

..... and dulcis in fundo

Borexino, CTF and the CNGS neutrino beam

Laura Perasso - INFN Milano

Content:

- I. The CNGS beam: its latest schedule
- II. Preliminary rate values for the detected CNGS beam induced muons
- III. Conclusions

Thanks to :

George Korga

Igor Machulin

Emanuela Meroni

Alessandro Razeto

April 6th Workshop at LNGS

The last meeting:
CNGS START-UP

LNGS, 6th April 2006
14:00 'E. Majorana' lecture hall

CNGS Project: Primary Beam	(35')	M. Meddahi (CERN/AB)
CNGS Project: Secondary Beam (CERN/AB)	(35')	E. Gschwendtner
CNGS Simulated Beam Fluxes	(5')	P. Sala (INFN/Milano)
Timing and Data Exchange btw. CERN and LNGS	(30')	D. Autiero (IN2P3/Lyon)

(from D. Autiero)

June 22nd Workshop at LNGS

“Waiting for the beam”:

Continuation more focused on the event signatures of the CNGS beam in the LNGS experiments.

Presentations by:

1. Dario Autiero : “Update on the CNGS beam”
2. Stefano Dusini : “CNGS beam monitoring with OPERA detector”
3. Gabriella Sartorelli : “CNGS beam monitor with LVD”
4. Laura Perasso: “Borexino, CTF and the CNGS neutrino beam”

(all on the LNGS web pages)

The CNGS beam

$\langle E_{\nu\mu} \rangle \sim 18 \text{ GeV}$
 Fluxes @ $E_\nu \sim 18 \text{ GeV}$
 [$\nu/\text{cm}^2/10^{19}\text{pot}$]:

$$\longrightarrow \nu_\mu \sim 3.2 \cdot 10^5$$

$$\bar{\nu}_\mu \sim 6.4 \cdot 10^3$$

$$\nu_e \sim 1.4 \cdot 10^3$$

$$\bar{\nu}_e \sim 1.8 \cdot 10^2$$

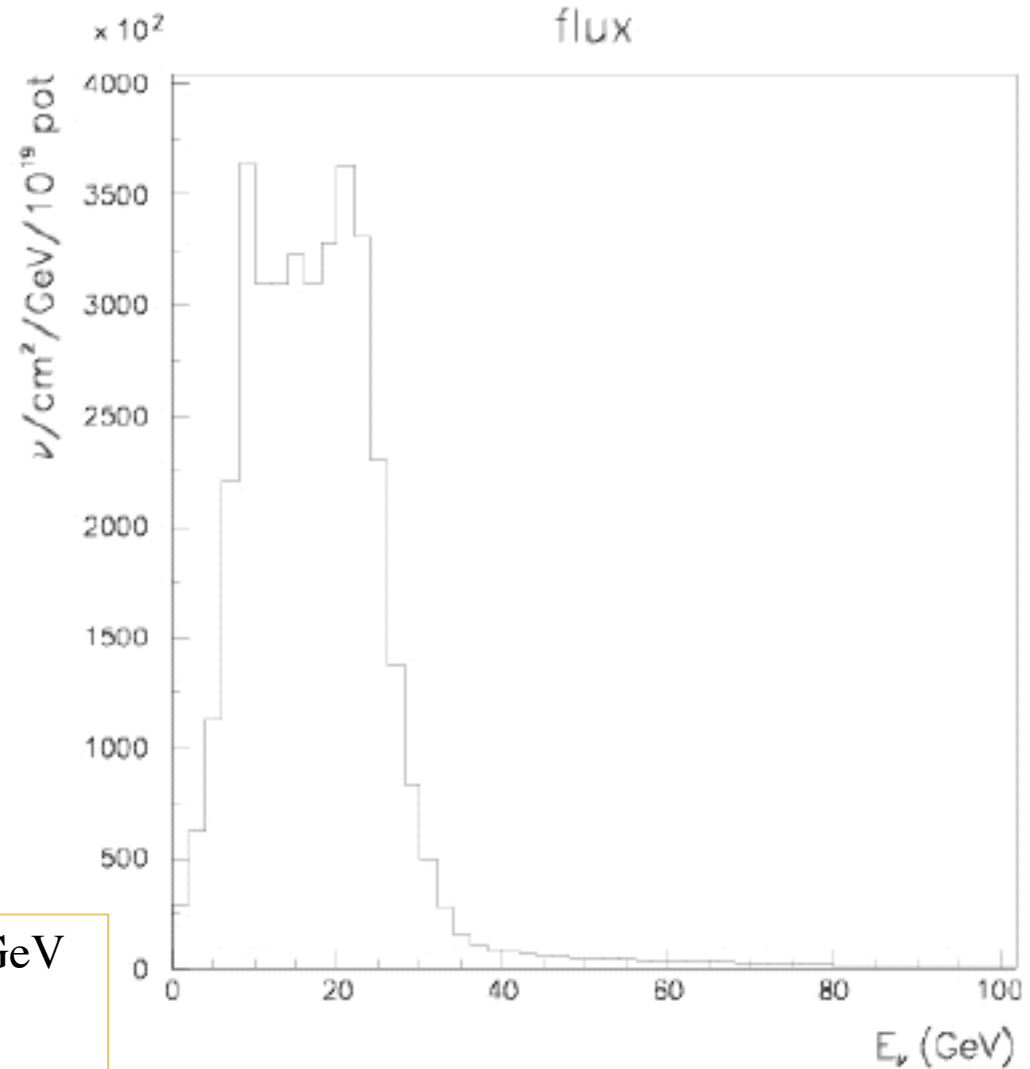
$$(\nu_\mu + \bar{\nu}_\mu) \sim 99.5\% \quad (2\% \bar{\nu}_\mu/\nu_\mu)$$

$$(\nu_e + \bar{\nu}_e) \sim 0.48\%$$

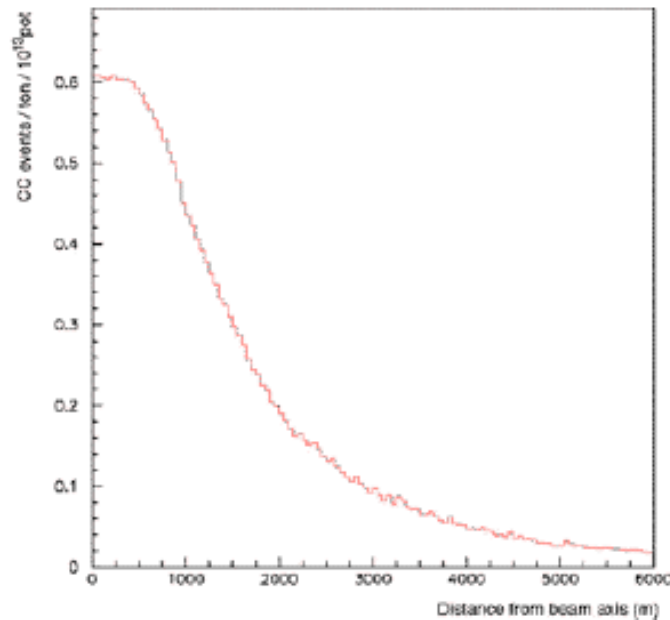
For comparison, MINOS, $\langle E_{\nu\mu} \rangle \sim 3 \text{ GeV}$

$$(\nu_\mu + \bar{\nu}_\mu) \sim 98.5\% \quad (6.5\% \bar{\nu}_\mu)$$

$$(\nu_e + \bar{\nu}_e) \sim 1.5\%$$



CNGS Geodesy:



Radial beam distribution at LNGS:

Full width at half maximum: 2.8 Km

Flat region at +/- 500 m

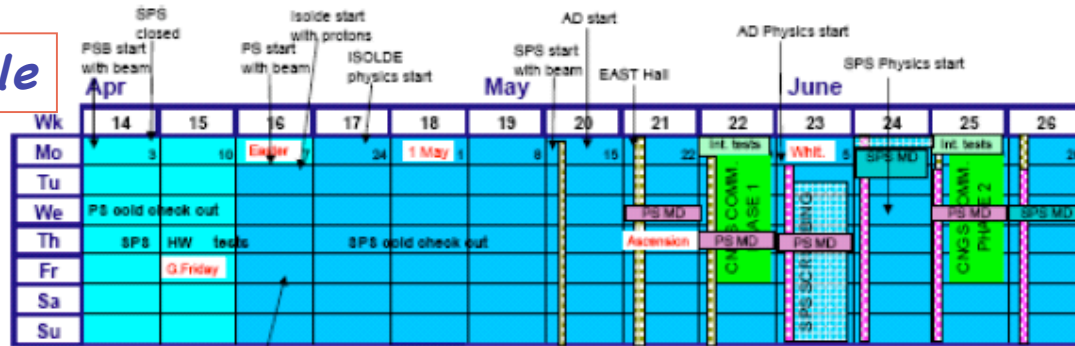
effect on cc events

- horn off axis by 6mm < 3%
- reflector off axis by 30mm < 3%
- proton beam on target off axis by 1mm < 3%
- CNGS facility misaligned by 0.5mrad (beam 360m off) < 3%

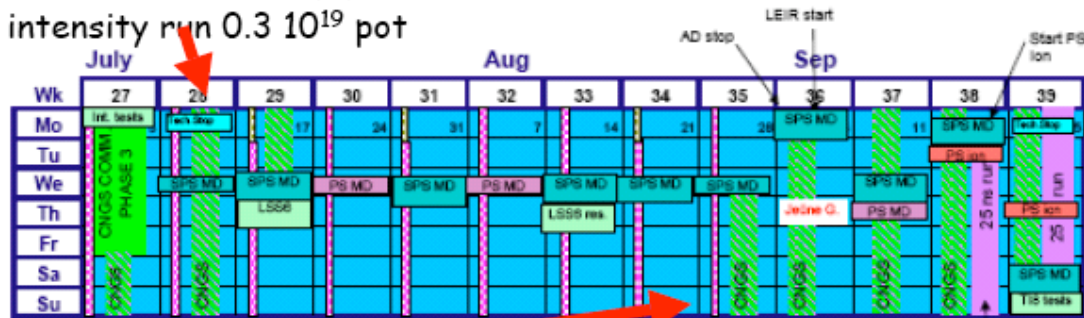
Angular accuracy of CNGS direction: 0.05 mrad -> 37 m over 730 Km
This uncertainty has practically no effect on the observed rates

G. Sartorelli, *Waiting for the neutrino beam*, LNGS, June 22nd 2006

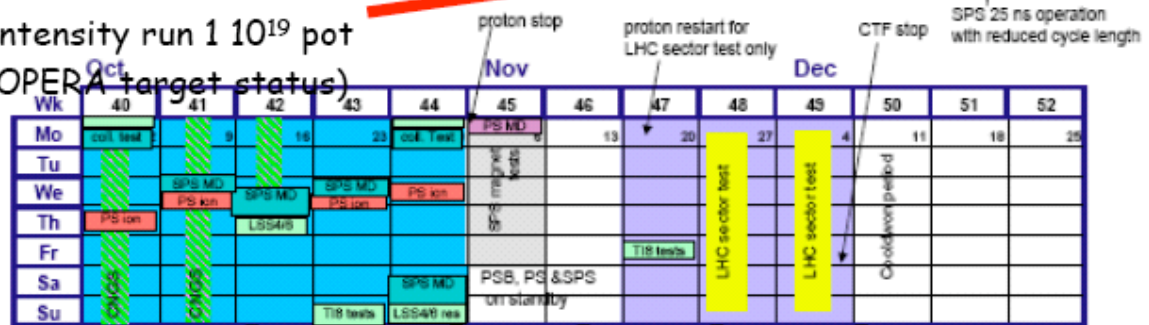
Initial 2006 SPS schedule



LEIR commissioning stop
 CNGS low intensity run $0.3 \cdot 10^{19}$ pot



CNGS high intensity run $1 \cdot 10^{19}$ pot
 (subject to OPERA target status)

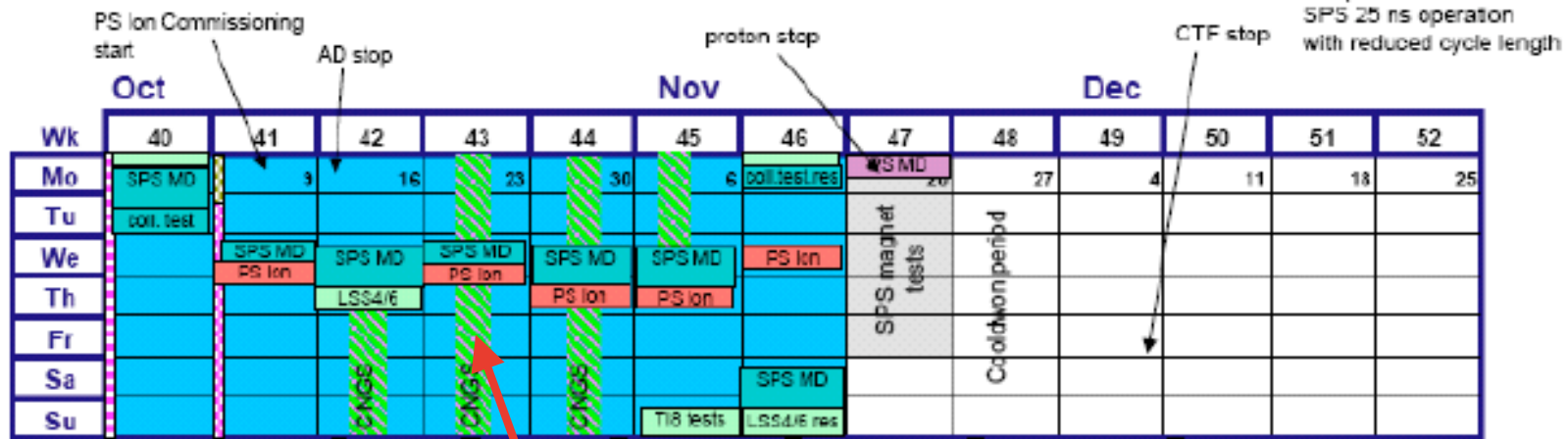
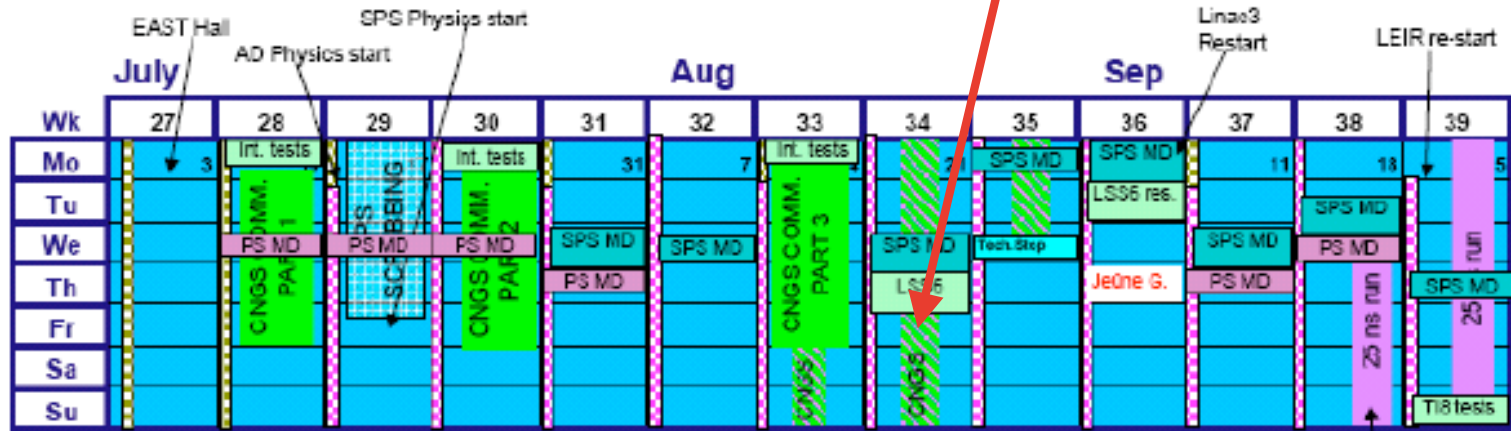


Modified due to a PS power supply (installed in 1968!!) fault on 18/5/2006
 It has been replaced....

New SPS schedule

(approved by the RB on 7/6/2006)

18-30 Aug 2006
low intensity (Scycle= 18 s)

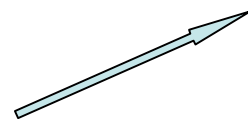


20 Oct-8 Nov

The CNGS beam monitoring at LNGS

The CNGS ν_μ beam can be monitored detecting the **muons** produced by the neutrino interactions

in the detectors

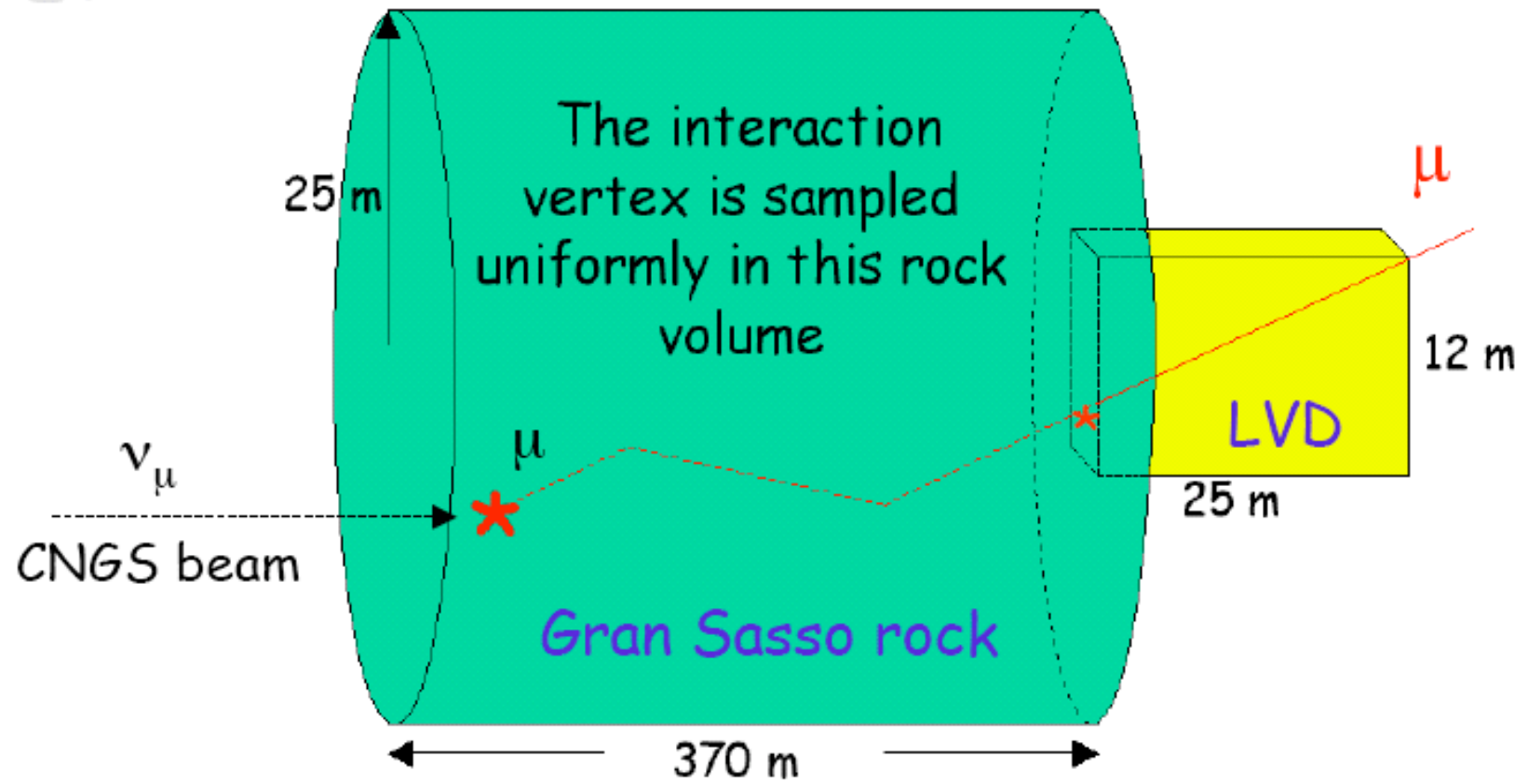


in the rocks in front of the detectors



with muon identification systems

Event Generation

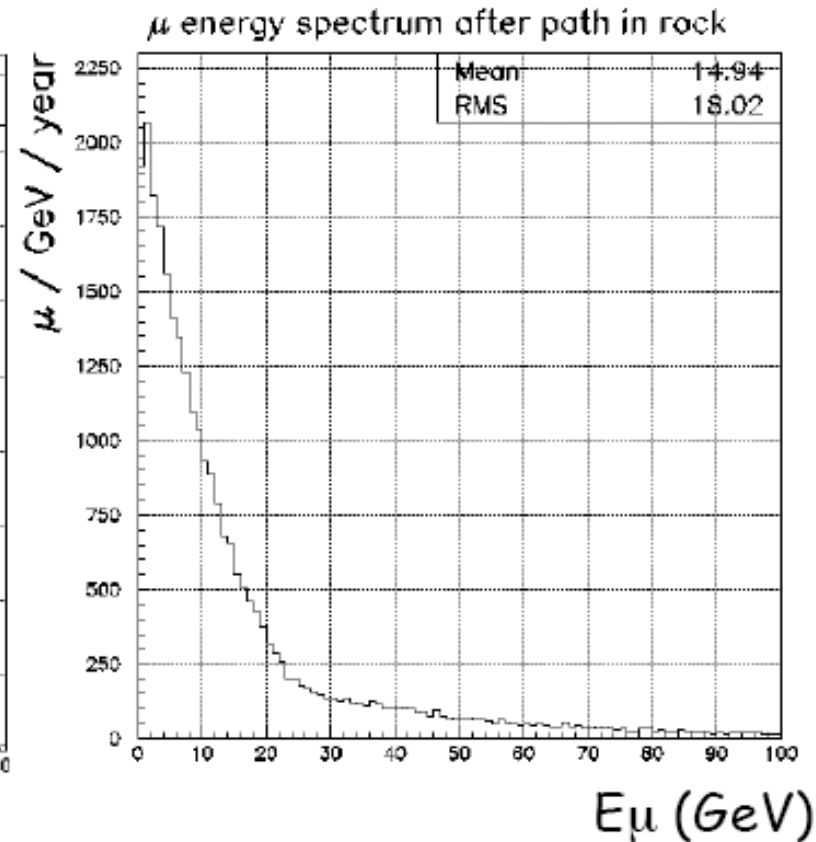
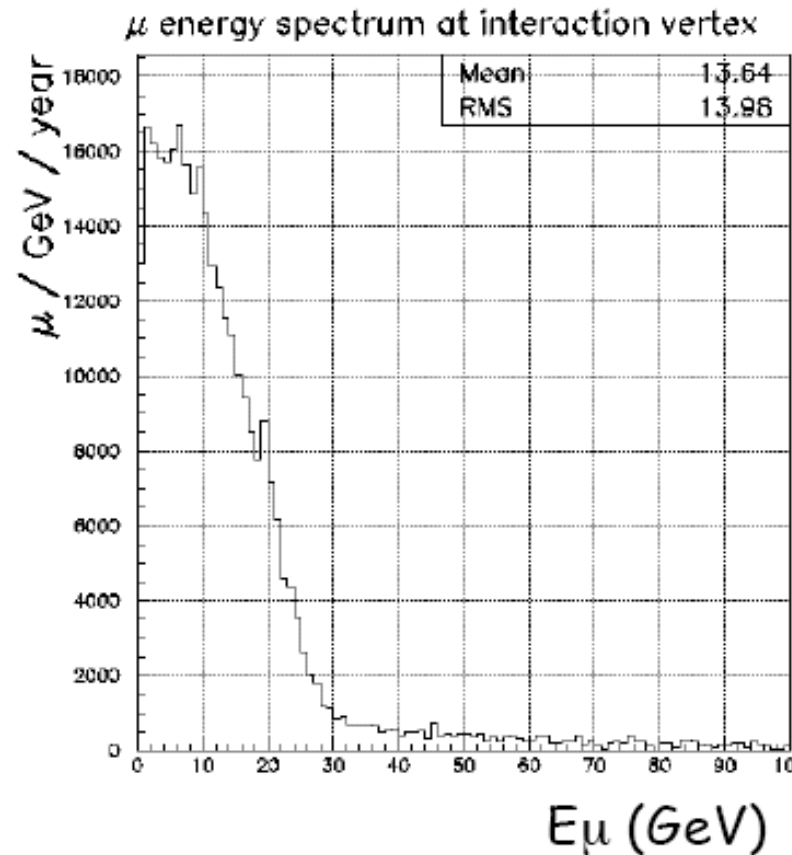
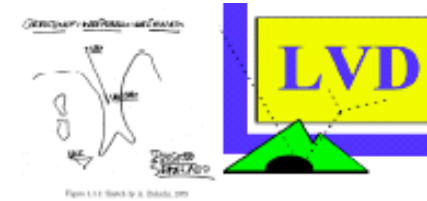


Interaction kinematics with LIPARI code

Muon transport in rock with MUSIC

LVD detector simulation with GEANT

μ energy spectrum



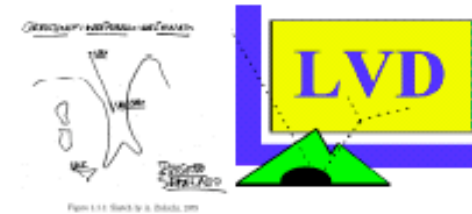
G. Sartorelli, *Waiting for the neutrino beam*, LNGS, June 22nd 2006

Number of μ from the rock



Rock Mass	1969 ktons
Nominal CNGS intensity	4.5×10^{19} pot/year
CC interaction rate	5.85×10^{-17} CC/pot/year
ν_{μ} CC in rock	5.18×10^6 / year
Number of μ in LVD "mother volume"	33600 / year
LVD geometric efficiency	79%
LVD global efficiency	72%
Detected μ in LVD	~ 120 / day

Number of internal ν events



Scintillator Mass	1000 tons
Steel Mass (tank and portatank)	850 tons
ν_{μ} CC in LVD	4770 / year
ν_{μ} NC in LVD	1460 / year
selection efficiency	97% (CC) 91% (NC)
Detected internal events in LVD	~ 30 / day

Preliminary rate values for the CNGS induced muons in Bx and CTF

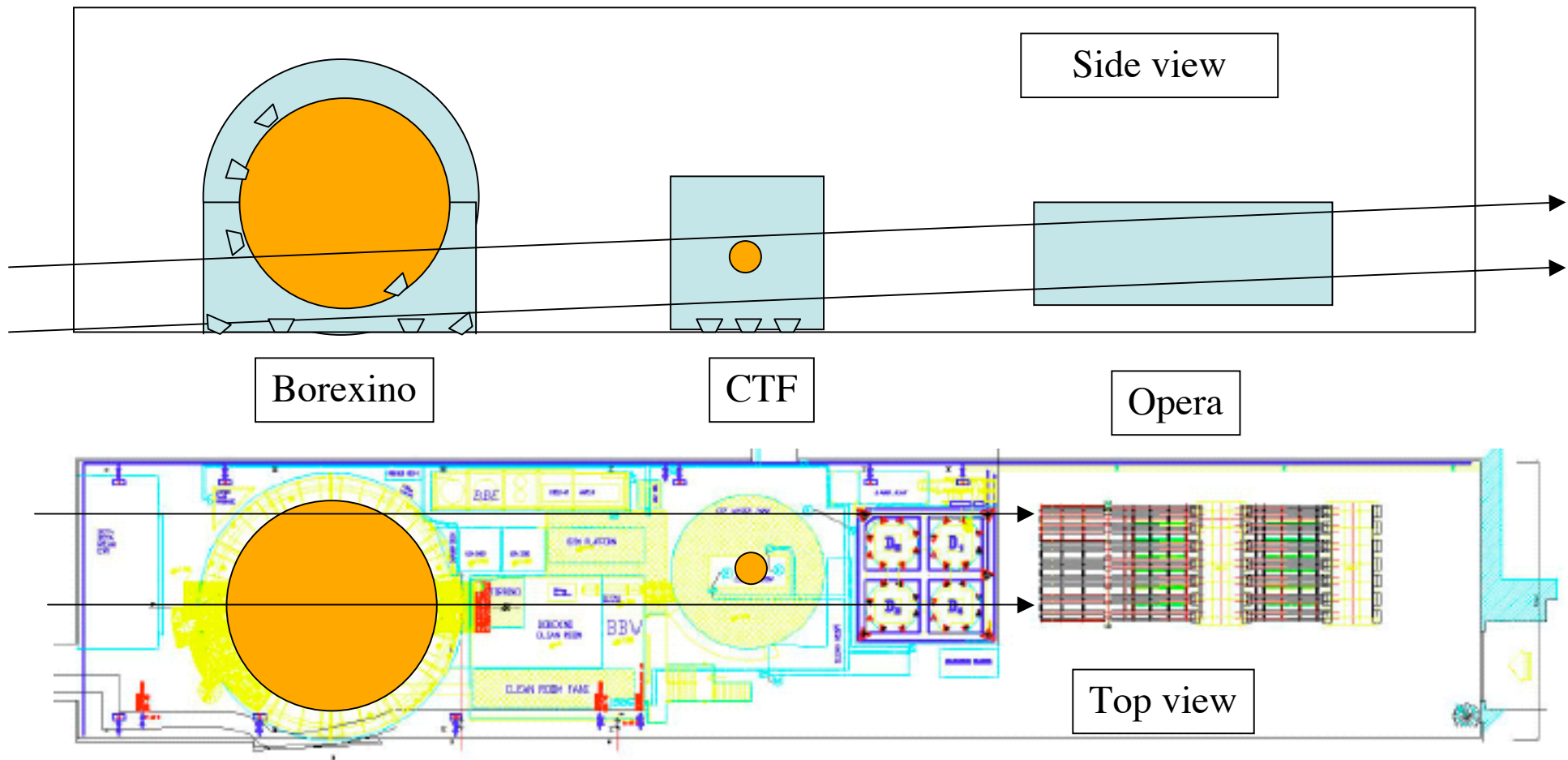
With the help of Igor Machulin and Emanuela Meroni

!! Warning !!

!! all these numbers are from very simplified calculations !!

!! no MC done so far !!!

Hall C side and top view :



How many ν_{μ} induced muon from the rocks do we have ??

Procedure:

Scaling the LVD results [M.Aglietta et al., hep-ex/0304018 v1 18 april 2003], with the usual assumptions:

33600 μ hitting the LVD “*mother volume*”/year

$$\Rightarrow 33600 / (\text{LVD sup}) \times (\text{Bx sup}) = 33600 / (13.75\text{m} \times 12\text{m}) \times 266 \text{ m}^2 =$$
$$54167 \mu/\text{year}$$
$$\Rightarrow 271 \mu/\text{day in Borexino}$$

$$\Rightarrow 33600 / (\text{LVD sup}) \times (\text{CTF sup}) = 33600 / (13.75\text{m} \times 12\text{m}) \times 110\text{m}^2 =$$
$$22400 \mu/\text{year}$$
$$\Rightarrow 112 \mu/\text{day in CTF}$$

How many CC + NC events do we have in the detectors ??

Assumptions:

these CNGS event rates in Borexino and CTF have been calculated assuming:

- Nominal CNGS beam intensity = $4.5 \cdot 10^{19}$ pot/year
- CC interaction probability = $4.96 \cdot 10^{-17}$ CC/pot/kton mass for $E_\nu < 30$ GeV
[P.Sala]
- One year = 200 days

For:

mass(Borexino) = 3.327 ktons mass(CTF) = 0.950 ktons

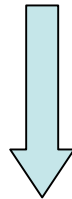
$\Rightarrow N_{\text{CCint}}(\text{Borexino}) \Rightarrow 37 \text{ CC } \mu/\text{day} (+ 11 \text{ NC ev/day})$
~ 48 ev/day in Borexino

$\Rightarrow N_{\text{CCint}}(\text{CTF}) \Rightarrow 11 \text{ CC } \mu/\text{day} (+ 3 \text{ NC ev/day})$
~ 14 ev/day in CTF

The total CNGS ν_μ induced muons (from CC in the detector itself or in the upstream rocks) or hadrons (form NC in the detector) calculated rates are:

$$48(\text{CC}+\text{NC}) + 271 \text{ (from rocks)} = 319 \text{ ev/day in Borexino}$$

$$14(\text{CC}+\text{NC}) + 112 \text{ (rocks)} = 126 \text{ ev/day in CTF}$$



How do they compare to our cosmic muon bkgnd ??

How many are detected, taking into account the detector efficiencies ??

CNGS muons vs. cosmic muons

Cosmic μ flux [μ /day] in Borexino (expected) :



IV	2025
Buffer	3125
SS Sphere	5150
Water tank	9900

and in CTF (measured):



IV	130
Water tank	2900

Considering the 10.5 μ s spill length (with a 50ms interspill gap) in a 18 s cycle, we have a reduction factor $\sim 10^{-6}$ corresponding to a cosmic μ flux in coincidence with the CERN spill :

$\sim 3 \cdot 10^{-2}$ ev/day in Borexino

$\sim 1 \cdot 10^{-2}$ ev/day in CTF

Total CNGS ν_{μ} induced events:

- *319 ev/day cross Borexino = 3% of the cosmics*
- *126 ev/day cross CTF = 4% of the cosmics*



BX and CTF *must* use the beam spill window (10.5 microseconds) info to identify the CERN μ

Expected CNGS performance: $4.5 \cdot 10^{19}$ pot/year

⇒ "standard" SPS cycle: $t = 16.8s = 12s$ FT + $4.8s$ MD

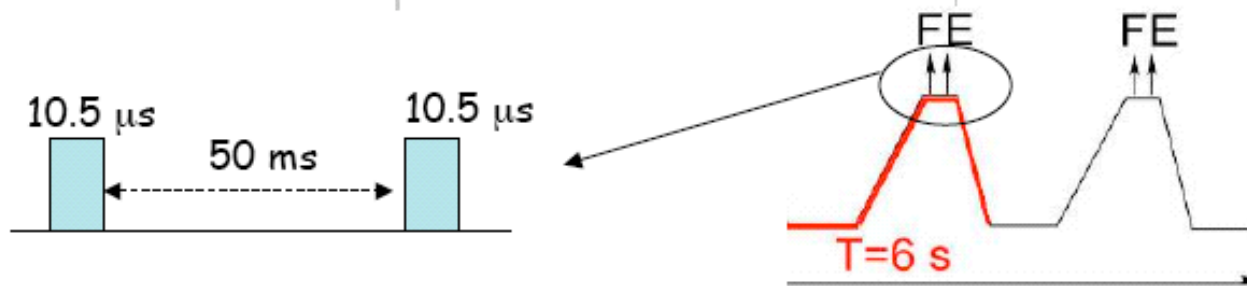
⇒ CNGS commissioning: $t = 18.0s = 12s$ FT + $6s$ CNGS

⇒ CNGS low intensity: $t = 18s = 12s$ FT + $6s$ CNGS ($0.3 \cdot 10^{19}$ pot)

⇒ CNGS high intensity: $t = 34.8s = 12s$ FT + $3 \times 6s$ CNGS + $4.8s$ MD ($1 \cdot 10^{19}$ pot)

Beam parameters	Nominal CNGS beam
Nominal energy [GeV]	400
Normalized emittance [μm]	H=12 V=7
Emittance [μm]	H=0.028 V= 0.016
Momentum spread $\Delta p/p$	0.07 % +/- 20%
# extractions per cycle	2 separated by 50 ms
Batch length [μs]	10.5
# of bunches per pulse	2100
Intensity per extraction [10^{13} p]	2.4
Bunch length [ns] (4σ)	2
Bunch spacing [ns]	5

pot for FT
reduced to 40%



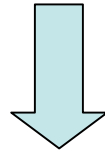
CNGS cycles

(from D.Autiero)

To correlate the events recorded by the experiments with the beam spill windows (10.5 microseconds):

$$T(\text{LNGS}) = T(\text{kicker at CERN}) + \text{TOF}$$

Using UTC times recorded at CERN and LNGS



UTC clocks synchronizations and calibrations needed

From Autiero's presentation:

- the *early warning signal*: the next neutrino spill can be predicted in advance of several seconds and this info can be transmitted through their network
⇒ *implemented and tested since March*
already used by OPERA ;
to be decided: the list of machines which should receive the signal
- the *complete calibration of the time distribution chain of OPERA*
⇒ *in progress*
 - Alessandro Razeto had contacts with LNGS Computer Center and Opera
for eventual use of this information by BX and CTF
- the *CERN-LNGS UTC clocks intercalibration* for the neutrino spill synchronization
⇒ *finished*:
 - understood and taken account of the 356 ns offset
 - $\Delta t < 100$ ns

- the *CNGS-LNGS database* (ORACLE based, 1TB/day info):
 - to correlate the events recorded by the experiments with the beam spill windows (10.5 microseconds) : $\Delta t < 100$ ns
 - the LNGS exp. will be able to write the events observed in correlation to the spills
- => *in progress*: access being tested by OPERA, docs available

Final rates taking into account the detector geom efficiencies

In Borexino :

muons generated		Det eff.	Final rate[ev/day]
inside the det.	48	~98%*	47
in the rocks	271	~99%	268
Total rate	319		315 [ev/day]
Cosmic muon rate bk			$3 \cdot 10^{-2}$ ev/day

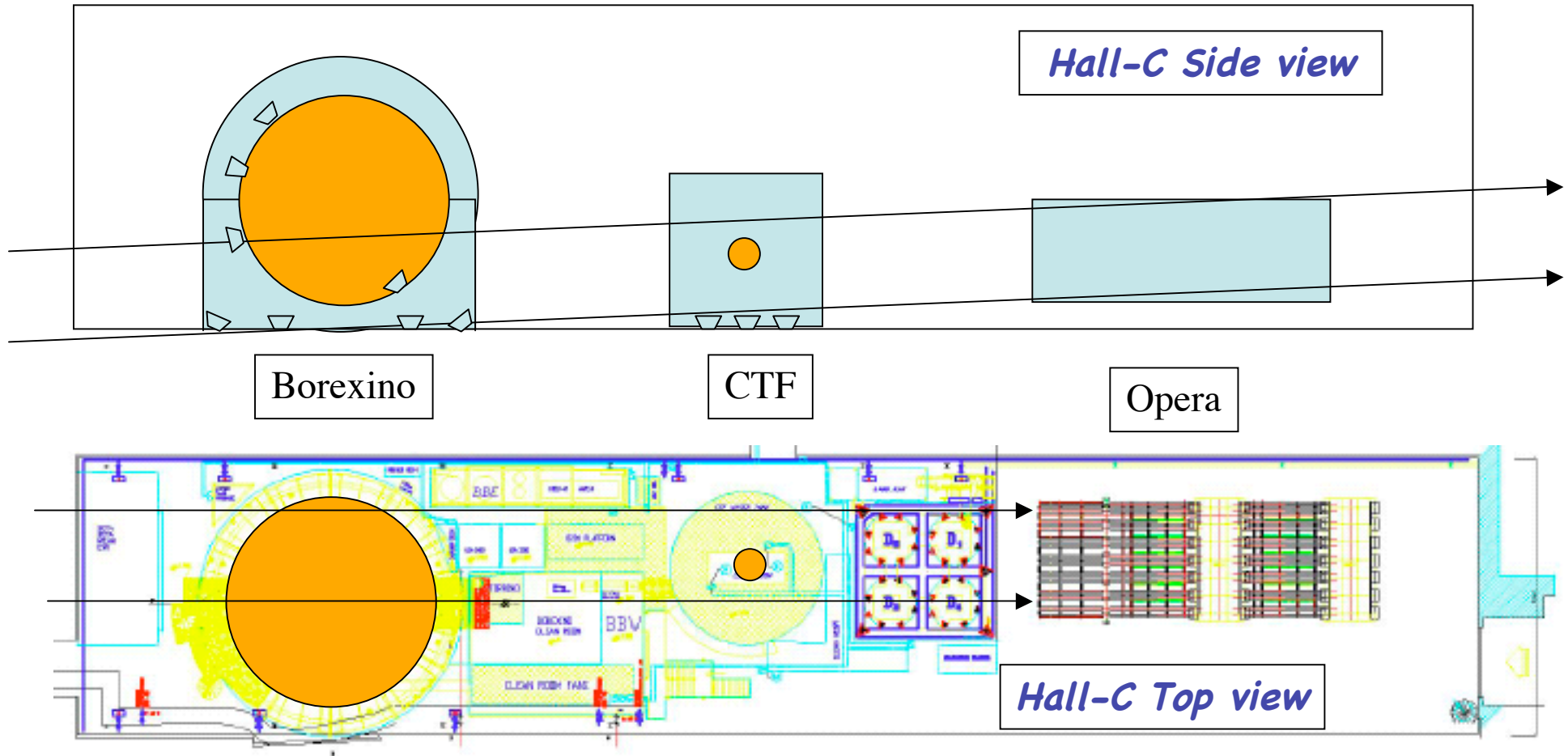
In CTF:

muons generated		Det eff.	Final rate [ev/day]
inside the det.	14	~50%*	7
in the rocks	112	~98%	110
Total rate	126		117 [ev/day]
Cosmic muon rate bk			$1 \cdot 10^{-2}$ ev/day

Final detected event rates in the first runs:

Run #		LVD	BX	CTF
nominal	4.5 10 ¹⁹ pot/year	~ 150 /day	315/day	117/day
1	2 10¹⁶ pot/week	~ 13/week	28/week	
2	3 10¹⁶ pot/week	~ 20/week	42/week	15/week
3	5 10¹⁶ pot/week	~ 33/week	70/week	26/week

We can have BX-CTF-Opera coincidences



How many ν_{μ} induced muon from the rocks do we detect both in Opera and in Borexino and CTF ??

Scaling the LVD results [M.Aglietta et al., hep-ex/0304018 v1 18 april 2003], with the usual assumptions:

33600 μ hitting the LVD “*mother volume*”/year

$$\Rightarrow 33600 / (\text{LVD sup}) \times (\text{Bx sup}) = 33600 / (13.75\text{m} \times 12\text{m}) \times (6.7 \times 6.7) \text{m}^2 =$$

9141 μ /year
45 μ /day

Conclusions

- **Can Borexino/CTF monitor the CNGS ν beam ??** **Yes !**

In LNGS - HallC we will have :

- **~ 315 ev/day in Borexino** (~ 150 detected ev/day in LVD)
 ~ 60 μ /day hit OPERA
- **~ 117 ev/day in CTF**

Corresponding to a 3% stat. error in: **3.5 days for Borexino (7 for LVD)**
9.5 days for CTF

What we have to do ??

These are very preliminary results

\Rightarrow MC- calculate all the acceptances of the detectors for these *horizontal* muons

- **What is needed for monitoring ??**

Spill timing information

- **Can Bx do something else ??**

Yes !! Beam burst structure, Calibrations, Track algorithm checks,
?? Some physics?? σ_{cc} ???

Conclusions for us:

What we have to do ??

Decide if/how we want:

- *to study this new bkgnd*
- *to monitor the CNGS beam*

=> decide which actions to do , who does what, by when

- *to take advantage of it*

=> decide which actions to do , who does what, by when

Needed:

Software:

- MC simulations
- Interface with the CNGS database (read and write)

Hardware:

- spill info read-out (BX clock calibrations)

•Can Bx do something else ??

- Think about it !!