

The CNGS beam and the Borexino events in October 2007

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Borex report - 21 November, 2007

1 Introduction

We present here a brief report on the CNGS beam in the period September 17th - October 28th 2007. During this time Borexino was taking data in its final configuration and 905 events have been tagged as "CNGS induced muon events".

The CNGS beam is expected to be back at the end of may 2008.

2 The CNGS beam in October 2007

The CNGS beam line commissioning phase was supposed to start in week 38 (September 17th) to go on during weeks 39 and 40; weeks 41-42-43 (October 8th up to October 28th) were supposed to be "good" beam period, with a long SPS supercycle (27.6 second period) made of 3 CNGS cycles (6 second period) (see ref [1] for more details on the beam structure).

The beam commissioning started on September 21st but info on the extraction time and intensity was available only since September 24th at 08:46. The final beam configuration - but still with low intensity - was reached on September 28th when we had ≈ 10 hours beam and on September 29th with ≈ 8 hours beam; there was beam again on October 1st and 2nd, for a total of ≈ 29 hours, and for a quite long period from October 5th till october 9th for a total of ≈ 96 hours. Shorter beam periods were available October 11 - 12 (≈ 12 hours) and October 19-20 (≈ 10.5 hours).

Then, after continuing problems with the controls of the ventilation units of the CNGS target area, it was decided to stop the CNGS beam on October 20th, at 02:55 a.m., eight days before the scheduled stop since the control system failures were caused by radiation damages (due to hard neutrons) of the devices and major modifications are needed.

Most of the time there were the expected two extractions in each of the 3 cycles in each supercycle, for a total of 6 extractions for each SPS supercycle; each extraction is $10.5\mu s$ long and the two are $50ms$ apart.

The time difference between the first extractions is plotted in fig. 1-top: the nominal "6 seconds" (inter-cycles) and "27.6 seconds" (inter-supercycles) values are achieved only in stable "good" beam situation, as can be seen in fig.1-bottom, where these values are plotted versus time (seconds [UTC] starting September 24th) ; there is a "12 seconds" difference whenever there is an empty central cycle and so on. The peak at 22.5 seconds corresponds to the spills at the beginning of the beam commissioning time, when there was only one extraction (the first one) in a 22.5s supercycle (see fig. 1-bottom).

The beam intensity for the first (second) extractions, is plotted in fig.2 (3) -top (intensity units are *pot*- proton on target- 10^{12}), and versus time in fig.2 (3) -bottom: the 6 beam periods are clearly visible as the missing of the second extractions in the first period. The intensity values were quite low at the beginning, reaching $\approx 1.7 \cdot 10^{13}$ pot/extraction only during the October 5th - 9th period. Still this value was lower ($\approx 41\%$) than the nominal $2.4 \cdot 10^{13}$ pot/extraction value.

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The number of the CNGS delivered extractions versus time is plotted in figure 4-top while in figure 4-bottom is plotted the CNGS proton integrated intensity during the 2007 (September and October) beam period. The delivered integrated intensity and the Borexino collected intensity are plotted in figure 5.

In total we were delivered $8.235 \cdot 10^{17} pot$ (proton on target) total - ≈ 14 times the pot delivered in October 2006 - and we took data for $6.5 \cdot 10^{17} pot$ corresponding to a $\approx 79\%$ efficiency.

3 The Borexino Data Sample

The analyzed runs (all validated) are listed in table 1, for a total of 6417742 events. The beam information was available for 171 h and 19 min and the analyzed runs correspond to 143h and 46 min (85 %) but these times not always overlap: sometimes there was beam and we were not taking data or viceversa, so the net efficiency, as written above, was lower.

RUN	starting	ending	events
5972	sep 24- 10:04	sep 24- 11:36	70346
5973	sep 24- 11:48	sep 24- 16:57	234906
5974	sep 24- 17:00	sep 24- 22:31	250758
5998	sep 28- 19:25	sep 29- 08:36	608712
6001	sep 29- 09:30	sep 29- 16:03	303698
6015	oct 01- 12:01	oct 01- 15:24	158604
6016	oct 01- 15:35	oct 01- 21:56	294365
6020	oct 01- 10:50	oct 01- 22:28	539059
6036	oct 05- 15:28	oct 05- 22:11	319204
6037	oct 05- 22:12	oct 06- 10:40	368086
6040	oct 06- 11:43	oct 06- 21:54	487436
6046	oct 07- 12:11	oct 07- 16:33	208407
6049	oct 07- 16:55	oct 07- 22:54	254206
6050	oct 07- 22:56	oct 08- 02:16	158066
6051	oct 08- 09:47	oct 08- 10:28	33705
6052	oct 08- 10:38	oct 08- 16:04	256810
6053	oct 08- 16:11	oct 08- 17:10	47035
6055	oct 08- 17:40	oct 08- 18:44	50377
6058	oct 08- 19:06	oct 08- 21:57	70530
6059	oct 08- 22:11	oct 09- 07:31	428324
6060	oct 09- 10:08	oct 09- 15:37	258395
6078	oct 11- 17:39	oct 11- 22:06	212124
6079	oct 11- 22:07	oct 11- 23:33	67015
6080	oct 12- 00:56	oct 12- 09:27	393262
6132	oct 19- 21:53	oct 20- 05:09	344312

Table 1: Good runs taken during the CNGS beam period. Note: times are italian Daylight Saving Times.

4 The Borexino expected muon events

For the Borexino running time ($\approx 79\%$ of the good beam time) we had a total beam intensity of $6.5 \cdot 10^{17} pot$, corresponding to ≈ 780 expected neutrino induced muons from the rocks and ≈ 140 from CC current interaction in the detector^[2] for a total of ≈ 920 events.

5 The Borexino detected CNGS muon events

Each extraction time (in UTC units) and intensity (in *pot* units) are written at CERN on the *LHCLOG_CNGS_OPERA* Data Base. These DB values are used to calculate the time difference between each Borexino event GPS time and the closest previous extraction UTC time. The differences smaller than 50 ms (we remind here that the time difference between the two extractions is 50 milliseconds) are plotted in figure 6-1. Clearly there is a peak around 2.4ms, the approximate Time of Flight between CERN and LNGS (see ref.1).

Smaller time differences are plotted on figures 6-2, 6-3 and 6-4 where, in particular, it can be seen that the beam generated events actually have a $\approx 10\mu\text{s}$ spread (being such the extraction time duration).

The events with the time difference values between 2.4 and 2.416*milliseconds* have been selected and written into a *DST* file; another DST file was written with all these "first" events plus the following ones with consecutive event number.

6 Conclusion

This CNGS beam period has proved to be very useful for Borexino: not only we were able to detect the expected number of events but also to test, debug and develop the data filtering, the available event displays and the OD muon track reconstruction program (see ref. 3 for this last point).

Their hit-time distributions could also help us to better understand the SSS light reflection behaviour.

Given the number of collected events we plan to try to identify the CC/NC interaction events and the passing muon events to use this information in future physics studies.

References

- [1] L.Perasso: *The CNGS beam and the Borexino events in October 2006* - Borexino internal note-jan. 2007
- [2] L.Perasso: *Borexino, CTF and the CNGS neutrino beam* Borexino General Meeting - 7 july 2006
- [3] M.Wurm et al.: *Status of the Muon Track Reconstruction* Borexino Interna Note, November 19, 2007

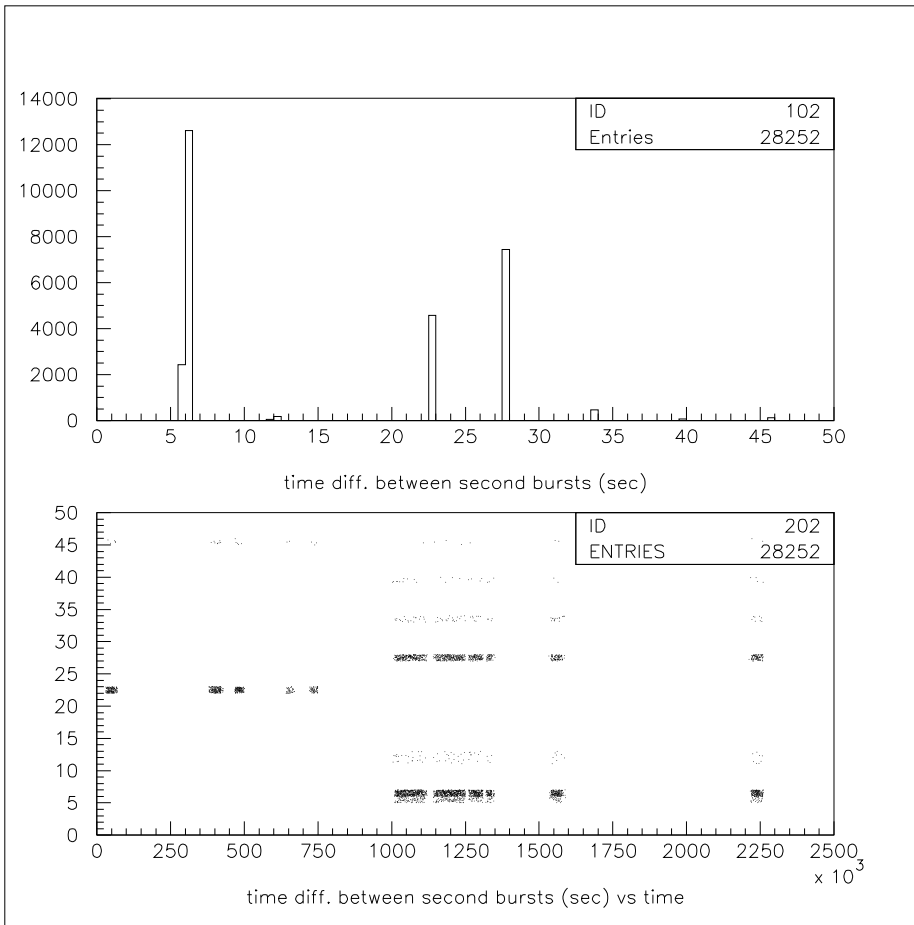


Figure 1: Top: time difference (units are seconds) between the first extractions in each cycle; Bottom: the same versus time [seconds since sept.24 - UTC] .

Figure 2: Top: The first extraction intensities (units are pot 10^{13}). Bottom: the first extraction intensities versus time [seconds since sept.24 - UTC].

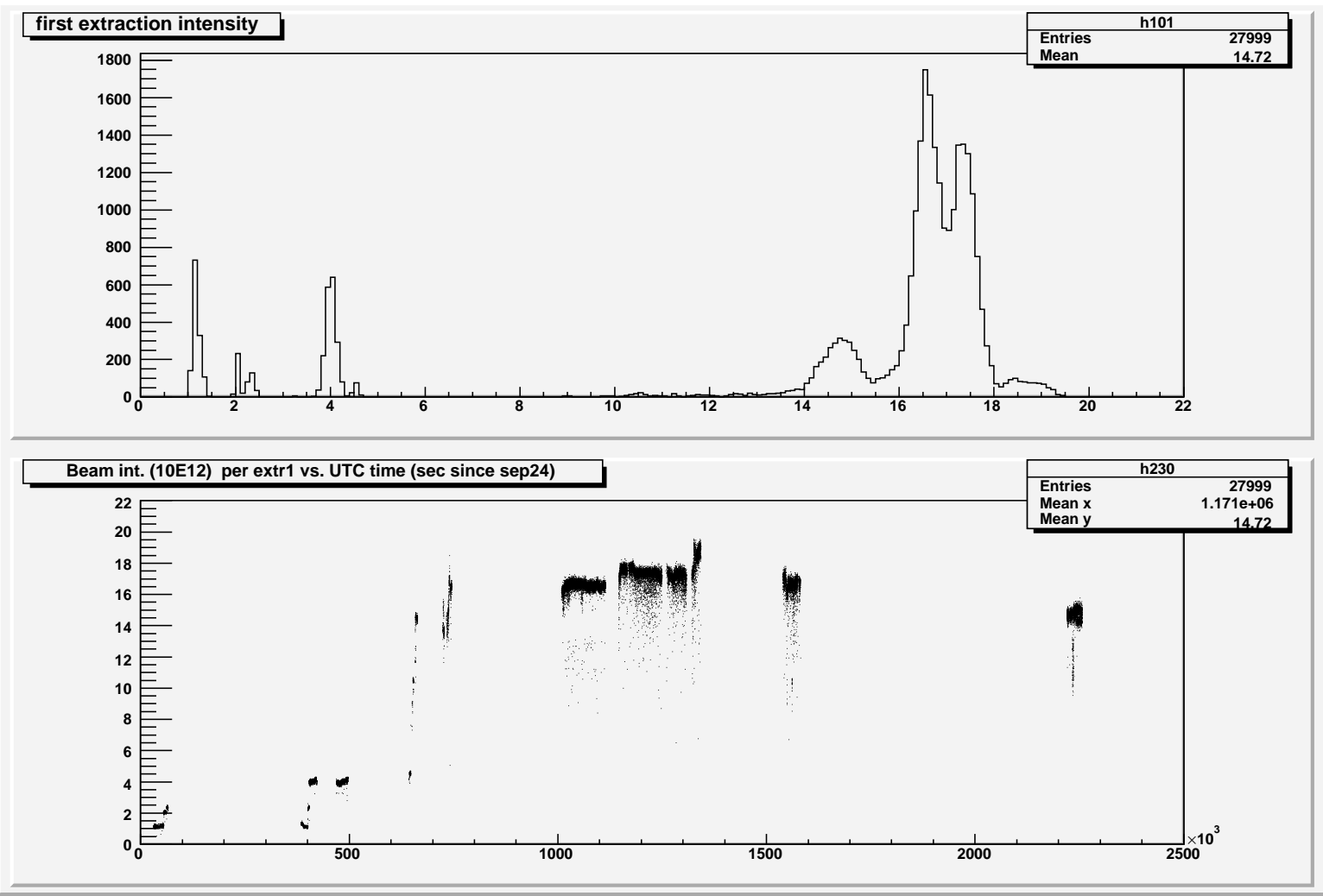
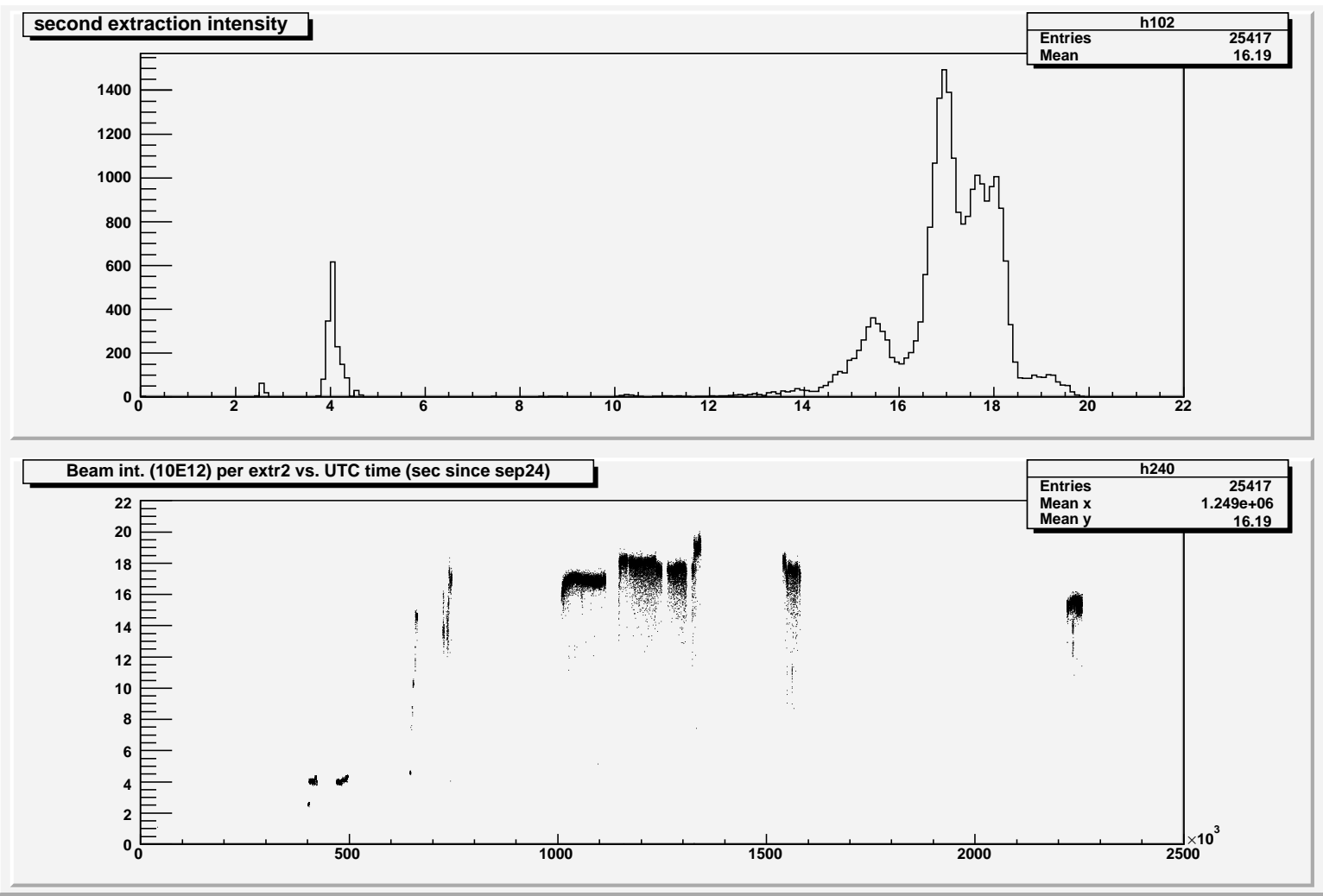


Figure 3: Top: The second extraction intensities (units are pot 10^{13}). Bottom: the second extraction intensities versus time [seconds since sept.24 - UTC].



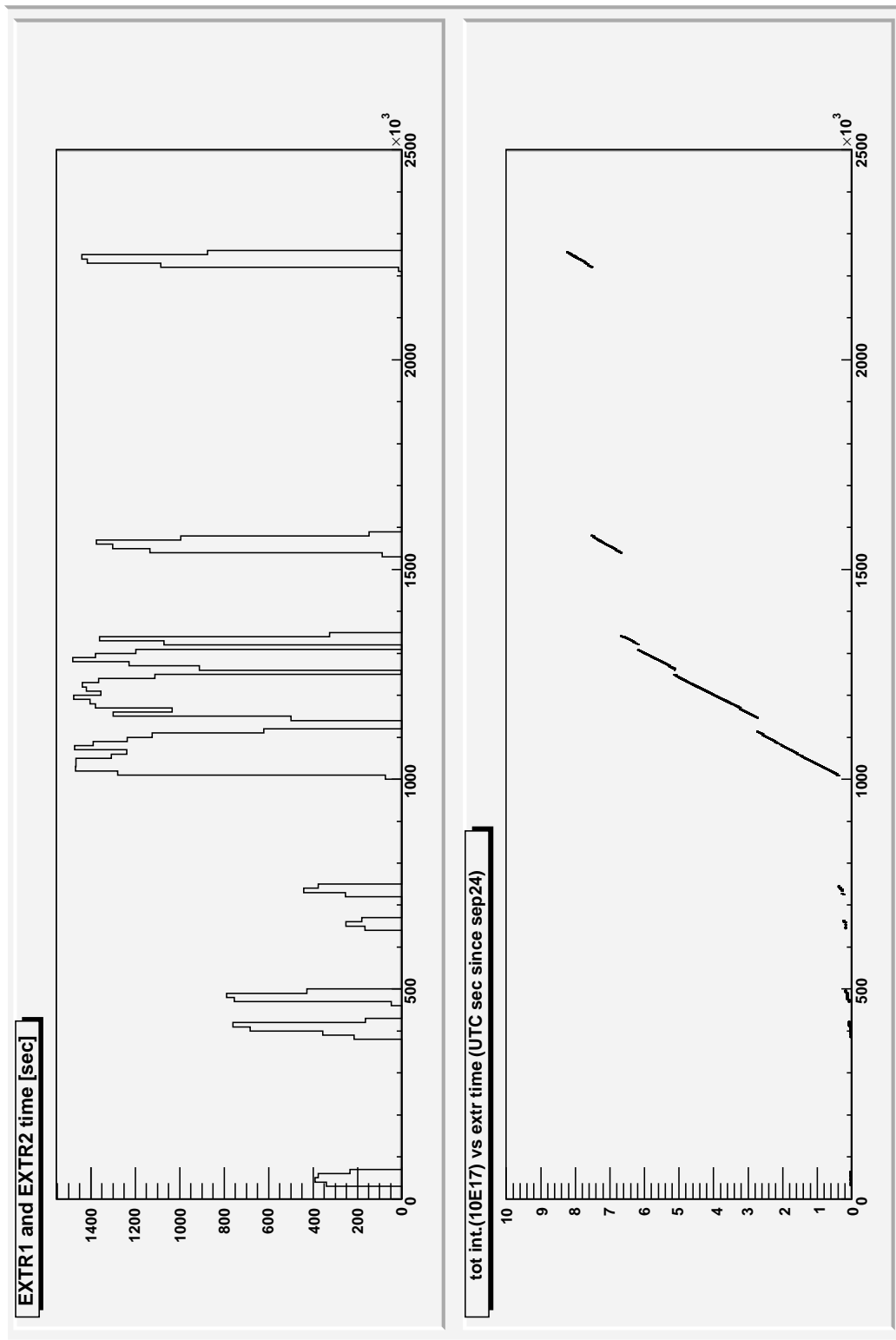


Figure 4: Top: The number of CNGS extractions delivered versus time: time units (x axis) are seconds, starting September 24th [UTC]. Bottom: the CNGS delivered proton integrated intensity in September and October 2007. Time units as above; beam intensity (y axis) units are "pot" (proton on target) 10¹⁷.

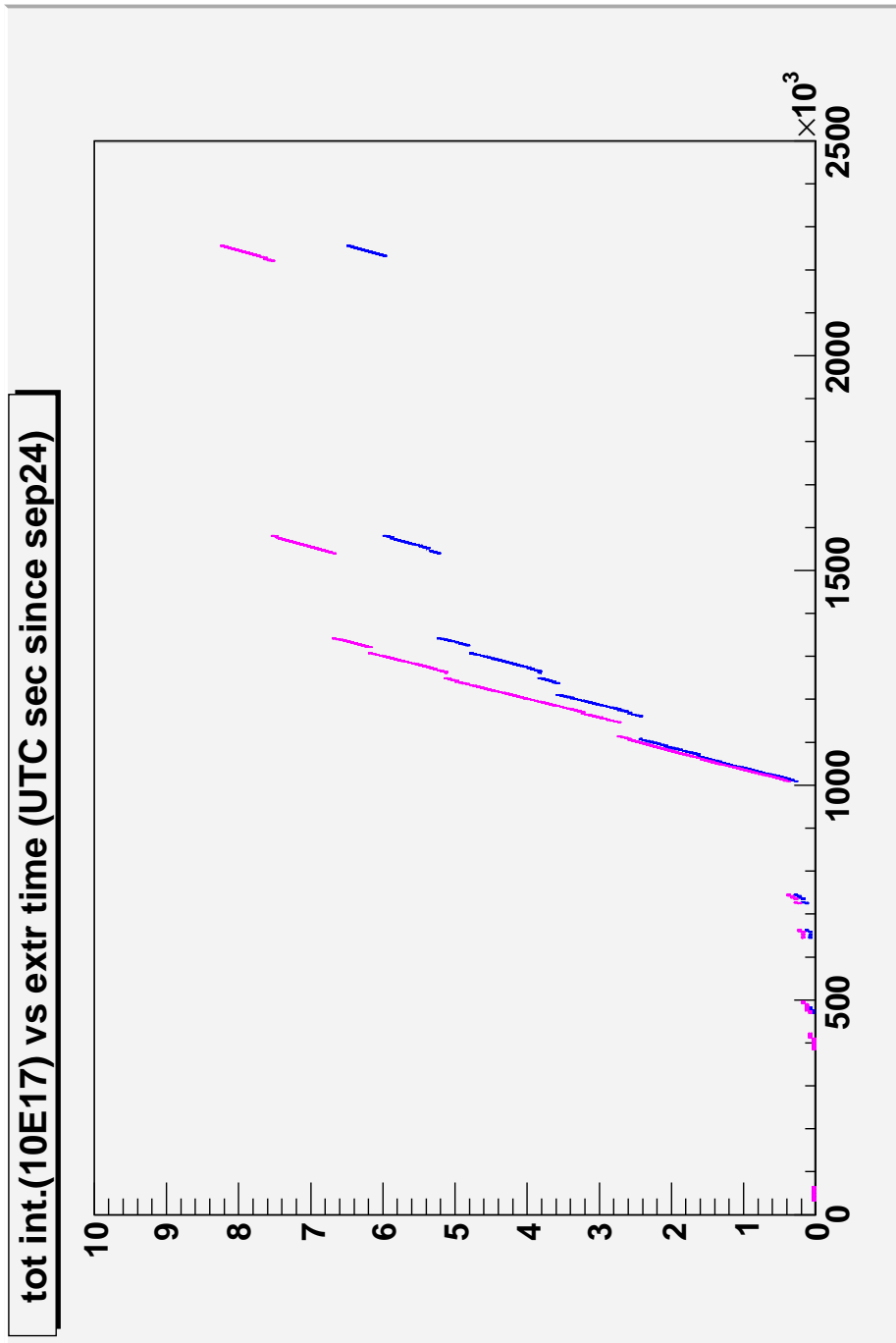


Figure 5: The CNGS (pink, higher) and Borexino (blue, lower) proton integrated intensity in September and October 2007. Time units (x axis) are seconds, starting September 24th[UTC]; beam intensity (y axis) units are "pot" (proton on target) 10^{17} .

Figure 6: Borexino event time difference: (BxGPS - CernUTC) in microseconds. The different plots are obtained just cutting on the time difference.

