Borexino, CTF and the CNGS neutrino beam

Laura Perasso - I.N.F.N. Milano

Content:

I. The Borexino and CTF Muon Identification Systems:
- the physics case
- descriptions, efficiencies

II. Preliminary rate values for the detected CNGS beam induced muons

III. Conclusions

in the detectors

The CNGS ν_μ beam can be monitored detecting the ***muons*** produced by the CC and NC interactions

in the rocks in front of the detectors

with muon identification systems

Borexino and ***CTF*** :

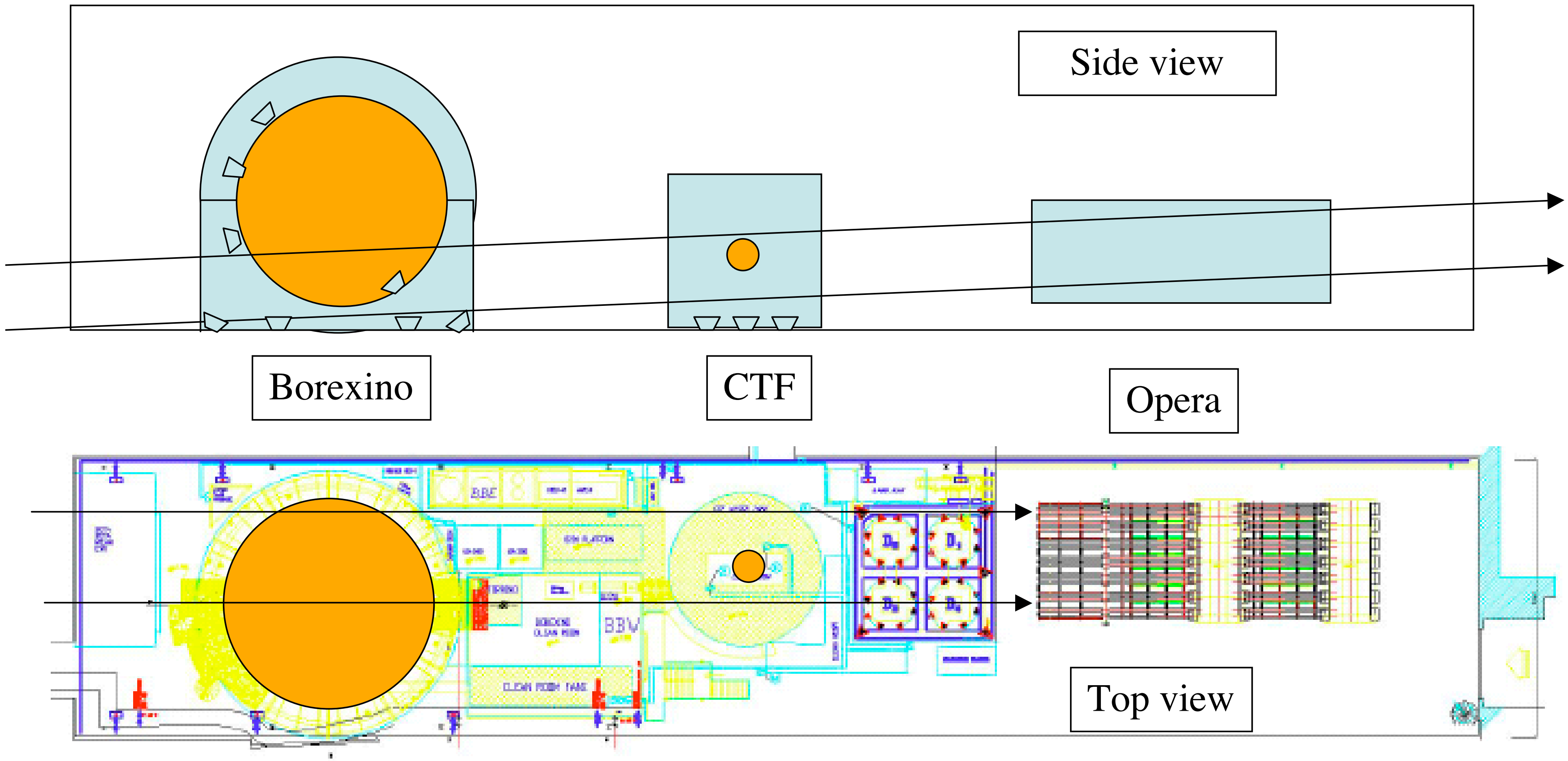
- have very good muon identification systems
  => hight det. eff.

- are huge (BX) / big (CTF)
  => high rates

- CTF is currently running and taking data

- are in Hall-C just in front of the Opera detector
  => coincidences are possible

Hall C side and top view :



Why BX has a Muon Identification system: The Physics case

The primary purpose of the Borexino Collaboration is
the measurement of the solar ν_e from ^{7}Be at the 5% level
through the el. scattering $\nu_e + e^- \rightarrow \nu_e + e^-$
for $E_\nu \in (0.250 \div 0.800)$ MeV ["Neutrino Window (νW)"]

Why:

- ~ 10% of the solar ν produced are 862-keV ^{7}Be ν_e
- the 98% of the total ν_e solar flux has E_ν<1MeV
- **so far no experiment** has directly observed *in real time* these neutrinos

Other goals at these low energies are:

- detect Solar pep and CNO neutrino fluxes
- explore the vacuum-matter transition region
- detect geoneutrinos and supernovae neutrinos
- measure the neutrino magnetic moment
- …….

In order to make these very difficult measurements

=> we MUST reduce the bkgnd in the νW - (0.250 ÷ 0.800) MeV - at not previously reached values at these dimensions

⇓

INSIDE the detector

AND

in the detector *SURROUNDING* materials (rocks, ..)

⇒ we MUST also be able to IDentify the cosmic muon bkgnd

- Cosmic ***muons*** crossing the detectors
- Radionuclides produced by ***muons*** in the scintillator

Cosmic muon crossing the detectors

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

Given the ~ 10^4 muons/day which hit Borexino, in order to have 1 muon ev/day

=> Borexino must have a ***muon identification*** (or muon veto) ***system*** to reduce the leak rate of muons into the ^{7}Be ν window below 10^{-4} => ***ε better than 0.9999***

=> a muon ID system is needed

Gamma rays and Radionuclides produced by muons in the scintillator

- ***gamma rays*** from capture of cosmogenic ***neutrons*** produced by cosmic ***muons*** primarily in hadronic showers

- ***radioactive nuclides*** : The ***muon***-induced nuclear cascade also produces radioactive nuclides in the Scintillator

=>> These bkgnd can be tagged by excluding pulses preceded by muon signal within a time window

=> this efficiency depends on the rad. nucl. lifetime

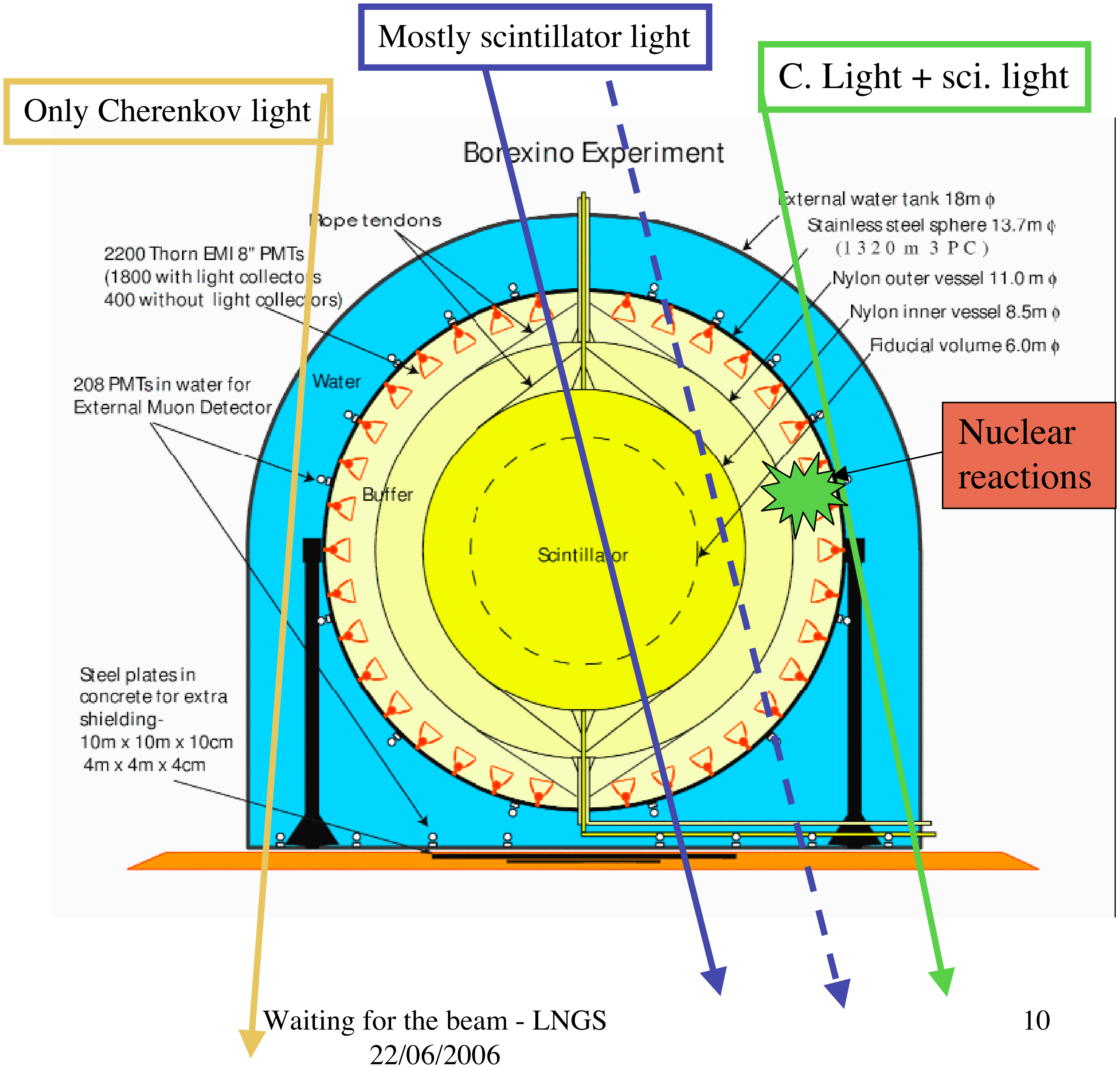
=> a muon ID system is needed

The Borexino μID Systems

It is composed of 2 independent subsystems, whose combined efficiency adds up to give the aimed rejection figure in case of prod. of prompt μ in the νW:

1) The Outer Muon System
2) The Inner Muon System

μ across BX



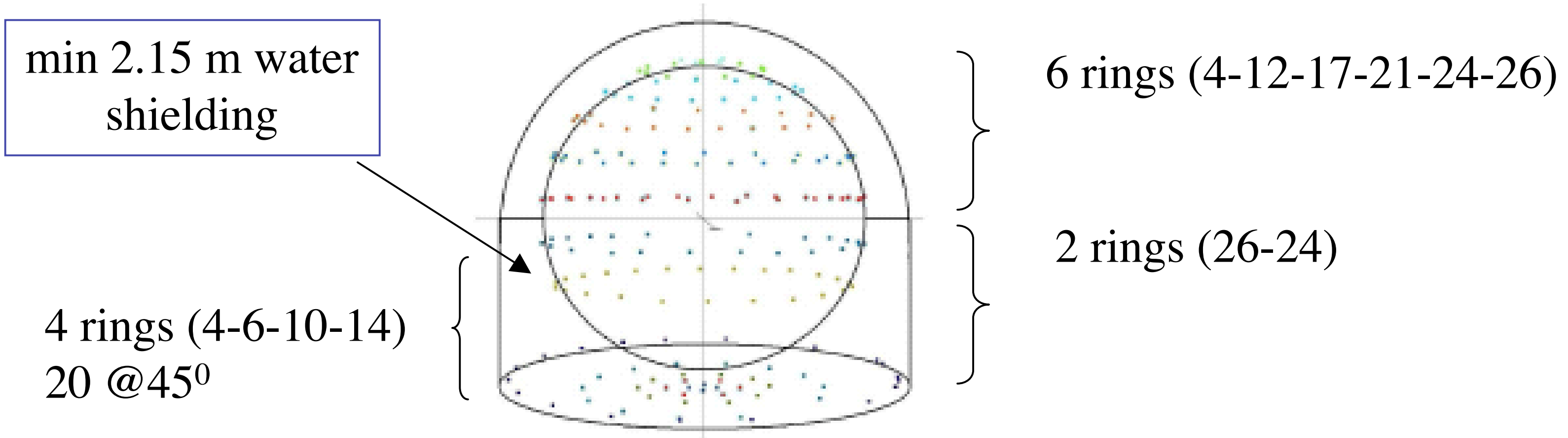
Only Cherenkov light
Mostly scintillator light
C. Light + sci. light
Borexino Experiment
External water tank 18m ϕ
Stainless steel sphere 13.7m ϕ
(1320 m 3 PC)
Nylon outer vessel 11.0 m ϕ
Nylon inner vessel 8.5m ϕ
Fiducial volume 6.0m ϕ
Rope tendons
2200 Thorn EMI 8" PMTs
(1800 with light collectors
400 without light collectors)
208 PMTs in water for
External Muon Detector
Water
Buffer
Scintillator
Steel plates in
concrete for extra
shielding-
10m x 10m x 10cm
4m x 4m x 4cm
Nuclear reactions

1) The Outer Muon System :

208 PMTs (8" ETL-9351) : 6 rings on the top hemisphere of the SSSphere outside surface
2 rings on the bottom one,
34 PMTs on the Water Tank floor and
20 looking up at 45^0 around the WT floor.

=> to detect the Cherenkov radiation from muon tracks in the shielding HP water

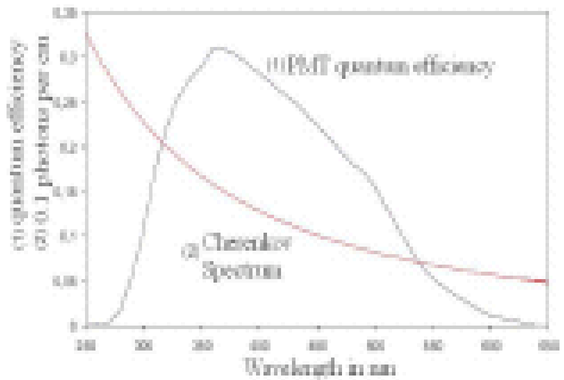
(geom. optimized for perpendicular tracks ID and reco !)



For μ passing between the SSSphere and the Water Tank (pure Water) => Cherenkov effect

$$\frac{d^2N_\gamma}{dx\, d\lambda} = \frac{2\pi\alpha z^2}{\lambda^2}\left[1 - \frac{1}{\beta^2 n^2(\lambda)}\right]$$

Integrating taking into account the PM QE and a "*practical factor*" (*Q.E.* X *p.f.* = 0.12)



=> # detectable *pe* in water ~ 32 *pe/cm*

In the OD:
- the min. Δx = 200 cm
- the OD PMs coverage is ~ 1.1%

=> ~ 70 *pe/ev*

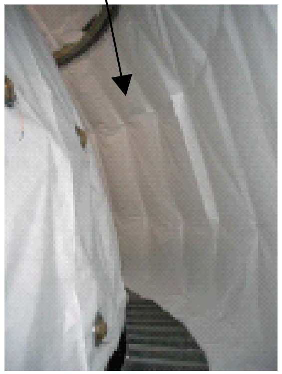
but with addition of the Tyvek surface we=>> expect ~*150 pe/ev*

R_{eff}^{STEEL}= ~ 38 % $R_{effTyvek}$= ~ 79.5%

Muon ID is path dependent ~ 98%

Outer Muon System PMs

Water buffer



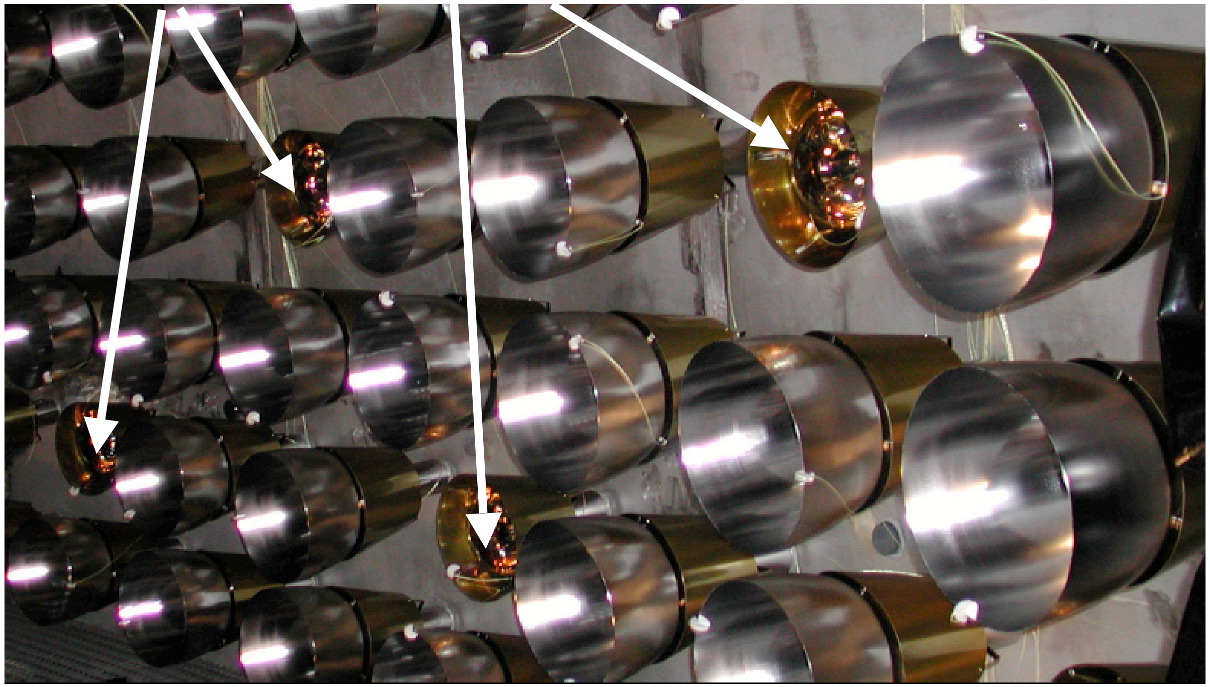
SS Surface is covered by Tyvek

2) The Inner Muon System:

374 (out of the 2212 total) 8” ETL-9351 PMs ***do not have*** the Al light concentrators (∅=20cm)

=> their acceptance angle is wider than the other ones optimized to view the Inner Vessel.

These 374 ***no-cone PMs*** will more likely detect particle not crossing the IV



a) For μ passing across the PC + DMP buffer => Cherenkov

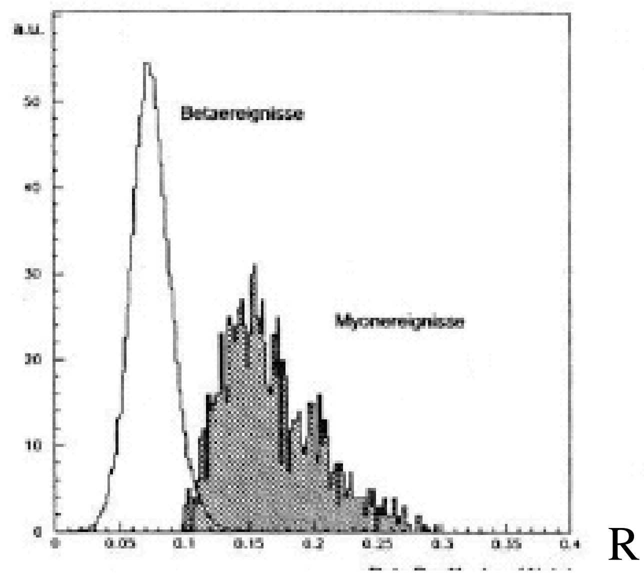
Cherenkov => # detectable *pe* in PC ~ 41 *pe/cm*

In the ID:
- the min. Δx = 260 cm X 2
- the ID PMs coverage is ~ 2.4%

⇒~ 500 *pe/ev*

(we assume here negligible scintillation)

Muon ID ~ 99 %



R= (Σ in the 374 PMs without light cone at the first pe) / Σ(of all the 2212 PMs)

[L.Oberauer]

b) For μ passing across the PC+PPO IV =>scintillation

of photon emitted from PC+PPO scintillation =

12000 photons /MeV * 0.87 g/cm^3 * 1.8 MeV/g/cm^2

=> *1.9 10^4 photons/cm*

=> ~ *650 pe/cm detected*

=>> for ~ 30 cm path inside the scintillator => the electronics will be saturated

Muon ID = 100%

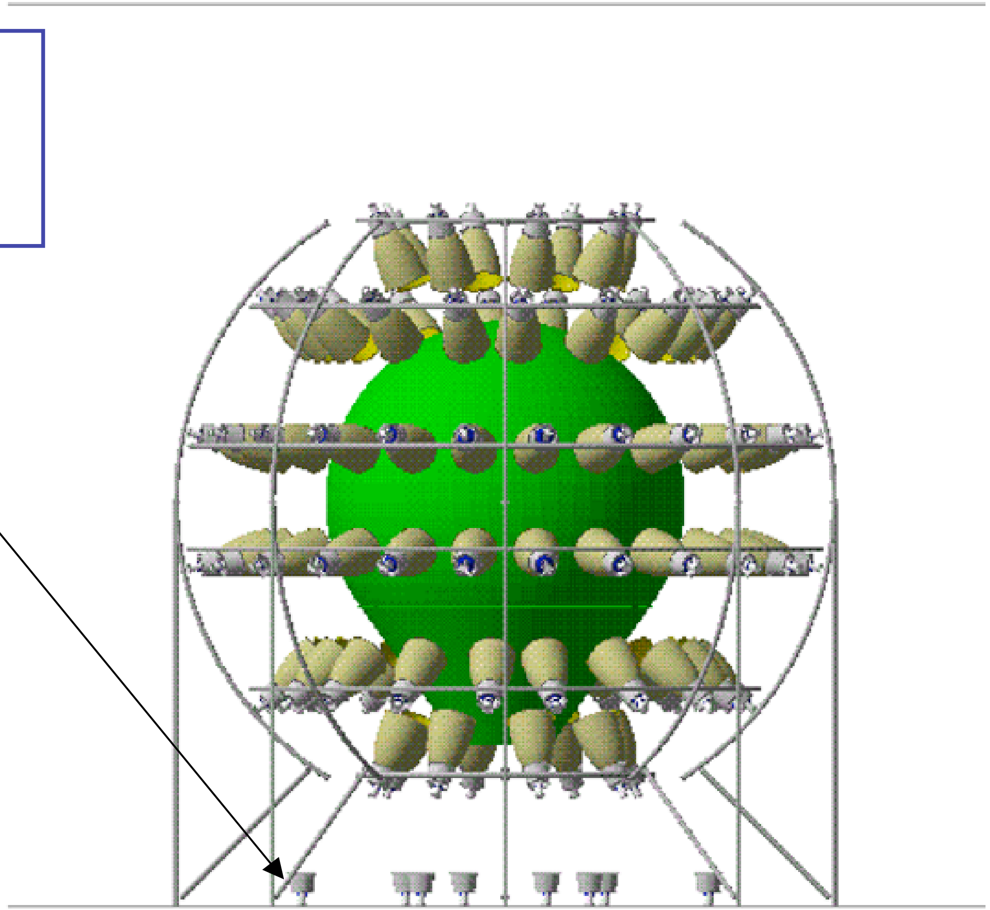
The CTF μID System

8+8 PMs on the floor in two concentric rings at 4.9 m and 2.4 m

100 PMT around a ~3 m radius open structure

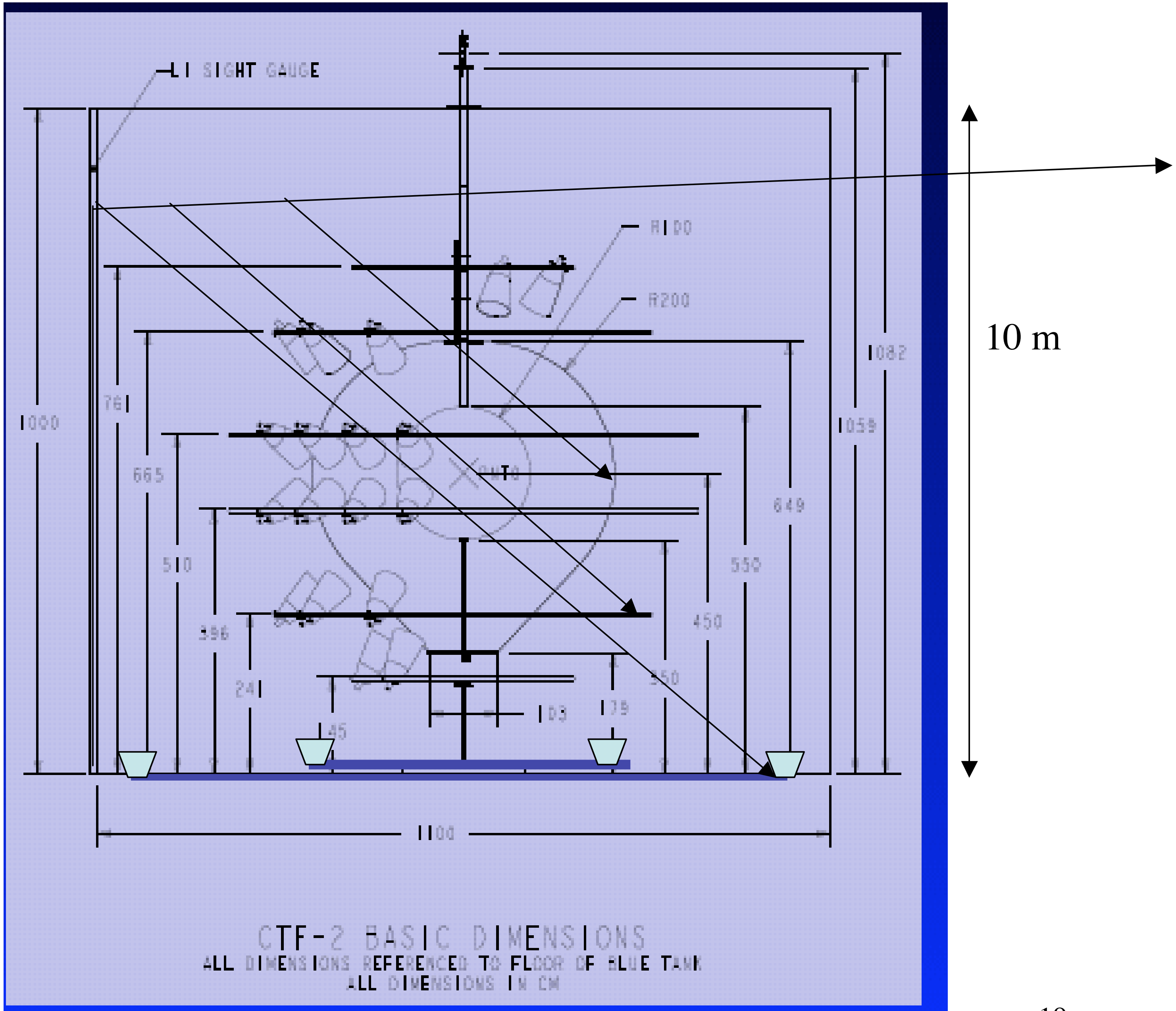
Cherenkov effect + scintillation when going through the 5.5m radius scint. IV

Muon detection efficiency depends on the path ~ 100%



z=8.4 m

h max to use the floor muon veto system



10 m

^{11}C bkgnd for pep and CNO neutrinos in Borexino

pep => 1.44 MeV monocromatic ν line
(Compton edge @ 1.22 MeV)

A measurement of pep neutrino flux :

- gives equivalent info on SSM fluxes and oscill parameters as a pp measurement [Bahcall & Pena-Garay, hep-ph/0305159]
- investigates the matter-vacuum trans. region for solar ν oscill.

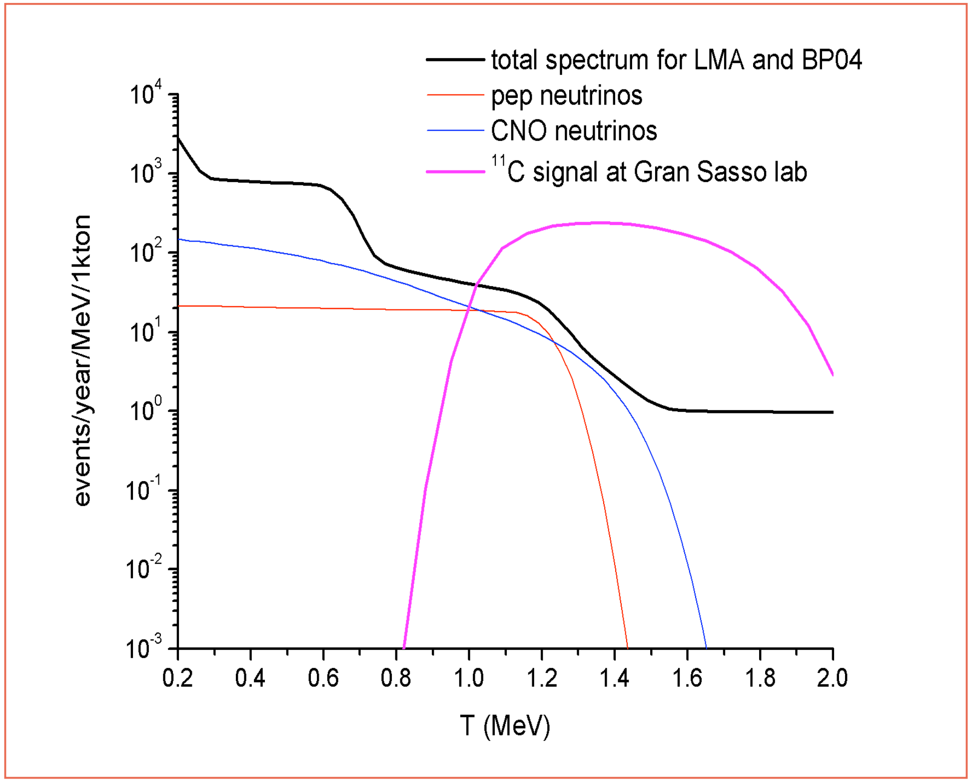
Difficulty => Very low rates:

pep = 2.1
CNO= 3.5 [ev/day in 100t]

Needed very low:

- Internal ^{238}U, ^{232}Th and Ext. bkgnds
- cosmogenic background

(ex: ^{11}C; $t_{1/2}$ = 21 min; 15 ev/day in 100 t)



=> a muon veto ID is needed

The ***CTF μID System*** has recently been proven to work successfully even for the tagging of the long (21 min) ^{11}C cosmogenic bkgnd [hep-ex/0601035]

^{11}C Trigger = (***muon ID***) x *n* x (^{11}C *decay*)

$$^{11}C \rightarrow {}^{11}Be + e^+ + \nu_e$$

$$E_{decay} \in (1.02 \div 1.98)\ \text{MeV}$$

Preliminary rate values for the CNGS induced muons

!! Warning !!

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

!! no MC done so far !!!

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

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

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

For:

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

$\Rightarrow N_{CCint}$(Borexino) = 7426ν_μ cm^{-2}/year => ***37 CC ev/day + 11 NC ev/day***

~ 48 ev/day in Borexino

$\Rightarrow N_{CCint}$(CTF) = 2120 ν_μ cm^{-2}/year => ***11 CC ev/day + 3 NC ev/day***

~ 14 ev/day in CTF

How many ν_μ induced muon from the rocks do we have ??

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

⇒33600 / (LVD sup) X (Bx sup) = 33600 / (13.75m X 12m) X 266 m^2=
54167 μ/year
⇒271 μ/day in Borexino

⇒33600 / (LVD sup) X (CTF sup) = 33600 / (13.75m X 12m) X 110m^2=
22400 μ/year
⇒112 μ/day in CTF

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

48(CC+NC) +271 (from rocks) = ***319 μ/day cross Borexino***

14(CC+NC)+ 112 (rocks) = ***126 μ/day cross 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 μs spill length with a 50ms interspill gap we have a cosmic μ flux in coincidence with the CERN spill :

~ 2 ev /day in Borexino ***~ 0.5 ev /day in CTF***

Total CNGS ν_μ induced muons :

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

→ BX and CTF must use the beam spill to identify the *CERN μ*

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			2 ev/day

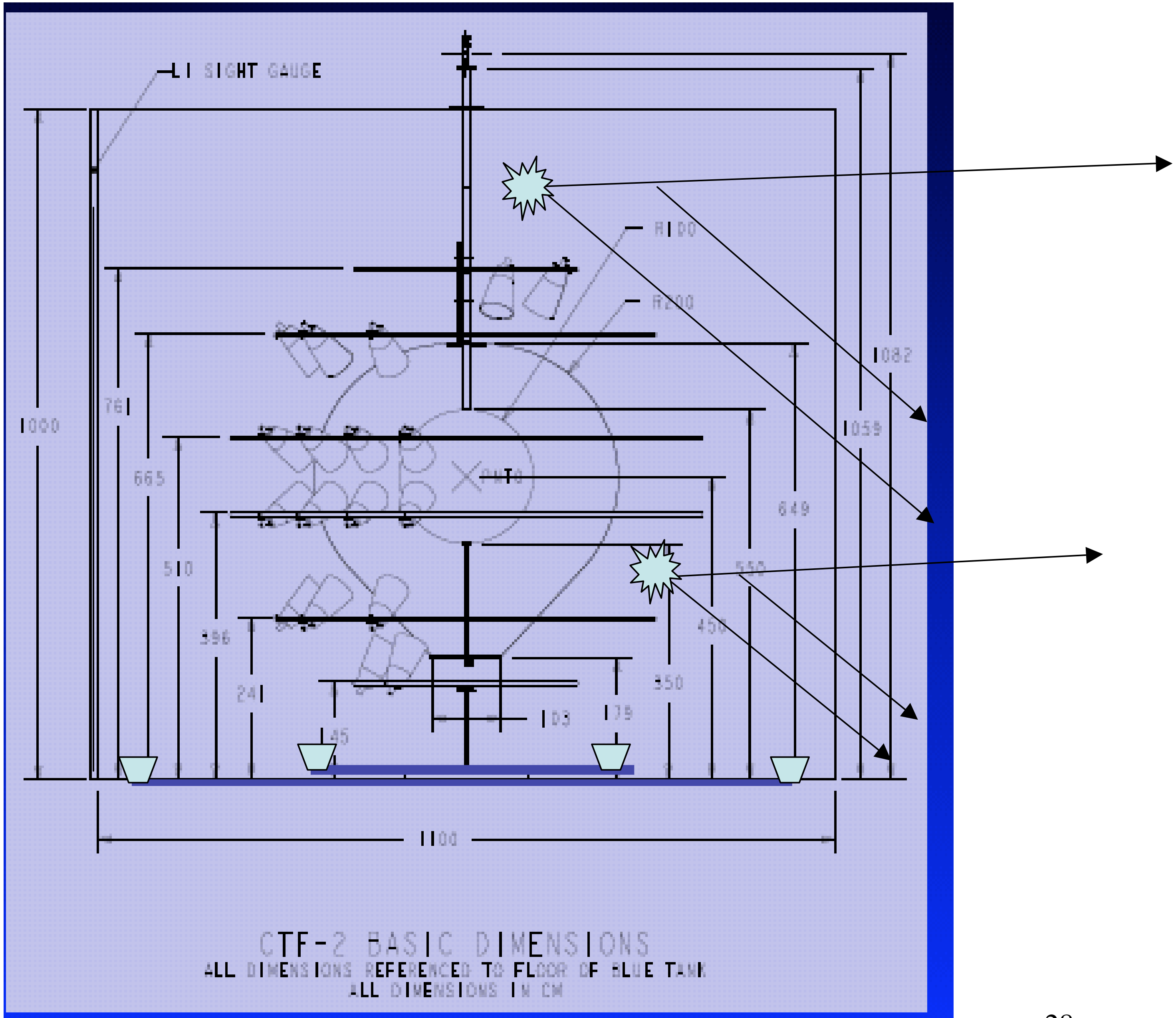
In CTF:

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			0.5 ev/day

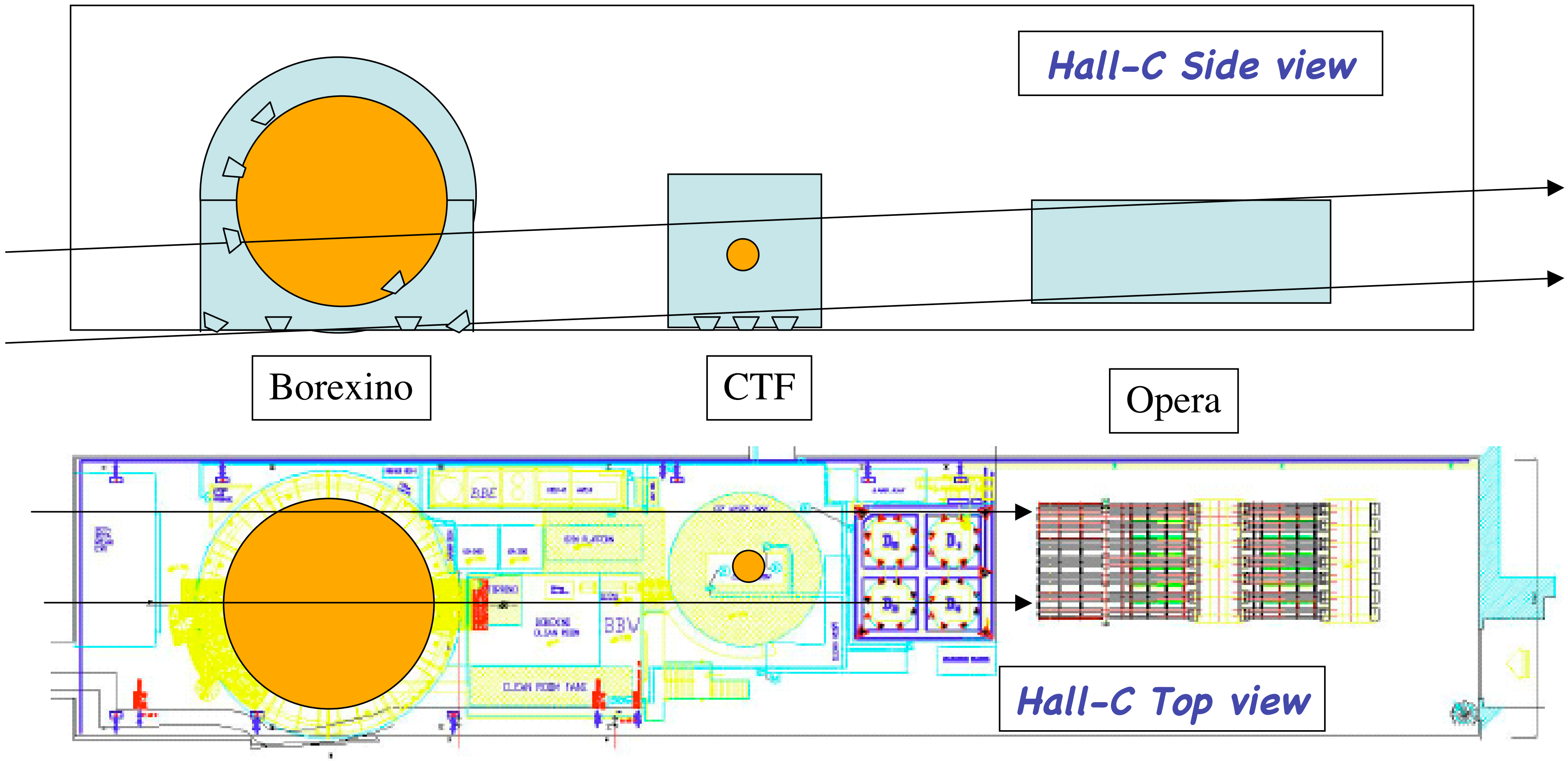
** dep. on the trigger thresh*

z=8.4 m

h max to use the floor muon veto system



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

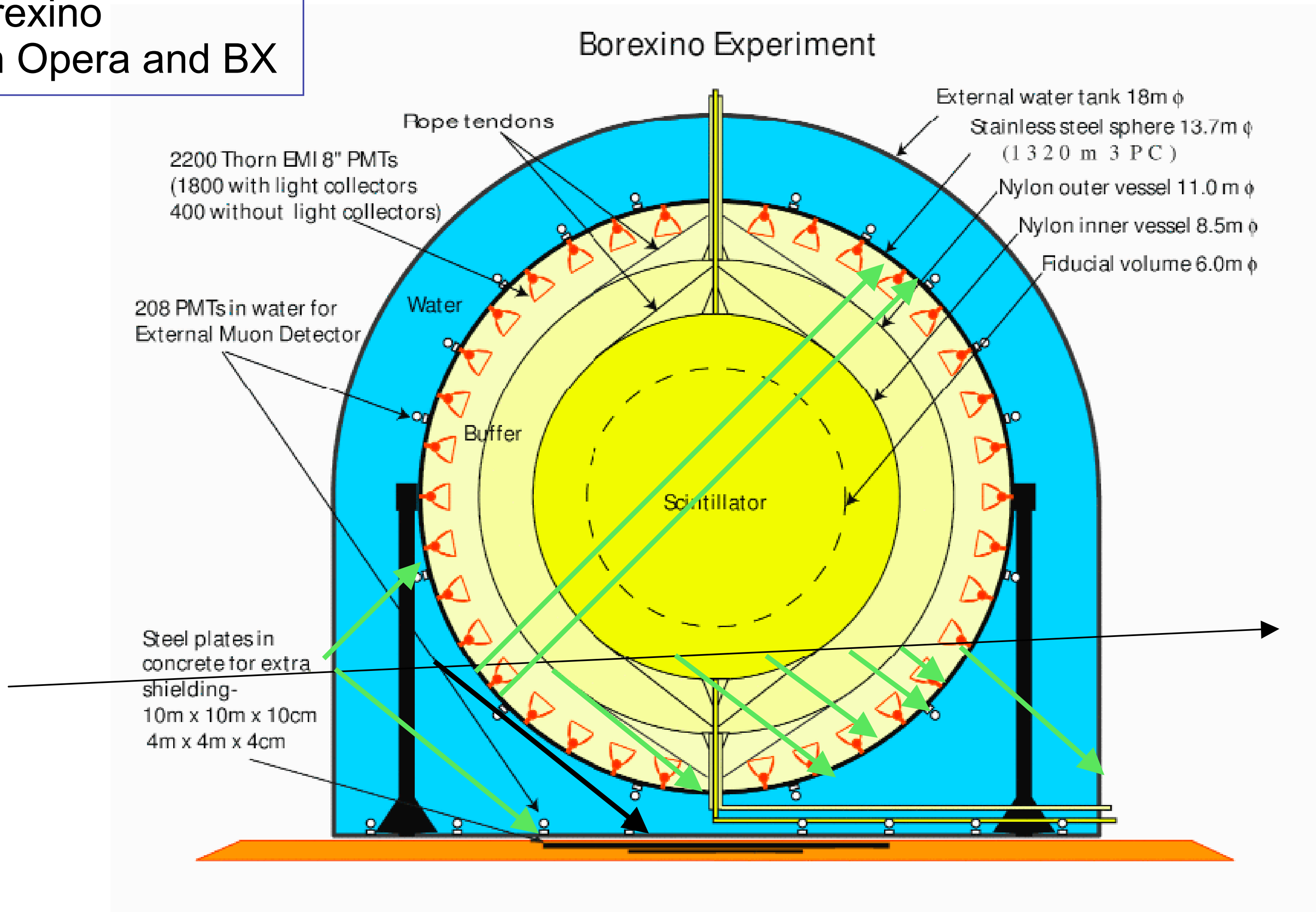
⇒33600 / (LVD sup) X (Bx sup) = 33600 / (13.75m X 12m) X (6.7 X 6.7) m^2=

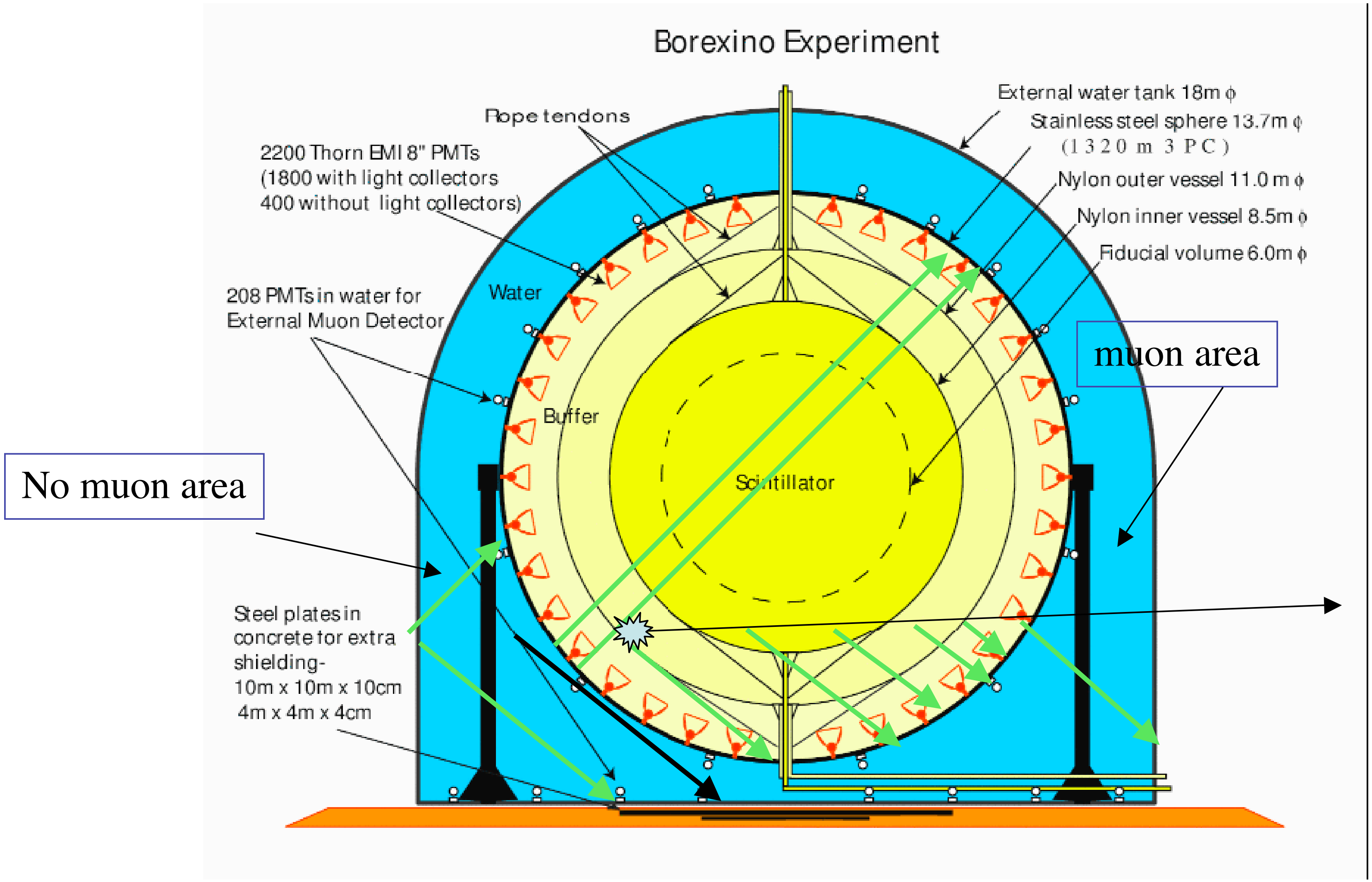
9141 μ/year

45 μ/day

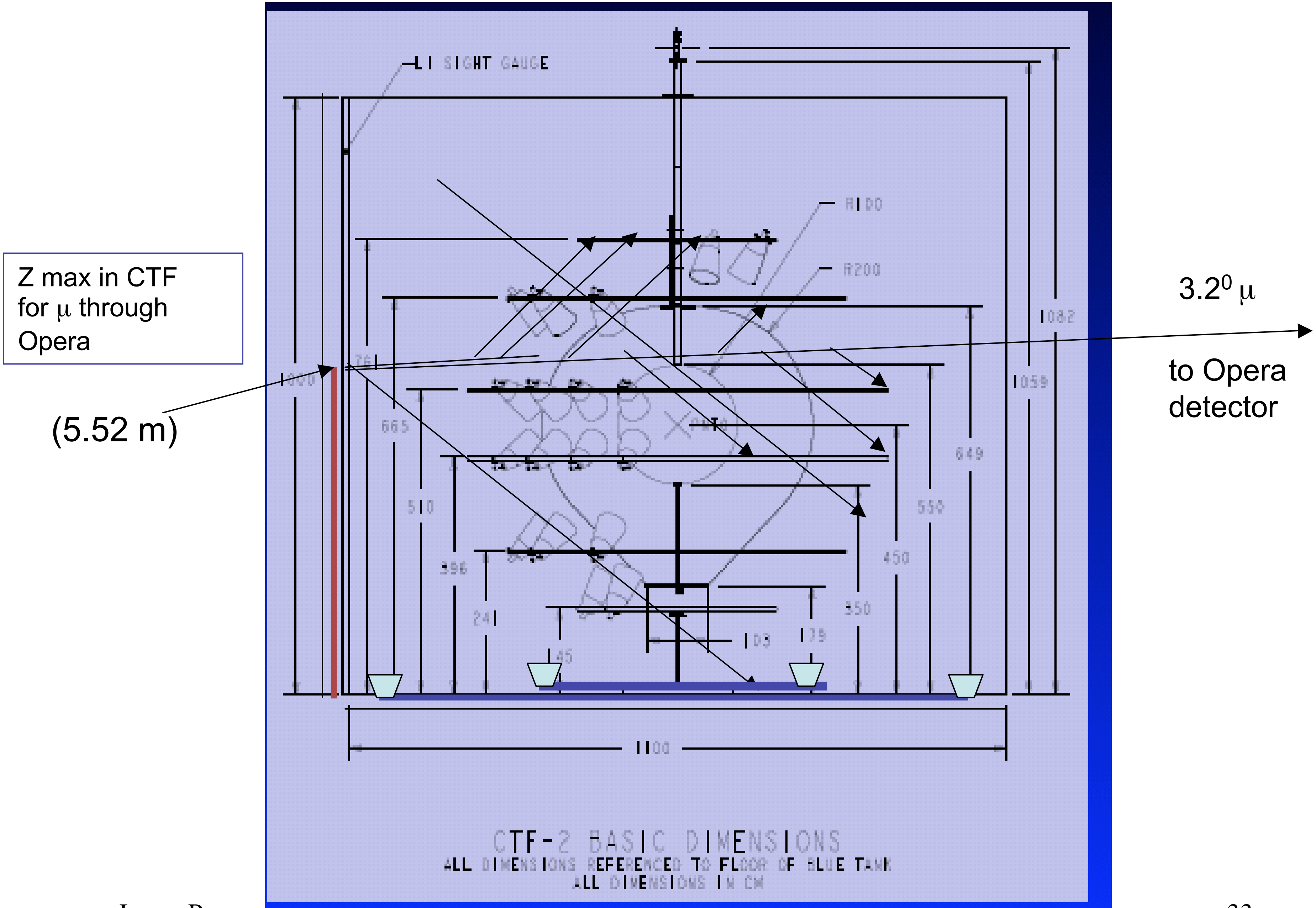
Z max in Borexino
for μ through Opera and BX

(3.66 m)





Borexino Experiment
External water tank 18m ϕ
Stainless steel sphere 13.7m ϕ
(1320 m 3 PC)
Nylon outer vessel 11.0 m ϕ
Nylon inner vessel 8.5m ϕ
Fiducial volume 6.0m ϕ
Rope tendons
2200 Thorn EMI 8" PMTs
(1800 with light collectors
400 without light collectors)
208 PMTs in water for
External Muon Detector
Water
Buffer
Scintillator
Steel plates in
concrete for extra
shielding-
10m x 10m x 10cm
4m x 4m x 4cm
No muon area
muon area


Z max in CTF
for μ through
Opera
(5.52 m)
3.2⁰ μ
to Opera
detector
LI SIGHT GAUGE
R100
R200
1082
1059
1000
761
665
510
396
241
649
550
450
350
179
103
45
1100
CTF-2 BASIC DIMENSIONS
ALL DIMENSIONS REFERENCED TO FLOOR OF BLUE TANK
ALL DIMENSIONS IN CM

Conclusions

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

In LNGS - HallC we will have :

- ***315 μ/day in Borexino***
- ***117 μ/day in CTF***

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

What we have to do ??

These are very preliminary results

=> 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}???