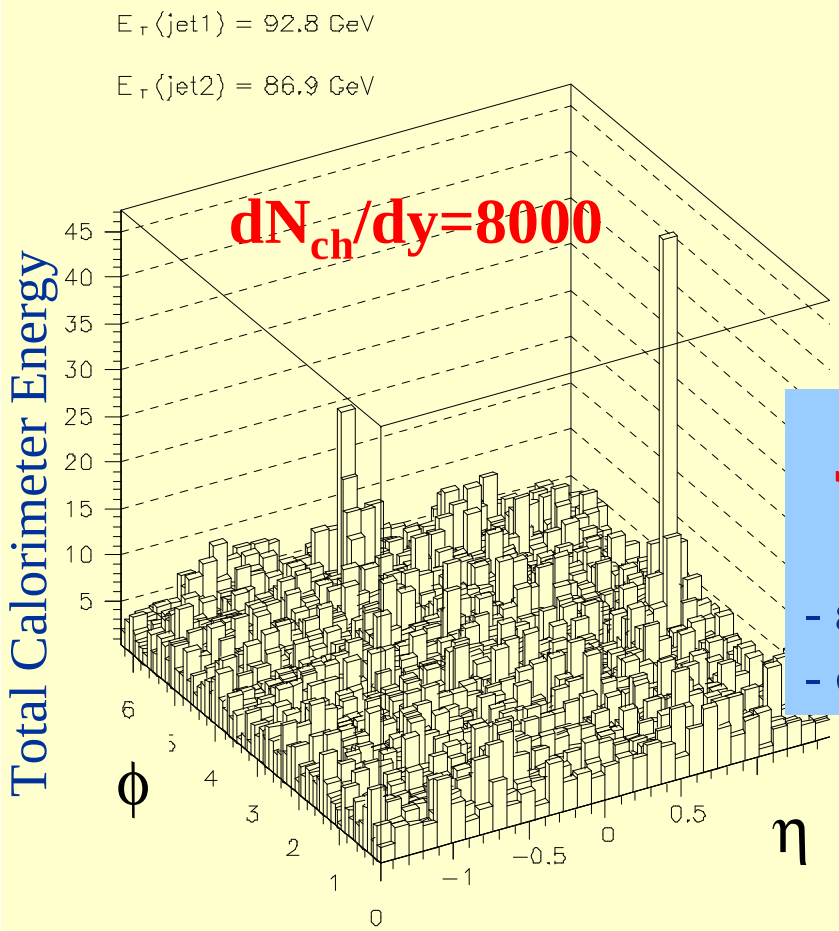
- At SPS, J/Ψ is compared to Drell-Yan.
- At LHC Drell-Yan contribution is negligible.
- Z^0 proposed as reference to ϒ production.
  - $M_Z > M_\Upsilon$
  - Different production mechanisms:
    - Z_0: antiquark-quark, quark-gluon and antiquark-gluon.
    - ϒ: gluon-gluon.
- Cross check di-muon reconstruction algorithm



Jets are Easy

Jet quenching

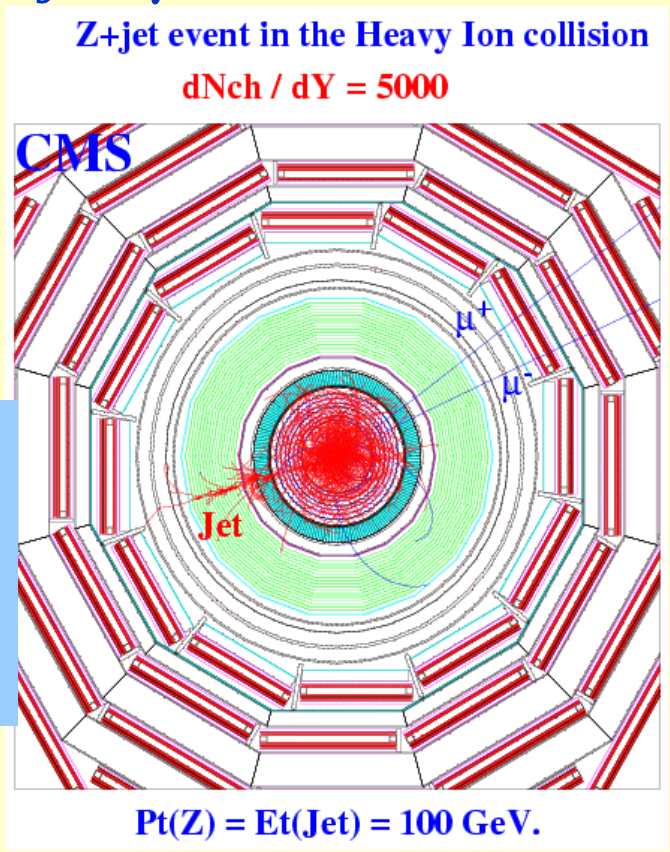
- monojet/dijet enhancement
- jet-$Z^0 \rightarrow \mu\mu$ or jet-γ



Jet Finding

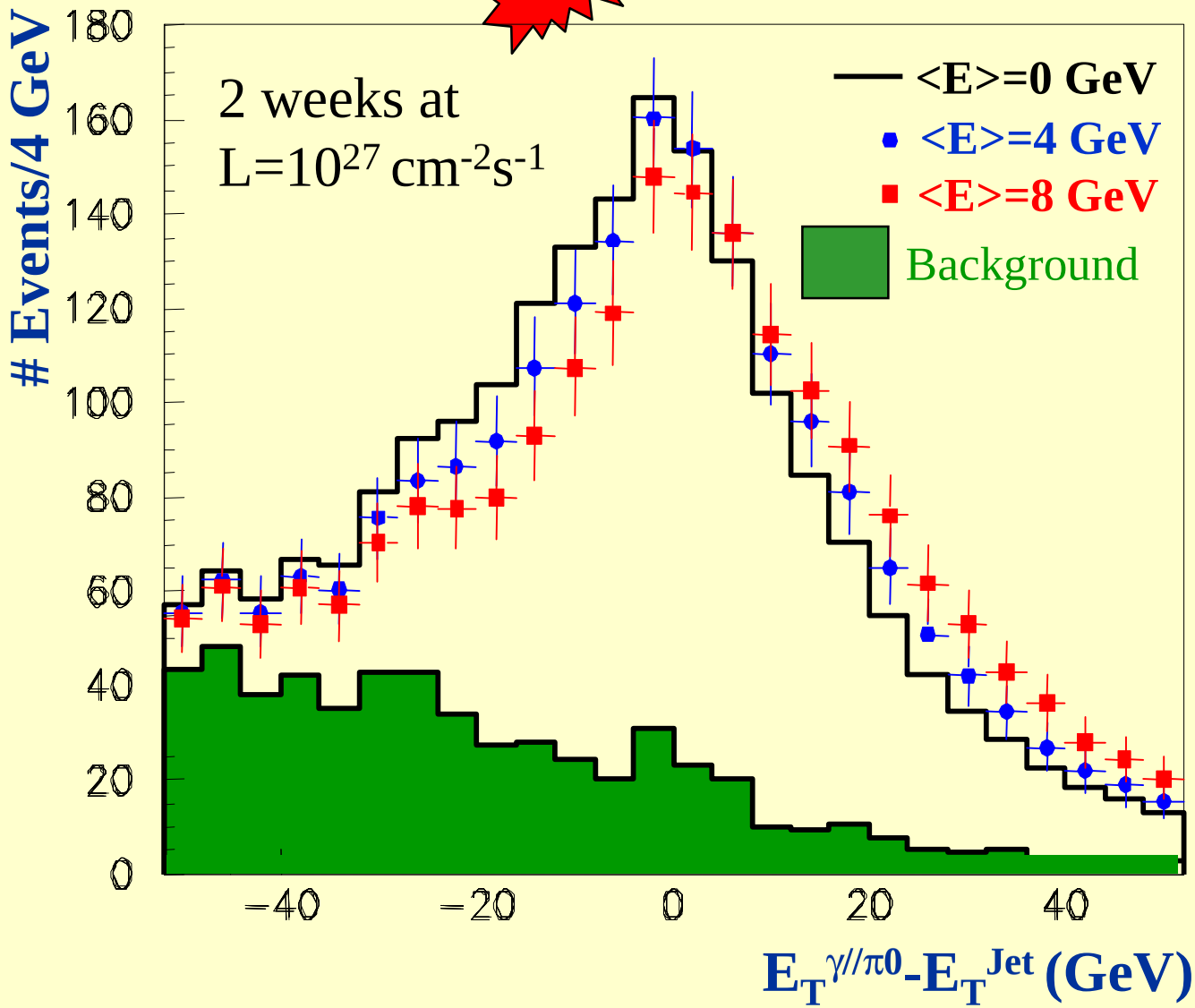
100 GeV E_T

- ε~100%
- $\sigma(E_T)/E_T$=11.6%.

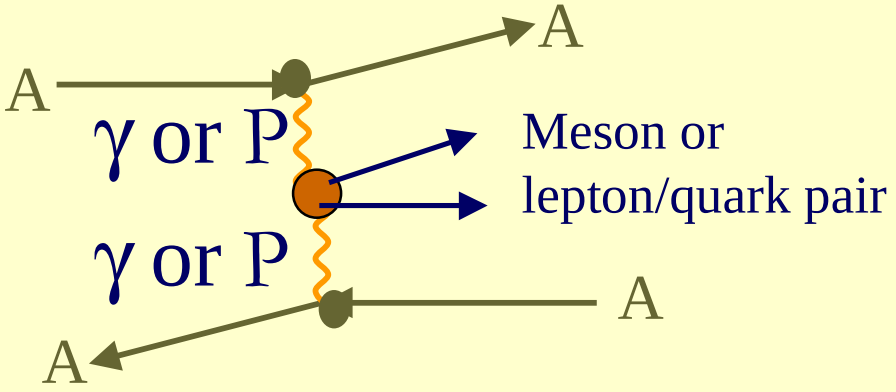


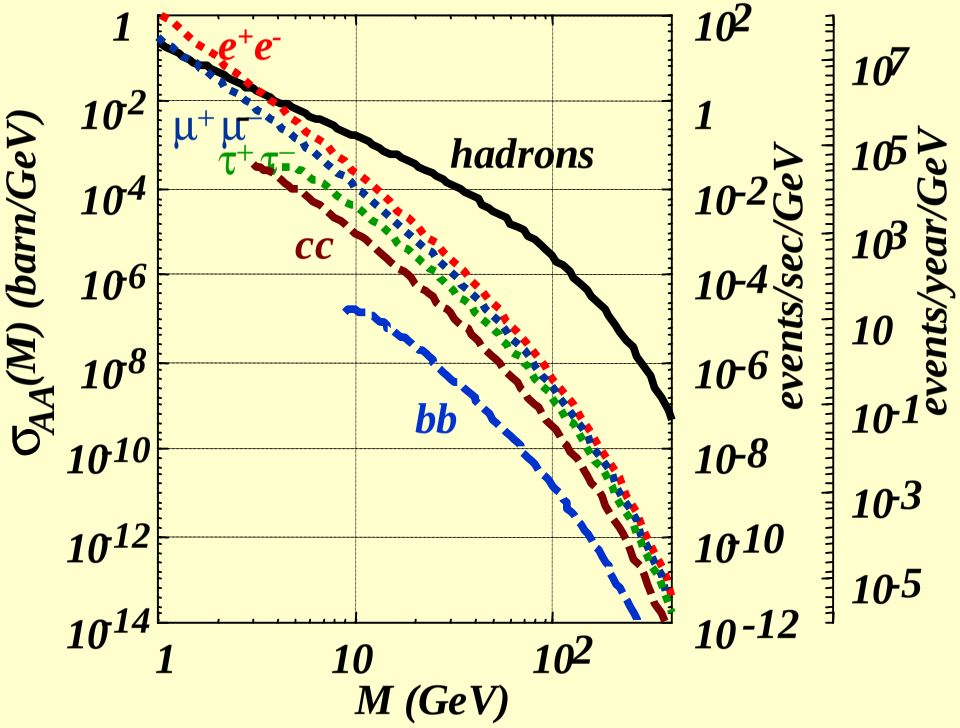
Balancing Photons and Jets

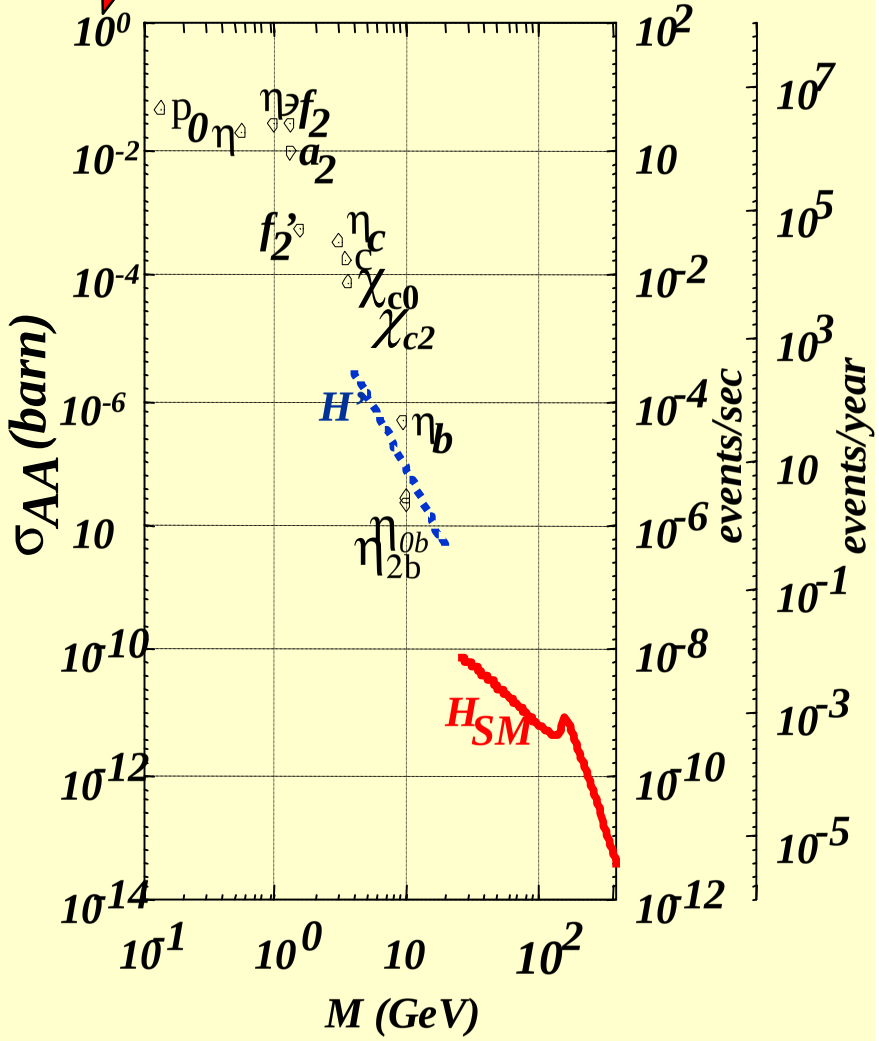
- $E_t^{jet, \gamma}$>120 GeV in the barrel
- 1 month:
  - 900 events for Pb-Pb
  - 10^4 events for Ca-Ca



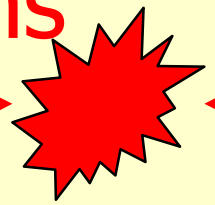
Ultra-Peripheral Collisions







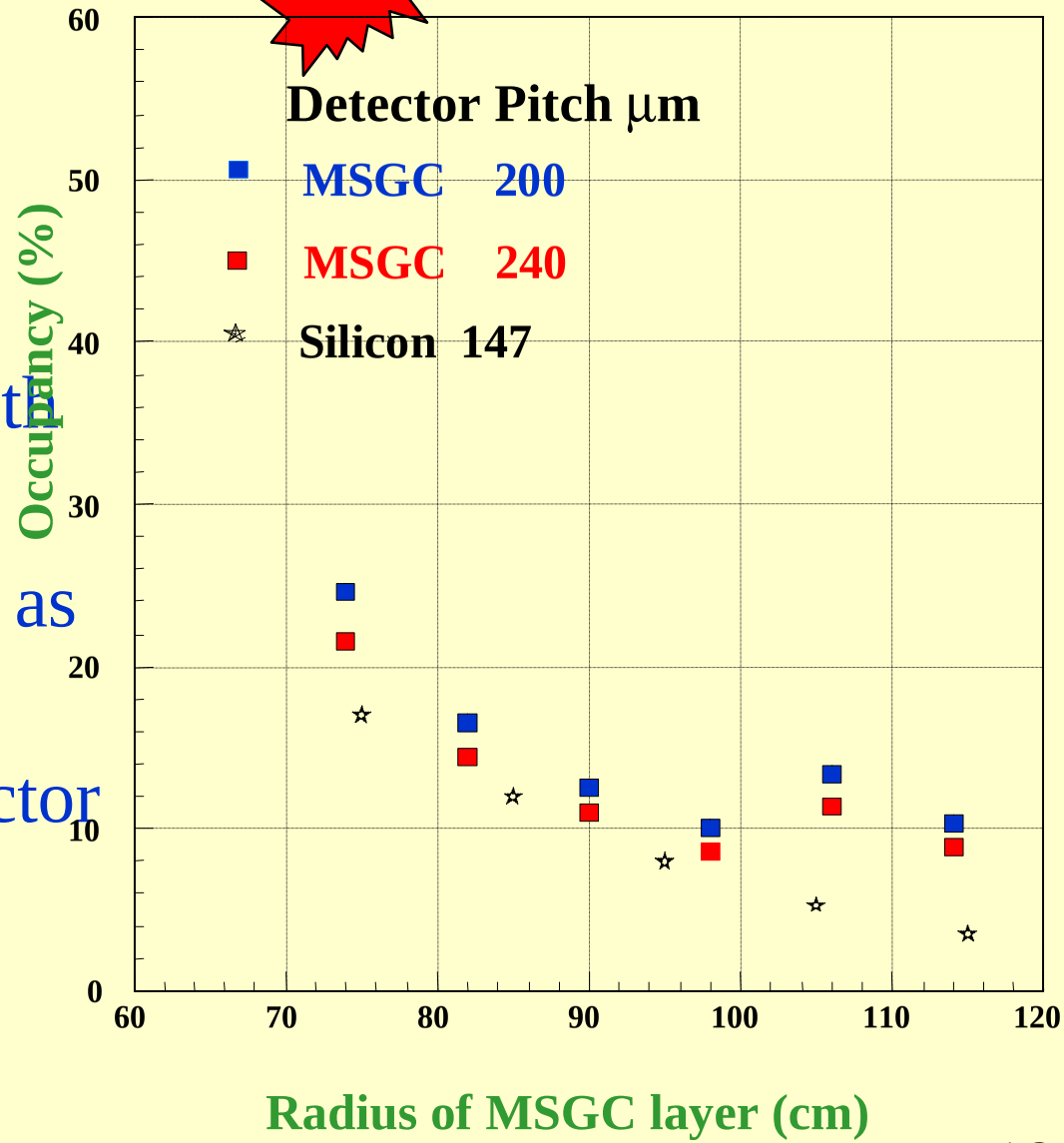
Conclusions



- CMS is provides unique tools to study Heavy Ion Collisions at LHC.
- Physics considered:
  - Event characterization with large rapidity coverage.
  - Quarkonium production: Υ and J/Ψ families.
  - Jet quenching.
  - Ultra-Peripheral collisions.

Addendum: Tracking

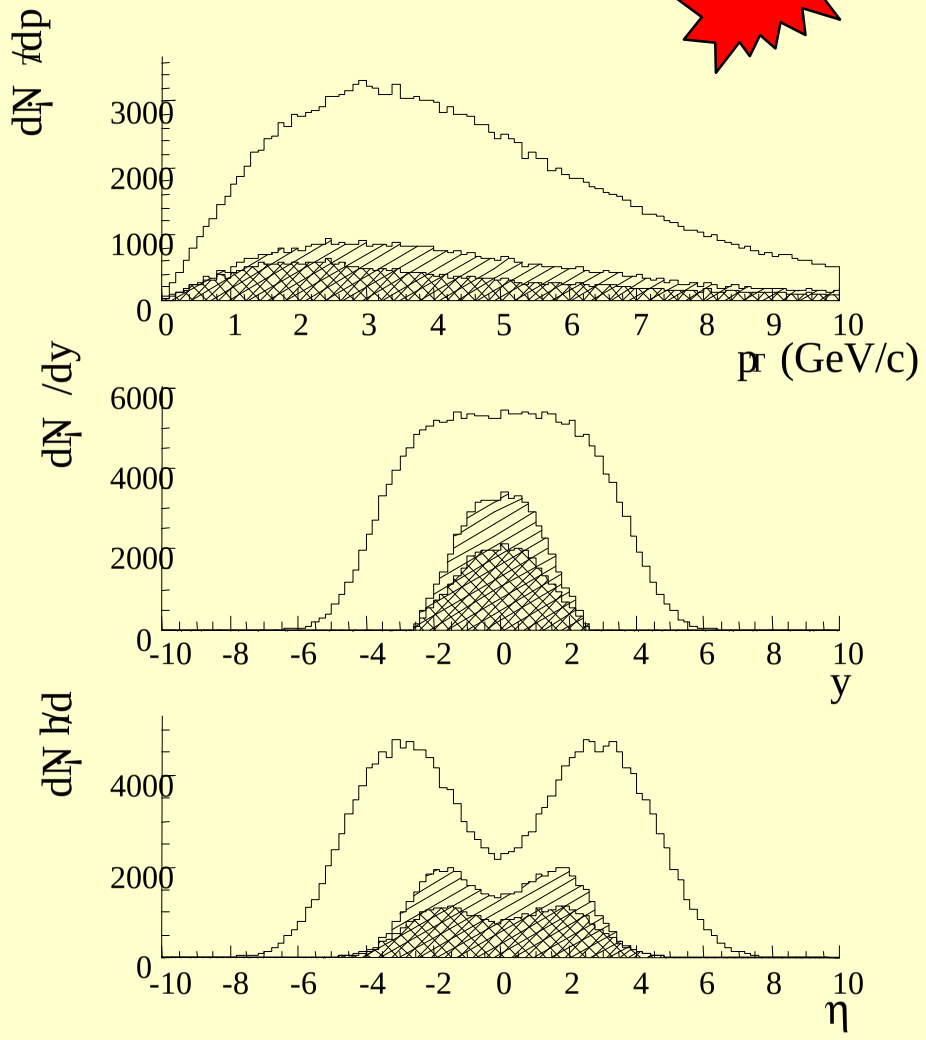
- Developed for $dN^{ch}/dy=8000$ and $dN^{0}/dy=4000$.
- Track only particles with tracks in μ detector.
- Use μ-chambers tracks as seeds.
- Use only tracking detector providing 3D space points.



LHC Parameters (Addendum)

- Bunches 7.5 cm long every 125 ns.

Addendum: Upsilon Acceptance

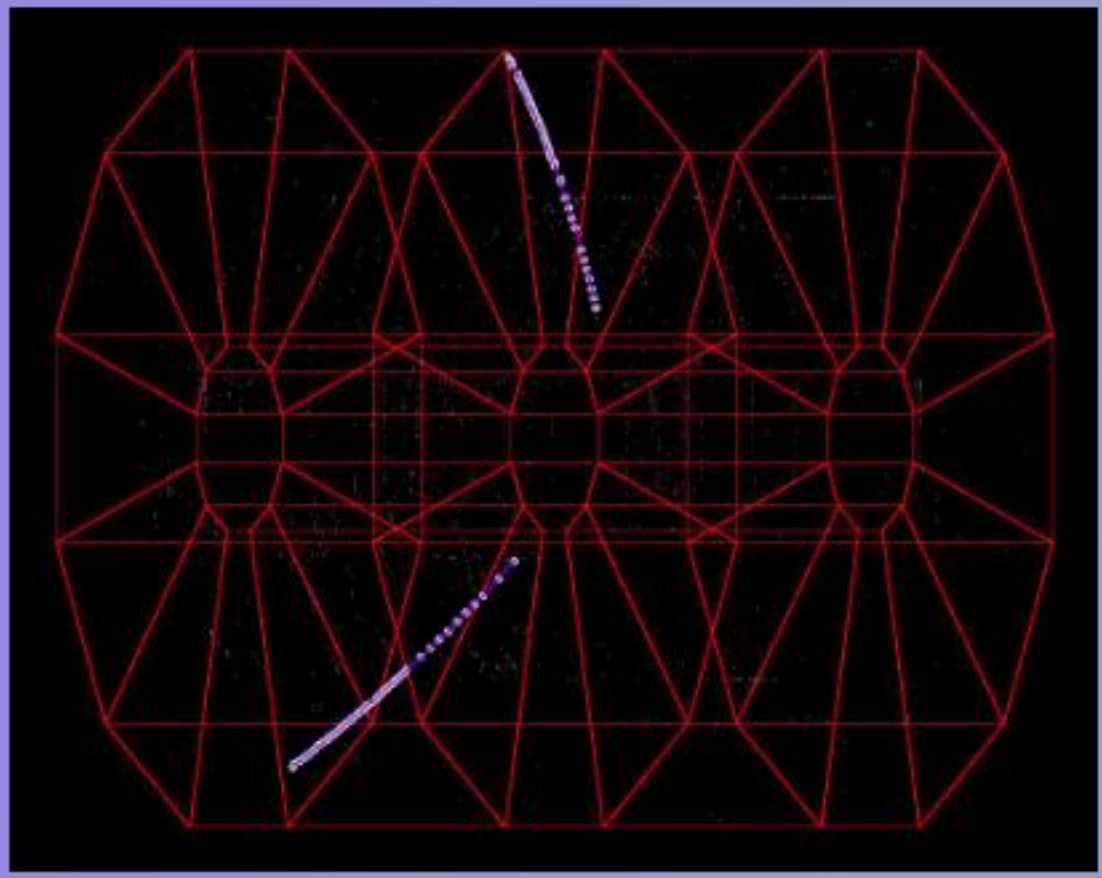


STAR First Ultra-Peripheral Collisions

Two oppositely charged co-linear tracks

Eventually additional coincident signal in ZDC

Typical Event :



Not as dramatic as central collision