Luminosity measurement at LHC (The machine point of view)

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Large part of the material presented here has been produced by the LBNL team, M.Placidi and E.Gschwendtner

Scope of the machine luminometers

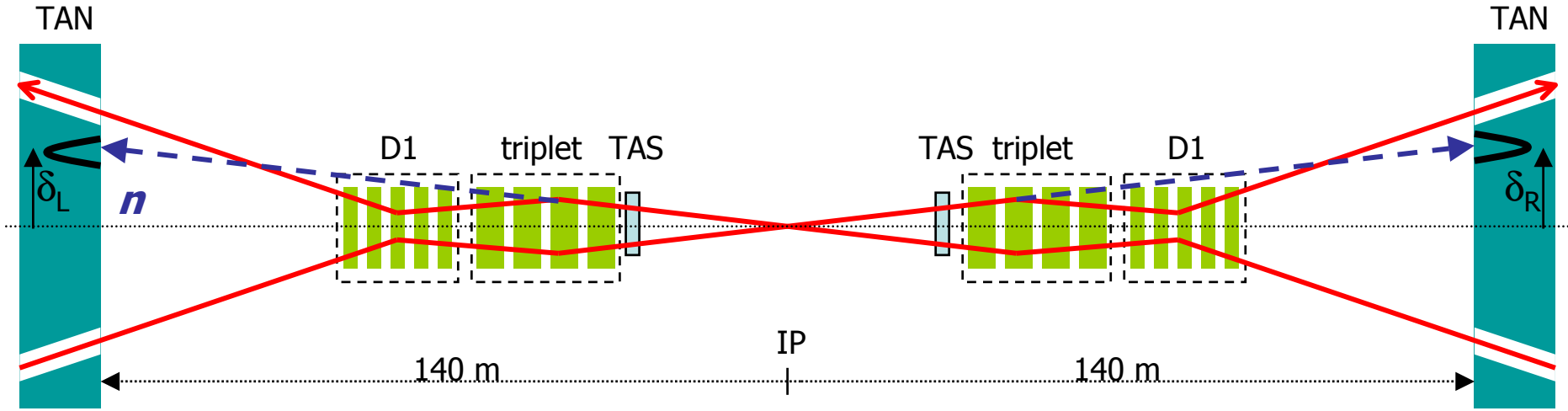
- Provide a quantitative tool for the operators
  - bringing the beams in collision
  - optimizing the machine
- Monitor and eventually correct drifts in the performances of the machine during coasting
- Equalize luminosity among the various experiments.

Machine parameters that affect luminosity

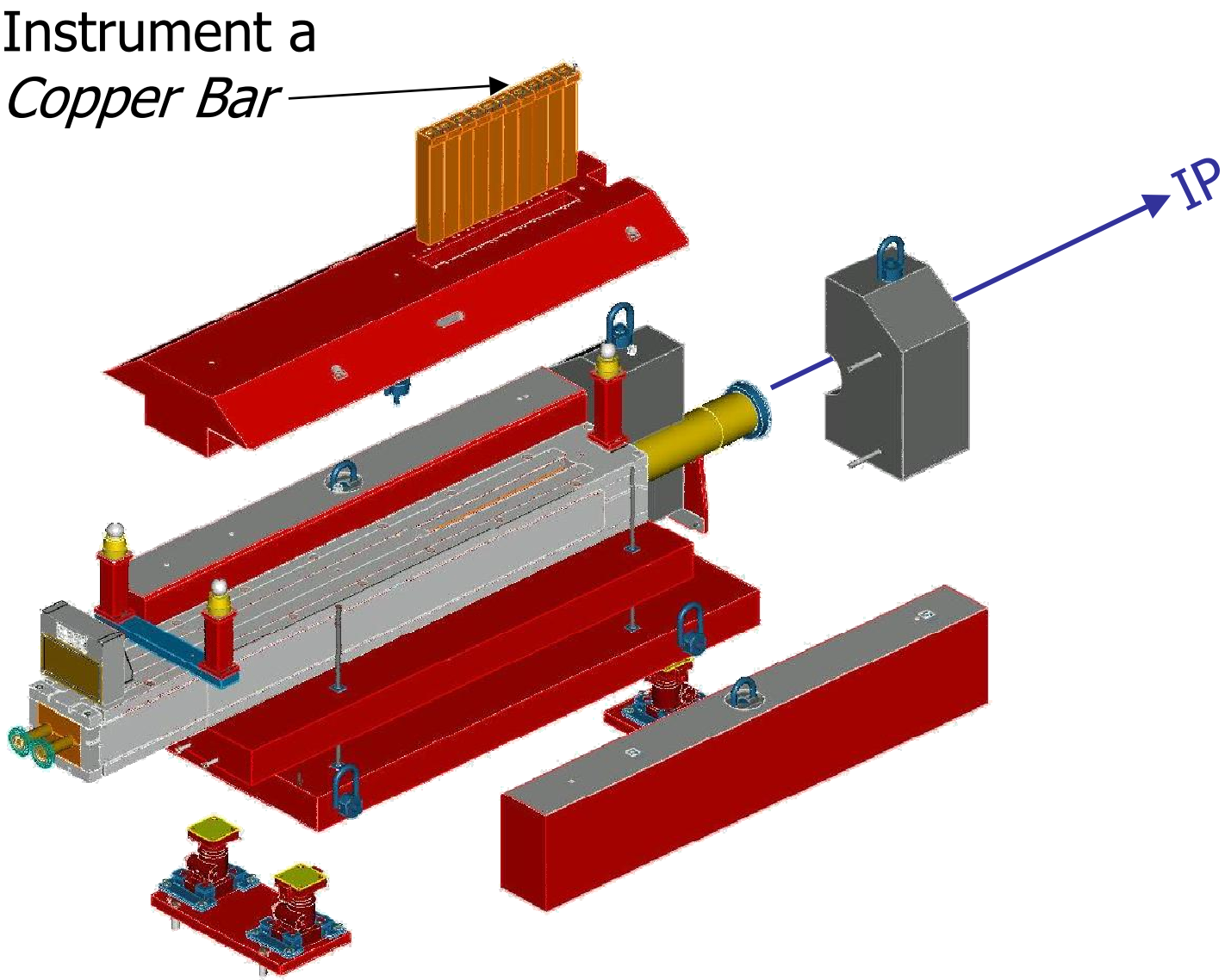
- Beam size (emittance, β*)
- Beam separation (transverse offset)
- Beam overlap (timing)
- Crossing angle
- Collective effects
- “Packman” effects etc.

Plan of action

Install rate monitors in straight line of fly of neutral particles from the Interaction Point



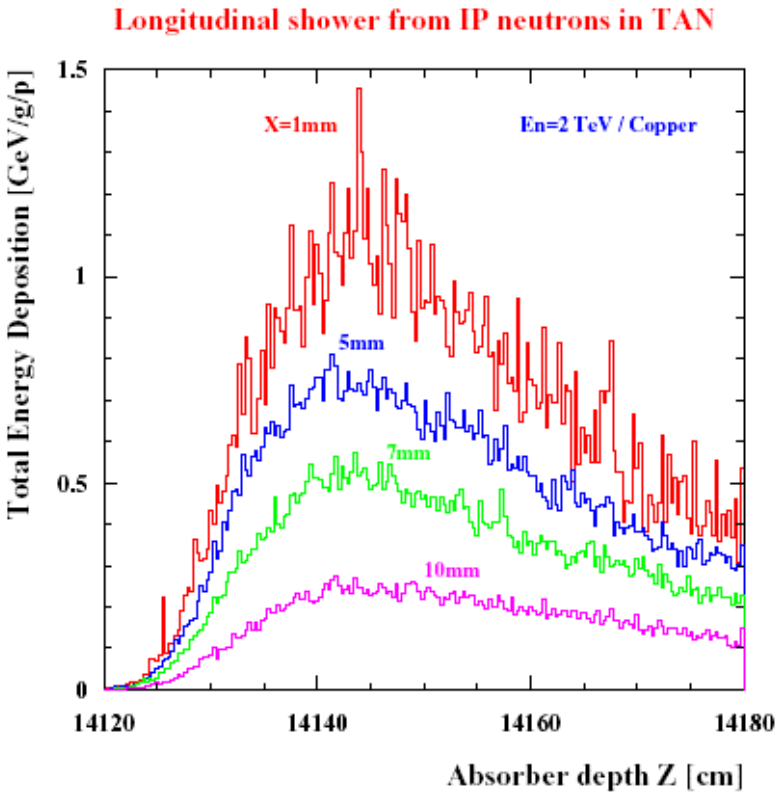
IP1 & IP5 have TAN's (neutral absorbers)

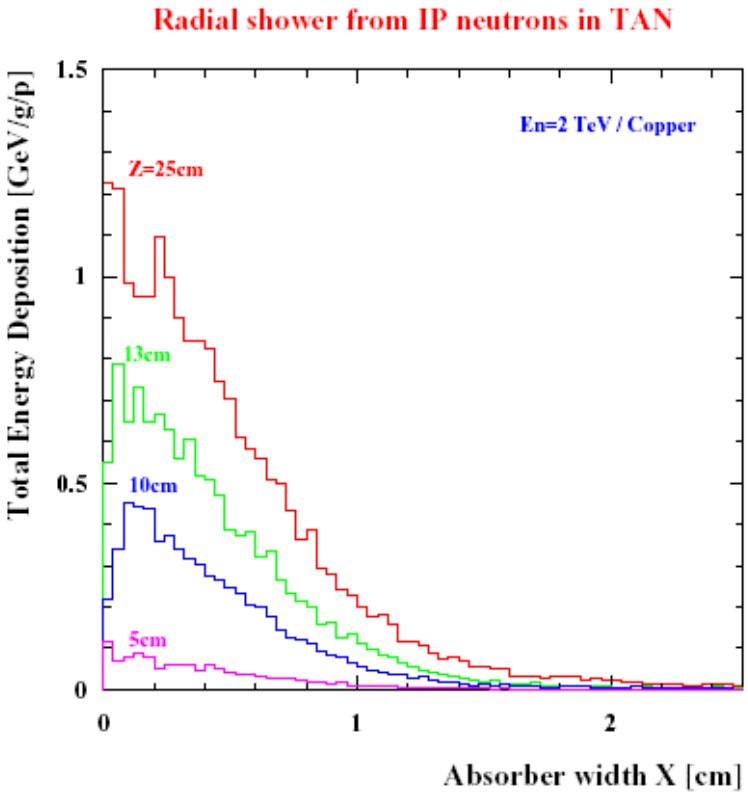


What rate monitors can measure

- The foreseen detectors are position sensitive (four quadrants) and fast (40MHz)
- The absolute signal value is proportional to the number of particles i.e. to luminosity
- The asymmetry among the four quadrants can be used to compute the position of the center of gravity

Energy Deposition from IP neutrons



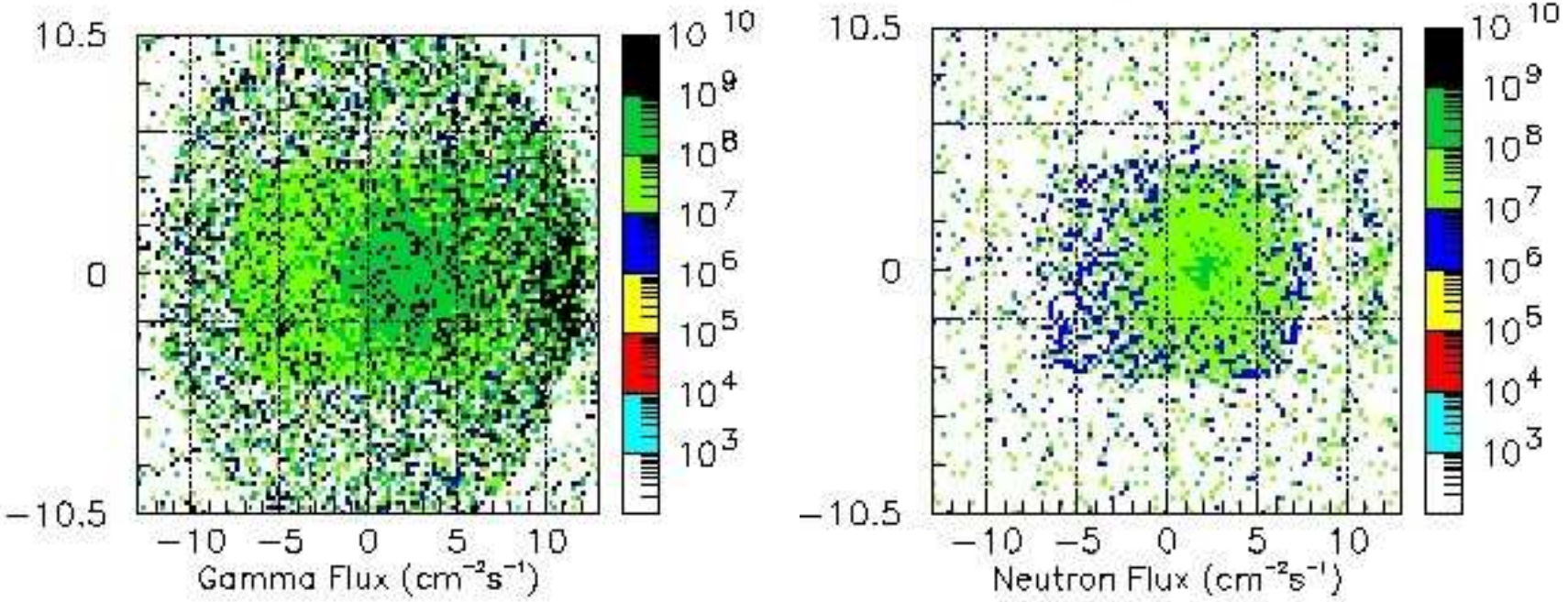


Energy Deposition at TANs in IP1 and IP5

MARS simulated **mean number** and **energy** of particles incident on TANs **per p-p collision** ϕ_{tot} : total particle flux at $8 \cdot 10^8$ p-p int./s ($\mathcal{L} = 10^{34}$ cm^{-2} s^{-1}).
(courtesy: **N. Mokhov, FNAL**).

Particle	$< N >$	$< E >$ [GeV]	$< N \cdot E >$ [GeV]	ϕ_{tot} [cm^{-2}s^{-1}]
neutron	0.492	1480	**727**	$\mathbf{1.2 \cdot 10^6}$
photon	311	2.13	**661**	$\mathbf{7.4 \cdot 10^8}$
proton	0.131	786	103	$\mathbf{3.0 \cdot 10^5}$
$\pi^{\pm}$ $K^{\pm}$	0.899	63	56.6	$\mathbf{1.9 \cdot 10^6}$
$e^{\pm}$	25.4	0.280	7.12	$\mathbf{5.4 \cdot 10^7}$
$\mu^{\pm}$	0.004	5.02	0.02	$\mathbf{8.5 \cdot 10^3}$

Spatial distribution of n and γ



Detector technology

- The first choice was to use a ionization chamber to measure the integral luminosity
- Dynamic range considerations and collective effects suggested a bunch by bunch measurement
- A fast ionization chamber capable of resolving the 40MHz filling pattern was proposed and is currently under development (LBNL)
- An alternative solid state CdTe detector was explored. The radiation hardness of this technology is however not sufficient for IP1 & 5 (CERN/LETI)

Project status of the detector

- LBNL (Berkeley) is responsible for the whole luminosity monitor system. The financing of the project comes trough LARP
- Due to under founding and general resources scarcity the R&D for the F.I.C. is in an advanced state but not yet completed

Project outlook

- During autumn 2004 the R&D for the F.I.C. should be completed and a review will take place toward the end of the year
- After the review depending on the results a decision will be made at CERN on the way forward (3 major scenarios)
  - All IP's F.I.C.'s @40MHz
  - IP1+5 F.I.C's @ <40MHz; IP2+8 CdTe @40MHz
  - All IP's F.I.C.'s or other I.C. </<< 40MHz
- Available CERN resources will matter ;-)

Our wishes

- Our (and other's) wishes are collected in the document LHC-B-ES-007 "On The Measurement of The Relative Luminosity at The LHC". This document contains the specifications according to which we are developing our detectors
- Nature and resources, though, might limit the results…

Summary of the specifications

- Total p-p L 2 10^{26} / 2.3 10^{34}
- b.-b. p-p L 2 10^{26} / 8.2 10^{30}
- Crossing angle 0 / +/- 150μrad
- Beam finding (set up) resolution ~10% int. time minutes.
- Nominal L p-p (coasting for physics) resolution ~1% in 1s (reproducibility from fill to fill at the same level)
- Absolute calibration (with experiments or other method Van der Meer) 5 – 10%

Luminosity modes at IR1&5

Bunch population	Number of bunches	Bunch spacing	Mode	IP beta	Luminosity [cm^{-2} s^{-1}]
Collision studies with single pilot bunch, no crossing angle					
$5x10^{9}$	1		p-p	18 m	2.0×10^{26}
Collision studies with single high intensity bunch					
1.1×10^{11}	1		p-p	18 m	9.9×10^{28}
Nominal p-p luminosity run					
1.1×10^{11}	2808	25 ns	p-p	0.5 m	1.0×10^{34}
Ion runs					
7×10^{7}	1		Pb-Pb	0.5 m	0.9×10^{24}
7×10^{7}	592		Pb-Pb	0.5 m	0.5×10^{27}

Resolution and integration times

Luminosity sub-range	particle	Resolution		integration time
		Beam structure	Luminosity	
$1.0 \times 10^{26} \rightarrow 1.0 \times 10^{28}$	p-p	beam	± 10%	~ 1 mn
$1.0 \times 10^{28} \rightarrow 3.0 \times 10^{34}$	p-p	beam	± 1%	~ 1 s
$1.0 \times 10^{33} \rightarrow 3.0 \times 10^{34}$	p-p	bunch	~ ± 1%	~ 10s
$1.0 \times 10^{24} \rightarrow 5.0 \times 10^{25}$	Pb-Pb	beam	± 10%	~ 1 mn
$5.0 \times 10^{25} \rightarrow 0.5 \times 10^{27}$	Pb-Pb	bunch	± 1%	~ 1 s

The detectors

CdTe detector (LETI)

Fast Ionization Chamber
LBNL