kinematics

Opportunities and issues

Luminosity

- **Intensity: expect 5.10^8 protons.s^{-1}**
  - **Beam:** 2808 bunches of 1.15×10^{11} protons = **3.2×10^{14} protons**
  - **Bunch:** Each bunch passes IP: 3.10^5km.s^{-1}/27 km ~ **11 kHz**
  - **Instantaneous extraction:** IP sees 2808 x 11000~3.10^7 bunches passing every second ➔ extract $5.10^8/3.10^7$ ~ **extract 16 protons in each bunch at each pass**
  - **Integrated extraction:** Over a 10h run: extract 5.10^8p x 3600s.h^{-1} x 10h=1.810^{13}p.run^{-1} ➔ extract $1.8\times10^{13}/(3.2\times10^{14})$~**5.6% of the protons stored in the beam**

- **Instantaneous Luminosity**
  $\mathcal{L} = N_{beam} \times N_{Target} = N_{beam} \times (\rho \times e \times \mathcal{N}_A)/A$
  - $N_{beam}=5\times10^8$ p^+/s
  - **e** (target thickness) = 1 cm

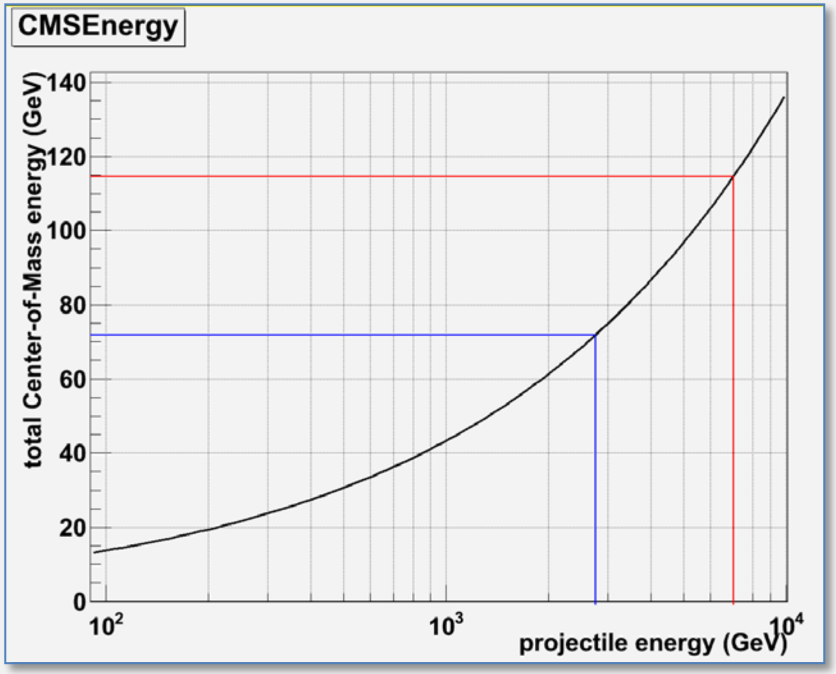
- **Integrated luminosity**
  - 9 months running/year
  - ➔ 1year ~ 10^7 s
  - ➔ $\int_{year}\mathcal{L} = \mathcal{L}_{inst}\times10^7$

Targ	ρ ($g.cm^{-3}$)	A	$\mathcal{L}_{inst}$ ($\mu b^{-1}.s^{-1}$)	$\int_{year}\mathcal{L}$ ($pb^{-1}.y^{-1}$)
Liq H	0.068	1	26	260
Liq D	0.16	2	20	200
Be	1.85	9	60	600
Cu	8.96	64	40	400
W	19.1	185	30	300
Pb	11.35	207	16	160

Reach few fb^{-1} with 10cm liq H/D target

Energy – rapidity

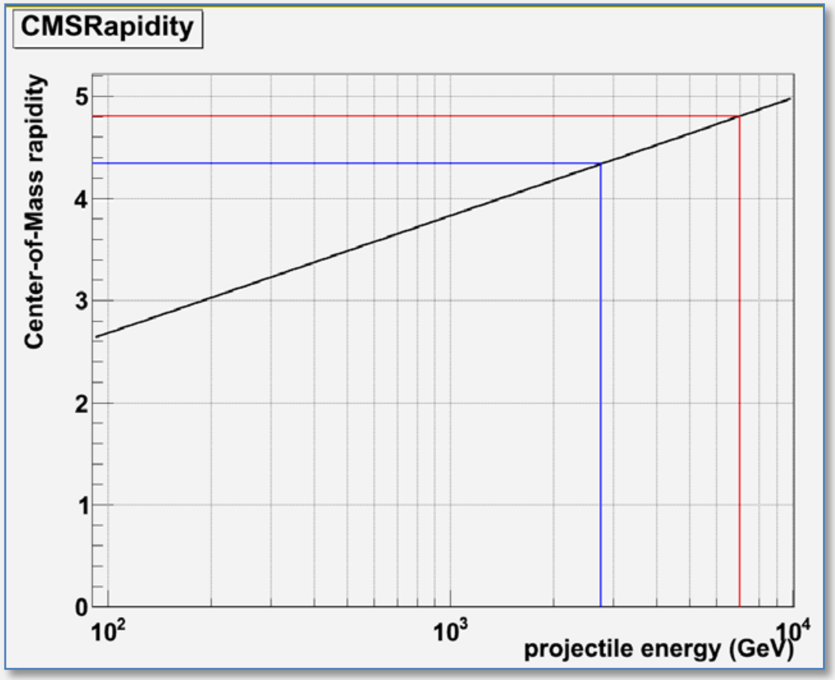
Energy



p+p run : 7 TeV p→p : **E_{CMS} = 114.6 GeV**

Pb+Pb run : 2.75 TeV p→p : **E_{CMS} = 71.8 GeV**

Rapidity



p+p run : 7 TeV p→p : **y_{CMS} = 4.8**

Pb+Pb run : 2.75 TeV p→p : **y_{CMS} = 4.3**

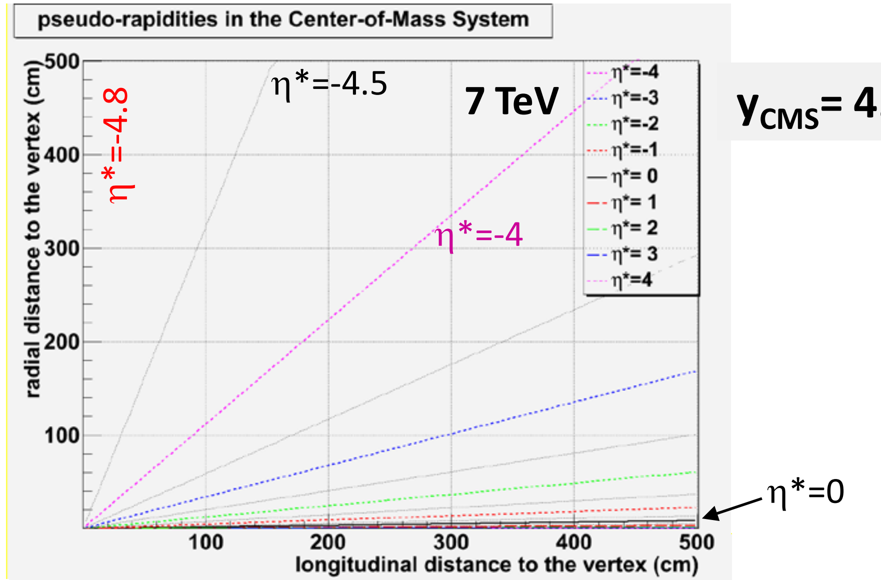
Pseudo-rapidity

$\eta^* = \eta - y_{CMS}$

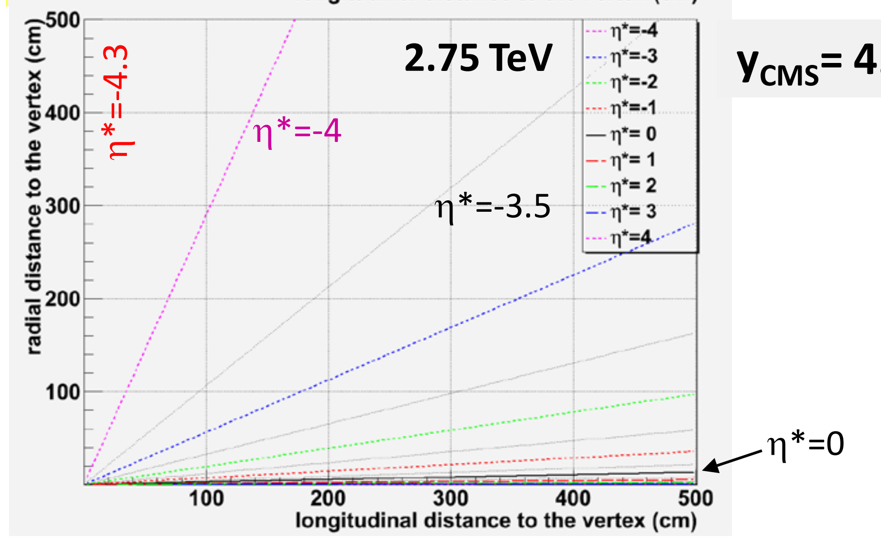
forward region: $\eta^*>0$

backward region: $\eta^*<0$

- ***Very high boost:***
  - *With 7 TeV beam : γ = 61.1*
  - *With 2.75 TeV beam: γ = 38.3*
- ***Very well placed to access backward physics***
- ***Forward physics difficult to access***



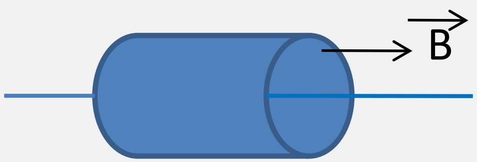
y_{CMS}= 4.8



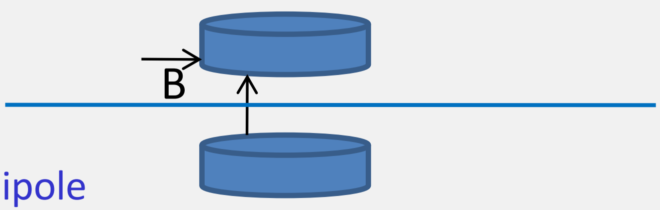
y_{CMS}= 4.3

Detector constraint

- **Geometry**
  - The geometry of the detector is related to the geometry of the magnet

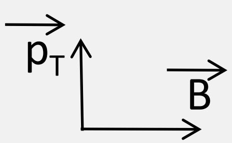


solenoid
→ detector parallel to the beam

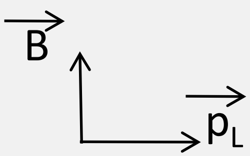


dipole
→ detector transverse to the beam

  - The magnet geometry is constrained by the outgoing particle momentum



large p_T particles
→ Solenoid is better



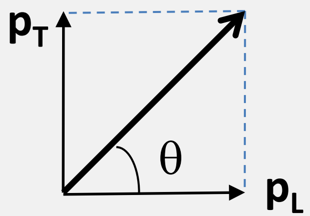
large p_L particles
→ Dipole is better

  - **In principle**
    - **If $p_T > p_L$ use a solenoid**
    - **If $p_L > p_T$ use a dipole**

Detector constraint

- **Geometry**
  - In principle : If $p_T > p_L$ use a solenoid, if $p_L > p_T$ use a dipole

- **Converting $p_T = p_L$ in rapidity frame**



$p_T = p_L$ ➔ $\theta = 45°$ ➔ $\eta = -\ln \tan \frac{\theta}{2} = 0.88$

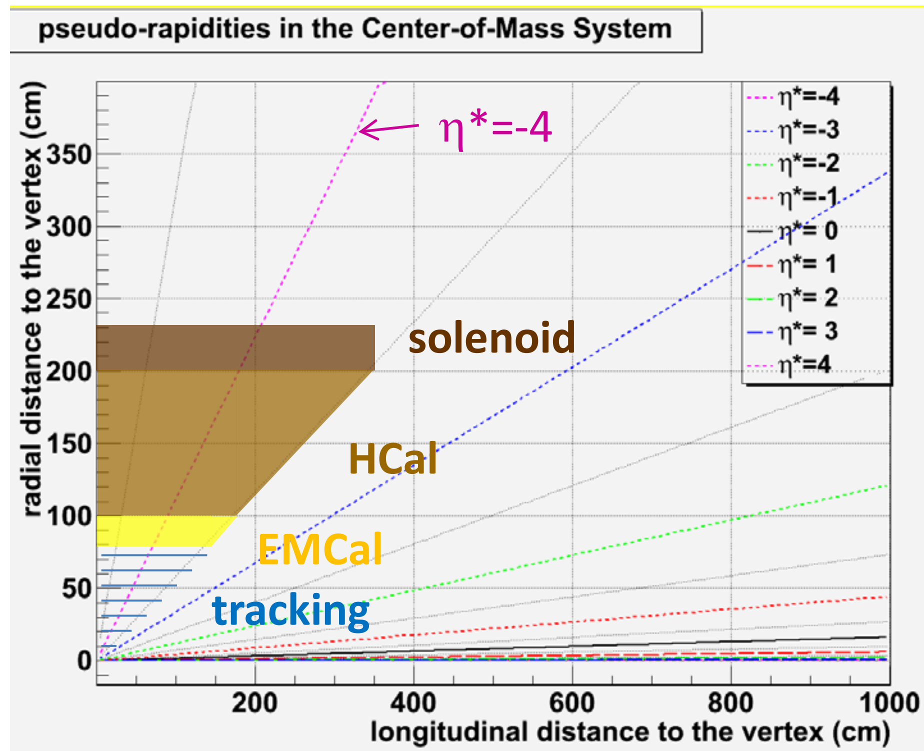
➔ $\eta^* = 0.88 - 4.8 \sim -4$ ➔ **If $p_T > p_L$, $\eta^* < -4$**
If $p_T < p_L$, $\eta^* > -4$

In principle:
- **one should use a solenoid to access $\eta^* < -4$**
- **one should use a dipole to access $\eta^* > -4$**

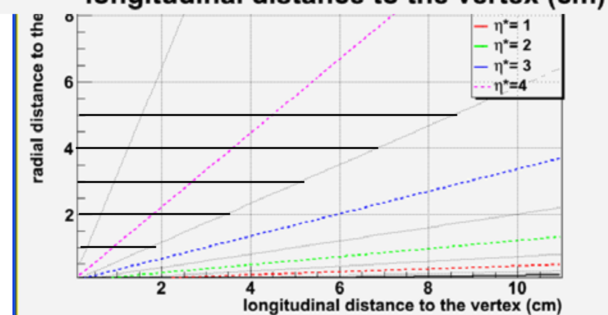
Longitudinal detector

- **Typical detector :**
  - $-4.8 < y^* < -3.5$
  - Multipurpose detector
    - Vertex
    - Tracking
    - calorimetry

- **Compact detector**
  - Because of the high boost, the detector must be as compact as possible
  - Compact calorimeters (Calice)
    - EMCal ~ 20 cm long
    - HCal ~ 1 m long
  - Vertexing + Tracking
    - 80 cm should be enough
    - To be checked

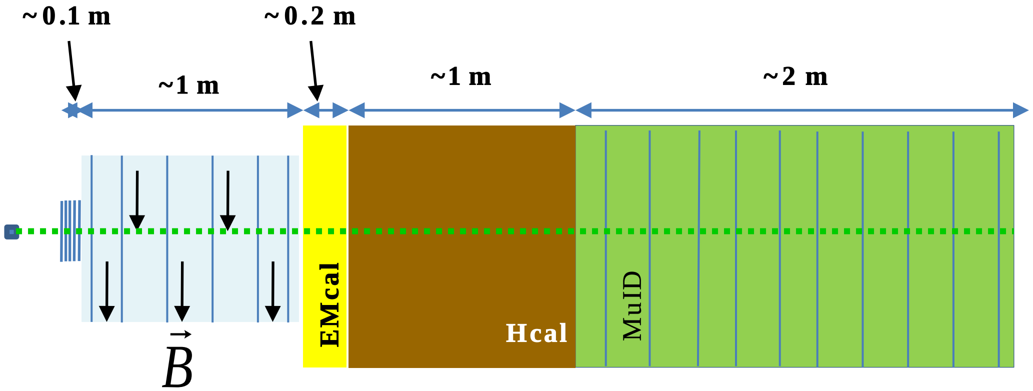


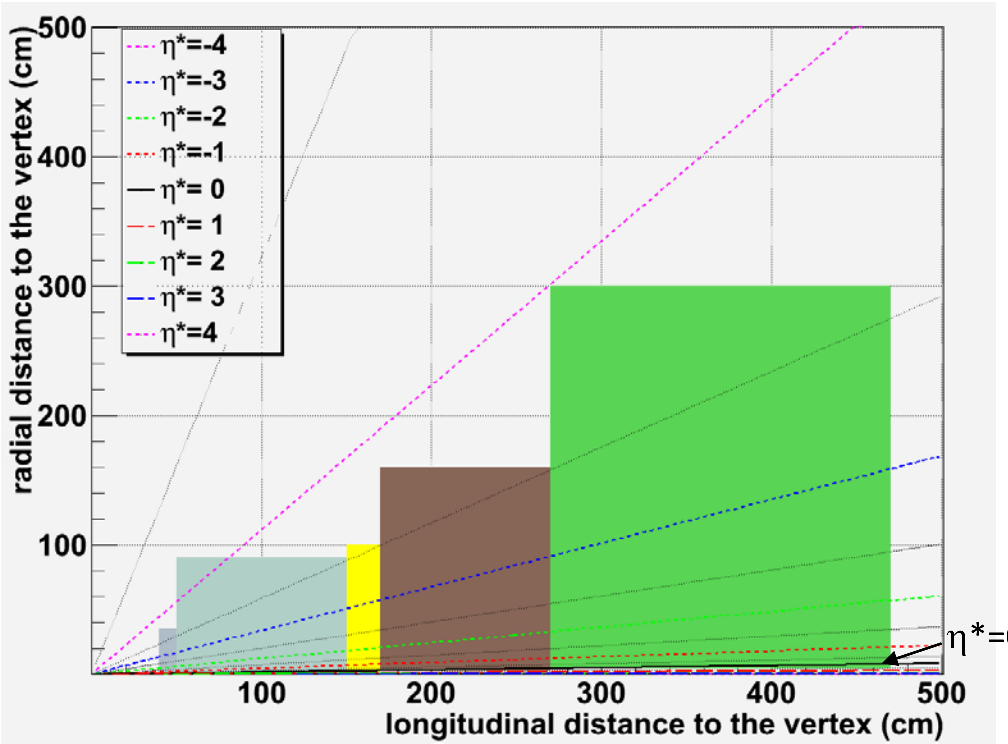
vertex



Transverse detector

- **Typical detector: -3.5 < y* < 0**
  - Multipurpose detector:
    - Vertex
    - Tracking
    - Calorimetry
    - Muons
  - Compact detector
    - Because of the high boost, the detector must be as compact as possible
- **Dimensions**
  - Vertex: z=40 / R_{min}=0.5 / R_{max}=35 cm
  - Tracker: z=50 / R_{min}=0.8 / R_{max}=90 cm
  - EMCal: z=150 / R_{min}=2 / R_{max}=100 cm
  - Hcal: z=170 / R_{min}=2.5 / R_{max}=160 cm
  - Muons: z = 270 / R_{min}=4 / R_{max}=300 cm

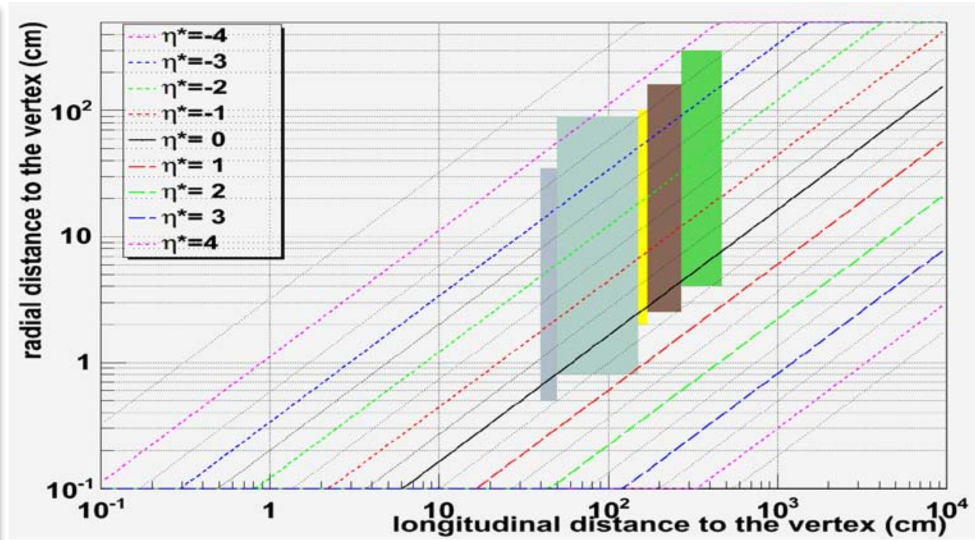


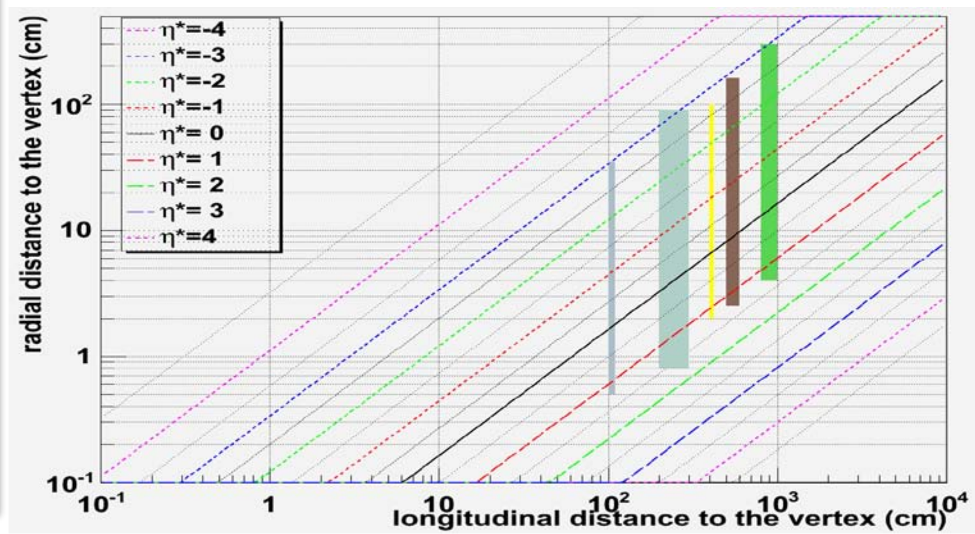


Transverse detector

- **Go forward ?**
  - Possibility to access y*=1 by shifting the detectors

Detector	Z_{min}/Z_{max} at η*=0	Z_{min}/Z_{max} at η*=1
Vertex	40/50 cm	100/110 cm
Tracker	50/150 cm	200/300 cm
EMCal	150/170 cm	400/420 cm
Hcal	170/270 cm	500/600 cm
muons	270/470 cm	800/1000 cm





Longitudinal .vs. Transverse

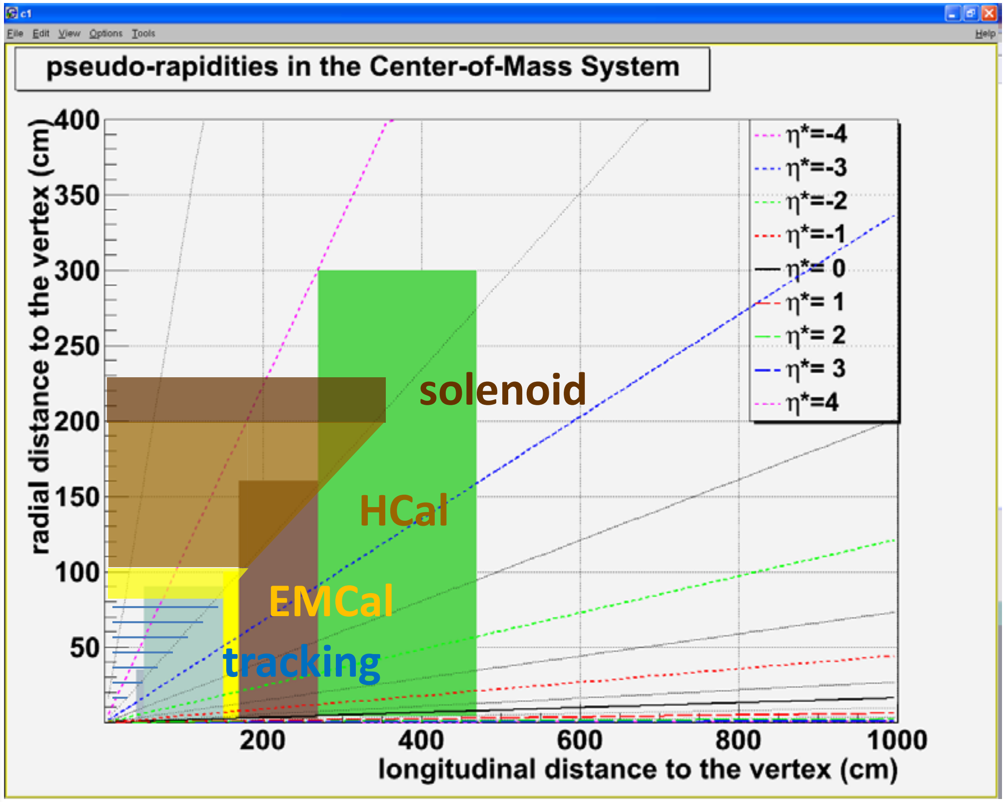
- **Impossible to deal with the two magnets at the same time**

- **Two options :**
  - limit ourself to -3.5<η*<0 (1)
  - build two setups

Note that:

$$x_F = \frac{2M}{\sqrt{s}} \sinh y^* = -1 \Rightarrow \begin{cases} y^*_{J/\Psi} = \mathrm{Asinh}\frac{\sqrt{s}}{2M_{J/\Psi}} = -3.6 \\ y^*_{\Upsilon} = \mathrm{Asinh}\frac{\sqrt{s}}{2M_{\Upsilon}} = -2.5 \end{cases}$$

Don't need longitudinal detector !



conclusion

- **LHC**
  - Very high luminosity accessible : **up to $fb^{-1}.y^{-1}$**
  - E_{CMS} = **114.6/71.8 GeV** in p+p/Pb+Pb
  - y_{CMS}=**4.8/4.3** in p+p/Pb+Pb

- **Detector : two options**
  - Measuring **$-4.8 < \eta^* < -3.5$** ➔ **longitudinal**/solenoid
  - Measuring **$-3.5 < \eta^* < 0$ (1)** ➔ **transverse**/dipole
  - Not possible to run both detectors at the same time, but, in principle, we don't need to reach $\eta^*<-3.5$ to access x_F=-1.