OPERA status report (SPSC 97)

OPERA Collaboration

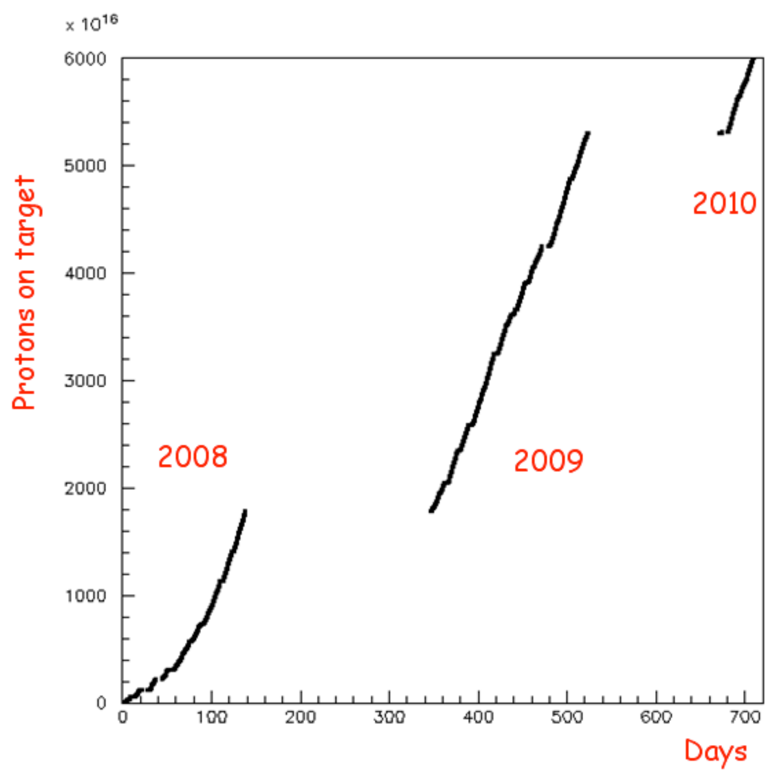
29-30 June 2010

Introduction

This document updates the status of OPERA after the last SPSC report of June 2009. The report presents the progress of the various subsystems and inform about the recent start of the 2010 run. In particular we focus on the analysis steps that go from the prediction of where the neutrino interaction occurred down to the decay search procedure and the following kinematical analysis. The analysis of the first OPERA tau candidate event is not discussed here, since details can be found in a paper accepted for publication on Physics Letters B and attached to this report.

CNGS beam and events

The global CNGS performance during 2008, 2009 and the already elapsed period of the 2010 run can be summarized by the plot below, were the integrated number of protons on target (pot) is reported as a function of time. The total number of pot integrated so far (13 June 2010) is 6.32E19.

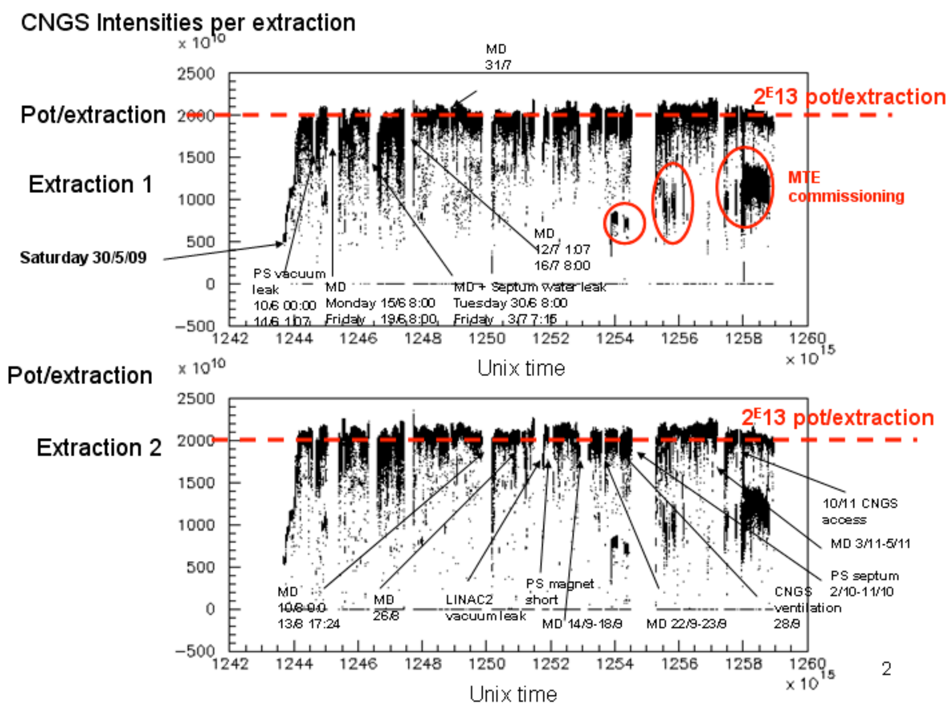


Integrated CNGS intensity since 2008.

The CNGS beam delivered 1.78E19 pot during the 2008 run with an average efficiency of 60.9% and 3.52E19 pot during the 2009 run with an average efficiency of 72.9%. 1698 and 3693 candidate interactions in the bricks were recorded by OPERA in the two runs, respectively. The inefficiency was largely dominated by problems occurring to the accelerators chain. The contributions to the inefficiency directly related to the CNGS beam line (problems and unforeseen maintenance operations) could be estimated on average around 3% during the 2008-2009 runs.

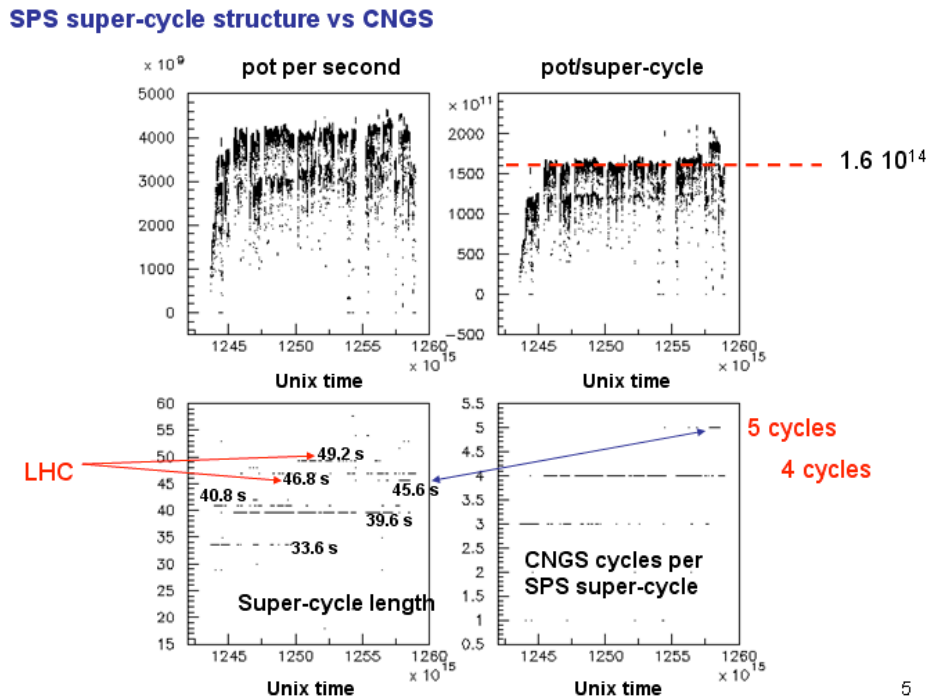
The 2008 run had very bad initial performance due to various problems occurred to the CERN accelerator complex. These caused several weeks beam stop that degraded the overall efficiency down to about 40% around the mid August (for more details see the OPERA SPSC report of June 2009). The situation improved within the last months of the run when the SPS worked in a semi-dedicated mode for CNGS, delivering about 8E18 pot just during this last period. Given its behavior, the 2008 cannot be used as reference to evaluate future CNGS runs.

The 2009 run has been smoother and more stable. The run lasted since June 1st till November 23rd corresponding to 155 fully active beam days, to be compared to 123 days for the 2008 run. The CNGS extraction intensity was stable and on average it was 1.92E13 pot and 2.0E13 pot for the first and the second extraction, respectively.



Extraction intensities during the 2009 run.

An effort was made in order to optimize the SPS super-cycle and to improve the CNGS duty-cycle by increasing the number of CNGS cycles and removing the MD and LHC cycles when not needed.



SPS super-cycle structure during the 2009 run.

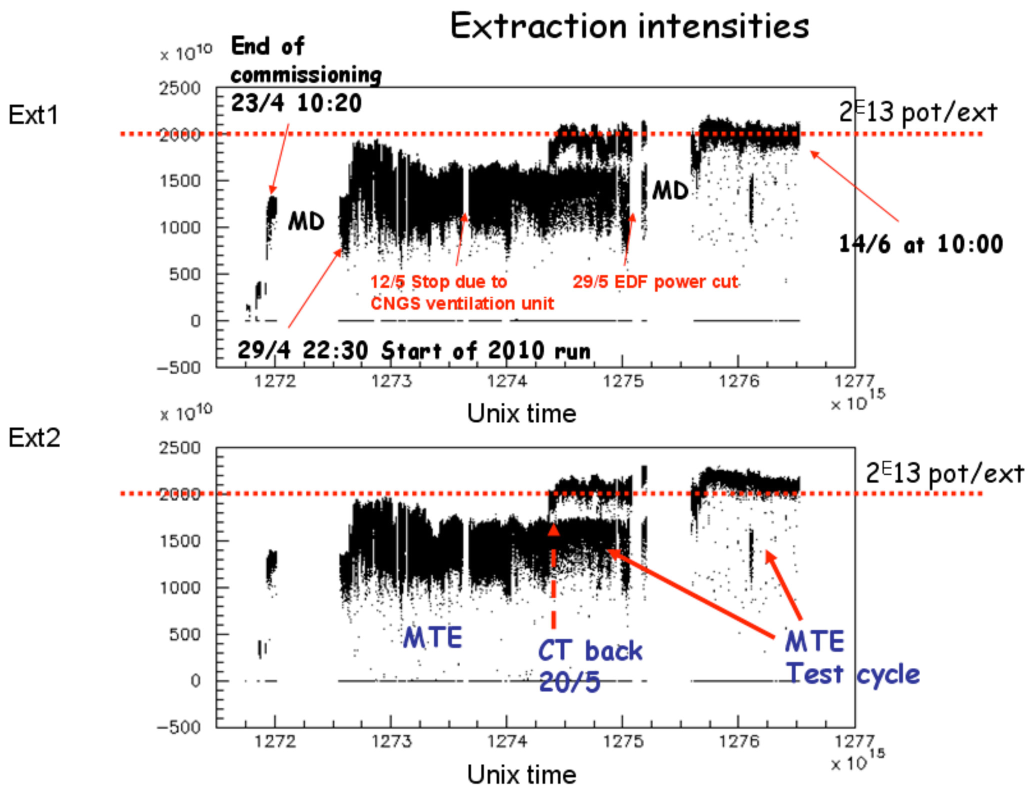
Towards the end of the 2009 run, the multi-turn extraction system (MTE) of the protons from the PS to the SPS entered in its commissioning phase by using one of the CNGS cycles in the SPS super-cycle. The MTE extraction system should eventually replace the traditional scheme of extraction of the protons from the PS, Continuous Turn extraction (CT), reducing the beam losses and guaranteeing better stability and more intensity. The MTE commissioning continued during the winter 2010 LHC run, with the goal of starting the 2010 fixed-target run directly with the MTE system only. The latter is a key element in order to overcome the actual limitations of the CNGS intensity around 2.0E13 pot/extraction, due to beam losses in the PS extraction area, and to achieve the nominal CNGS intensity of 2.4E13 pot/extraction, or even go beyond this value.

By just extrapolating the 2009 average performance, without assuming any improvement in the extraction intensity, to the duration of the 2010 run including 187 fully active beam days, one would expect to collect 4.25E19 pot, getting closer to a nominal year CNGS performance.

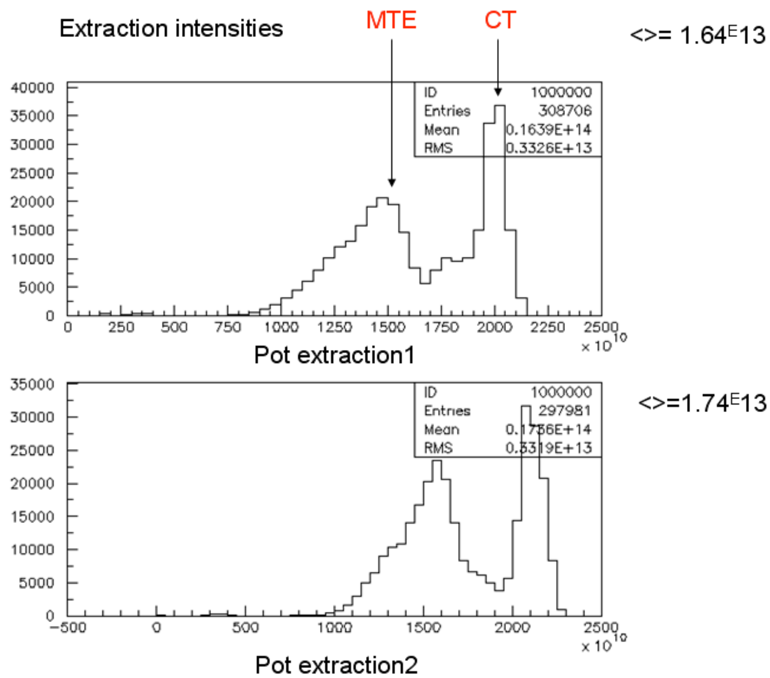
First results from the 2010 run

The 2010 started on April 29th with the exclusive operation of the MTE system. The average extraction intensity was 25% lower (around 1.5E13 pot/extraction) than the one constantly achieved during the 2009 run. After about 20 days of operation the MTE system was disabled going back to the traditional CT extraction mechanism that was operating in 2009. One of CNGS cycle can be still used for the MTE debugging. The reason for going back to the CT mechanism was due to some long-term instabilities of MTE, occurring over a period of about 10 minutes. The beam losses yielded an important activation of the PS beam extraction septum that could make interventions difficult and introduce the risk of a long stop in the operation of the machine.

The evolution of the situation during the 2010 run can be appreciated by the following figure:

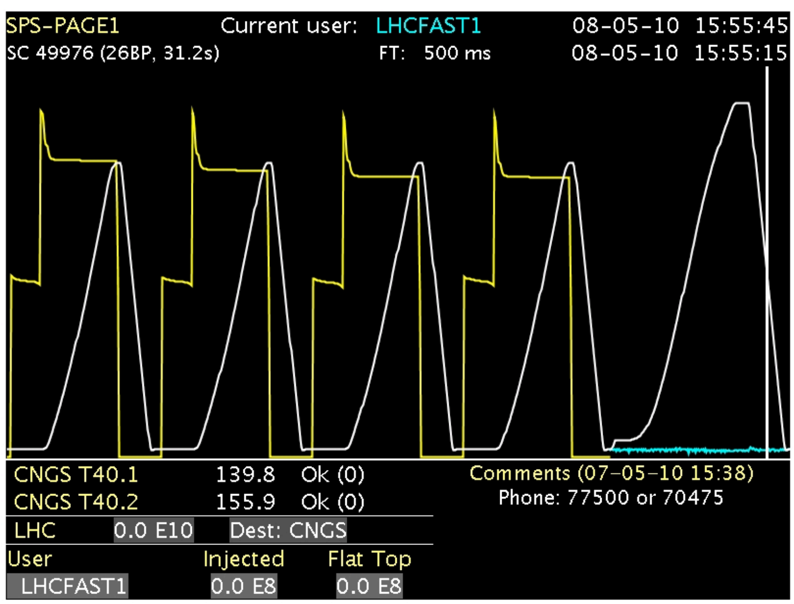


Extraction intensities as a function of time during the 2010 run.



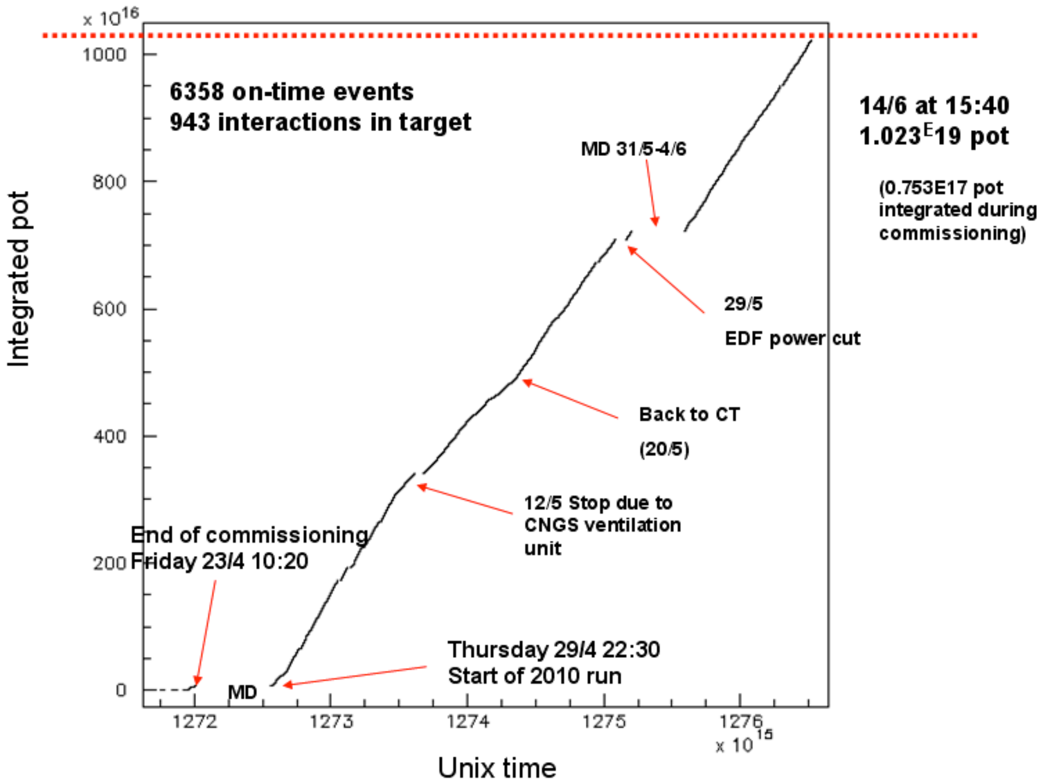
Extraction intensity distribution during the 2010 run

The first 11 days of the 2010 run benefited also of a favorable situation with a semi-dedicated SPS super-cycle without Fixed Target cycle.



Typical SPS super-cycle during the first 11 days of the 2010 run (LHC + 4 CNGS).

The number of pot delivered during this first period of the 2010 run was 1.02E19 pot (till Monday 14/6 at 15:40). Correspondingly, 6358 on-time events and 943 candidate interactions in the bricks were detected by OPERA.



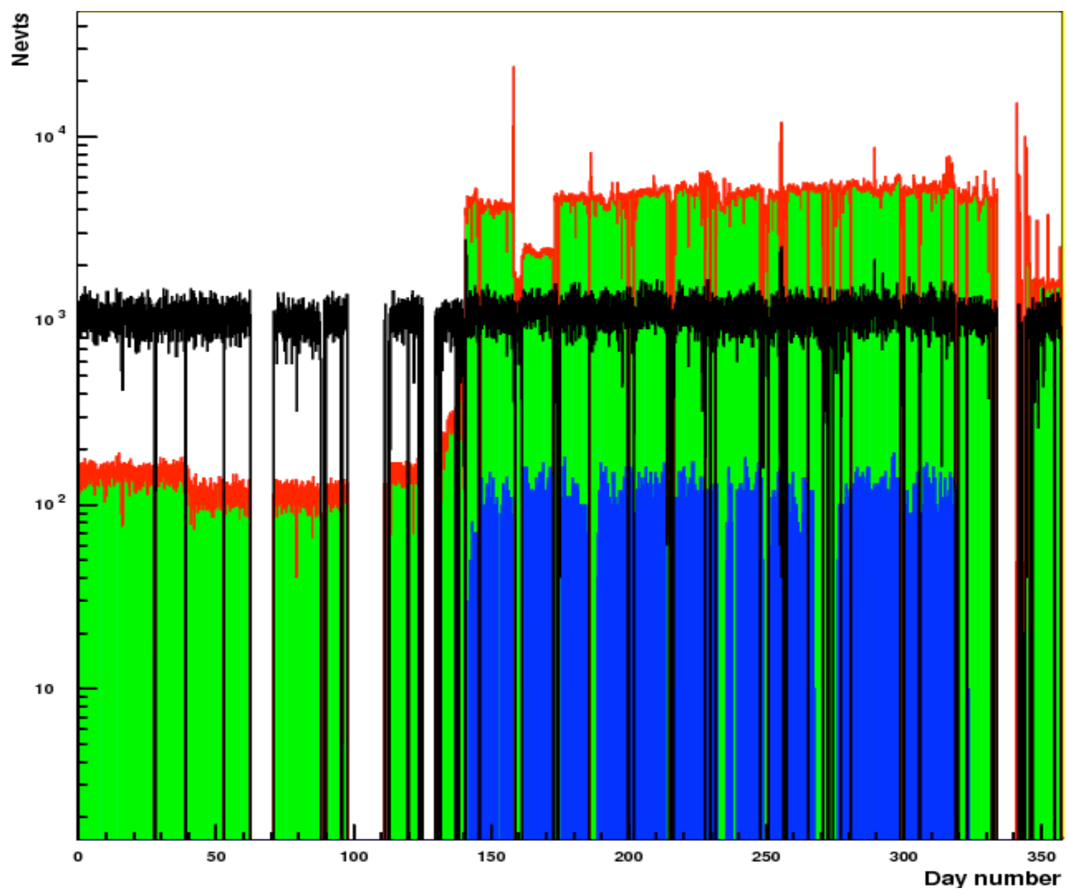
This integrated intensity of 1.02E19 pot can be compared to 0.965E19 pot, the latter corresponding to the extrapolation of the 2009 performance to the number of fully active beam days (42.5) of this first period. The two numbers differ by about 6%. This comparison is done just to get a reference figure. The agreement between the two numbers is determined by chance, since the running conditions of this first period were affected on one hand by a favorable beam sharing during the first 11 days and on the other hand by a lower intensity due to the MTE operation, these two effects partially compensated.

We remind that the nominal value of 4.5E19 pot/year is required to fully achieve the physics goal of the experiment based on 22.5E19 pot. We look forward getting as close as possible to the nominal CNGS performance during the 2010 run and beyond.

Electronics detectors and DAQ

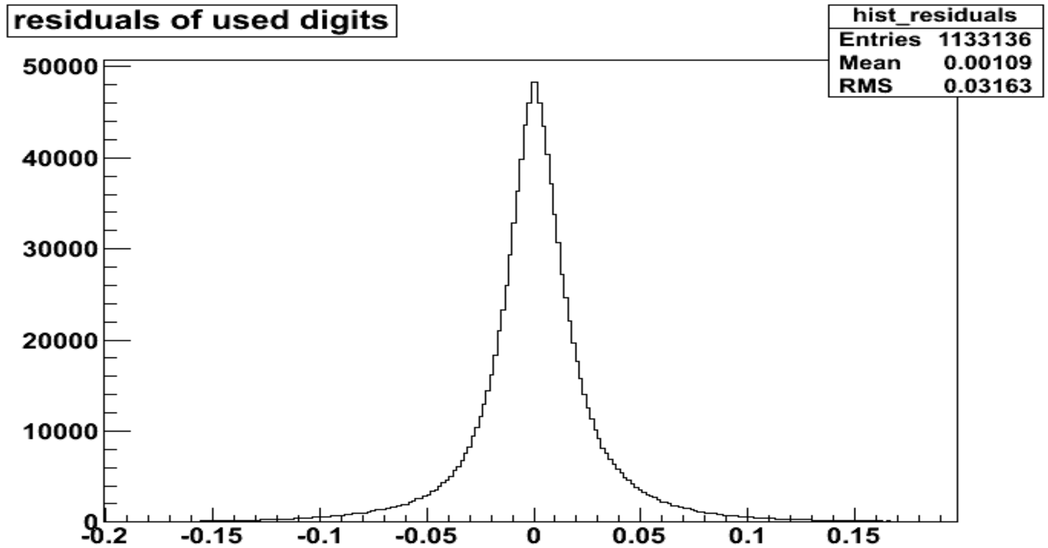
Details about the first months of the 2009 neutrino run can be found in previous reports (June and November SPSC reports). During October and November 2009 the run continued smoothly, except for a power cut occurring in the last days of run. We were able to restart the Electronics Detectors and their data acquisition in about two hours.

The complete 2009 data taking is summarized in the following Figure where the green histogram display the raw data, the blue stands for the CNGS on-time events and the black shows the recorded events (mostly cosmic-rays) where at least 5 TT planes are fired. The latter two histograms are scaled by an arbitrary factor. In total 21387 on-time events have been collected. The coincidence between the DAQ-uptime and the CNGS pot's delivery exceeds 99%.



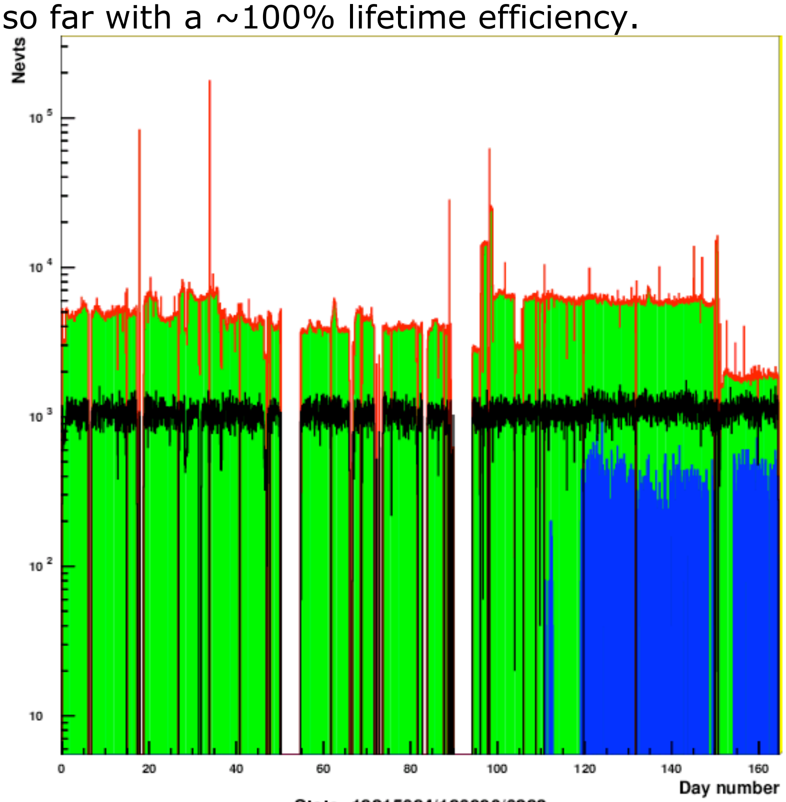
The maintenance of the electronics detectors was completed in coordination with the Brick Manipulation System (BMS) activity before the end of 2009. The TT has been continuously running to record cosmic-ray tracks, but for two-shutdown periods used for hardware maintenance.

The 2010 neutrino run started on April 29th and is going on without problems. During the CNGS commissioning we collected two weeks of cosmic-ray events without magnetic field in order to improve the alignment of the drift tubes. In the following figure the tracking residuals of the drift tubes are shown, corresponding to a space resolution of about 300 μm.



Since April 14th all sub-detectors have been collecting data in the 2009 configuration. Many upgrades have been performed on the DAQ software and on the database management resulting into an improved performance in terms of CPU resources. These features lead to a global stability of the system and encourage to define a dedicated ''CNGS-trigger'' where the global filtering cuts are lowered during two ~40 μs windows every 600ms. These time windows are centered on the CNGS extraction times and their position and width are monitored continuously.

The summary plot for the 2010 run is displayed in the following Figure (up to June 9th) with the same conventions as before. 5500 on-time events have been collected so far with a ~100% lifetime efficiency.



Operations on bricks

BMS and brick handling operations
Since two years, the two BMS machines (1 on each side of the detector) have been used very intensively on a daily basis to perform brick candidate extraction and various target manipulations. On average, the two systems are running 5 days/week during 80% of the year. Like it was in 2009 the BMS machines are scheduled to run 70% of the time (7 months) during 8h/day and 30% of the time (3 months) during 16h/day this year. This will allow the extraction of more than 6000 candidate bricks over the whole year.

In 2009 the BMS ran quite well all along the year in a stable way without major problems. The machines displaced 64000 bricks corresponding to 550000 kg of target with very good accuracy. The main difficulties encountered were due to problematic trays and blocked bricks preventing the extraction of about 88 bricks before April 2010. Those bricks were inaccessible due to problems on 80 rows. The main reasons identified were:

- 57% (46 rows) were related to blocking inside rows
- 23% (18 rows) were related to tray deformation and damages
- 20% (16 rows) were related to dirty or not clearly visible tray for the automatic accosting.

In trays with blocked bricks (first category equivalent to 0.8% of the whole detector trays) three different types of problems were found:

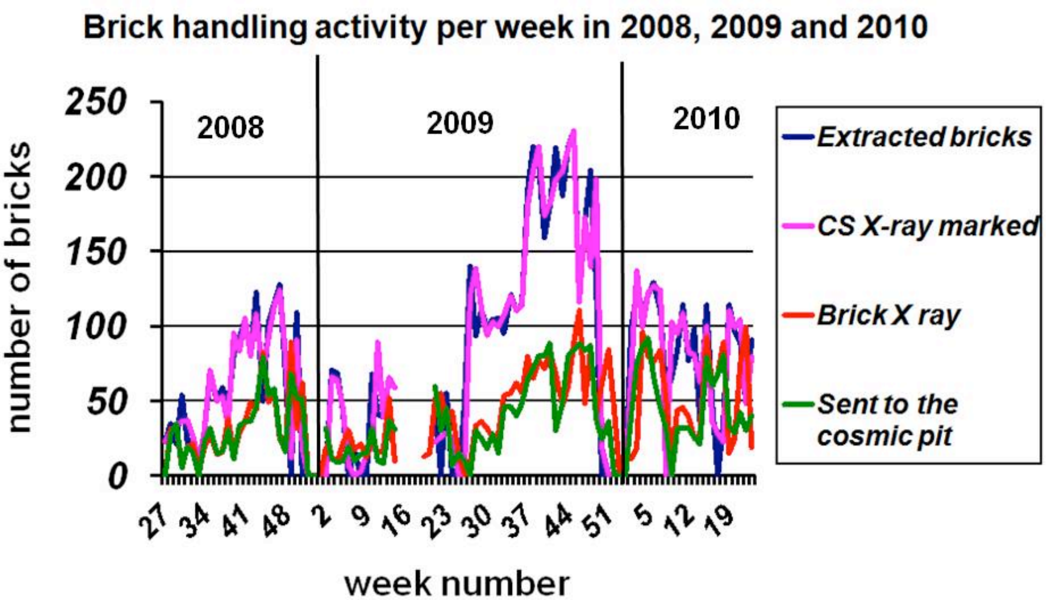
- Damaged skates under the bricks that were dispatching glue inside the trays forbidding the bricks to slide easily.
- The mechanical structure for some bricks had weaknesses and metallic clipping parts were touching the inside of trays; due to this, some aluminium wrapping and metallic frame pieces were then blocked in the walls.
- Some CS cover or boxes detached from bricks during initial insertion or manipulation and generated blocking effects.

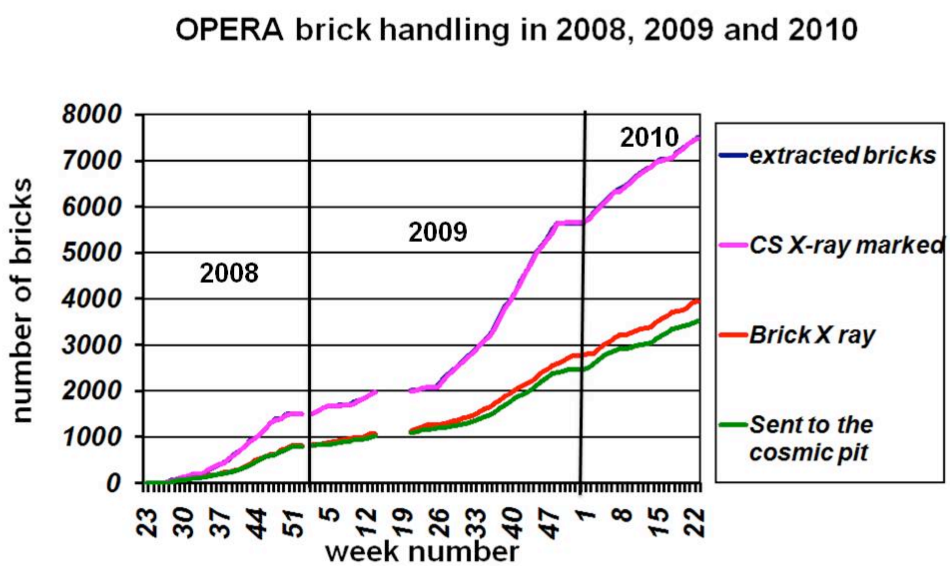
However, with custom designed tools and dedicated work performed in parallel during the usual BMS maintenance of April 2010 we solved about 83% of the blocked rows and 61% of the problematic damaged and dirty trays known as of 21st of March 2010. This result leads to a global CNGS brick extraction efficiency for 2008 and 2009 of about 99.43±0.01%.

Since July 2008, the extraction of candidate bricks is done with a mean rate of 100 candidate bricks/week and 200 candidate bricks in 2 shift/day mode. As a result for the RUN 2008, 2593 bricks have been extracted for 1700 events and for the RUN 2009, 4529 bricks have been extracted for 3200 events in the target.

Since January 11th 2010 the BMS works only in “brick candidate extraction mode” at a nominal rate of about 100 bricks/week. Most of those extractions concerned 2009 brick candidates up to middle of May. For the run 2010 which started on April 29th we have extracted already 317 bricks for about 700 events recorded in the target.

The BMS performance as well as various brick handling activities performed since 2008 are depicted in the two following pictures. The brick handling work in a regular manner following the procedures and rates already achieved last year. The curves in the plots show the number of bricks that have been treated at the different working points.





The maintenance of the BMS machines that need to keep mechanical and sensor accuracies at the top level are scheduled in a regular manner twice a year. One period is usually in May while the second maintenance is in December.

Emulsion development

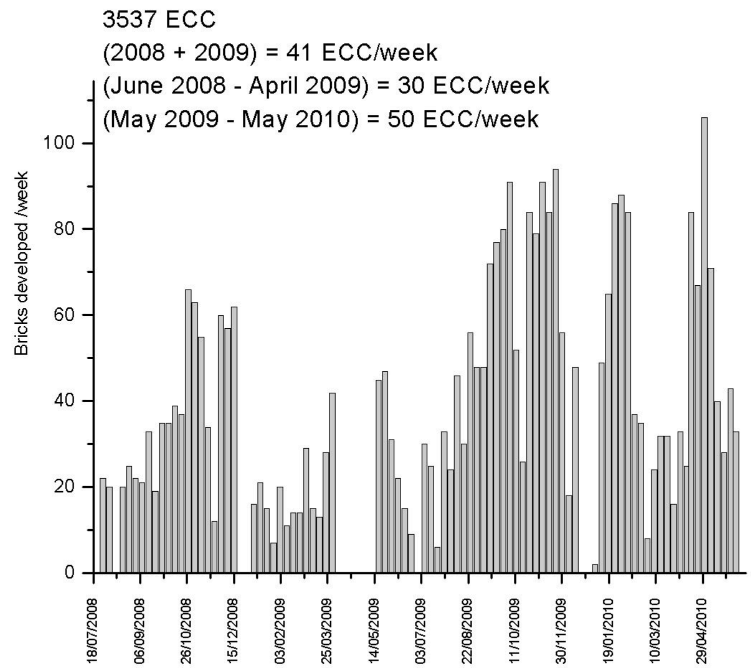
The OPERA bricks development is accomplished in two facilities: the first one is located in the external laboratory and it is devoted to bulk ECC treatment, the second one is located in Hall B and allows the treatment of CS doublets and of few ECC (in case we decide to avoid cosmic-rays exposure). The bulk ECC processing facility is equipped with:

- 1 semi-automatic system devoted to ECC opening;
- 2 semi-automatic systems able to divide emulsion films from lead;
- 2 semi-automatic systems devoted to optical films labeling;
- 6 automatic development lines working in parallel under remote control;
- 1 automatic plant for chemicals preparation.

The underground facility is equipped with a manual development line and one manual system devoted to films optical marking. The film development activity is currently organized in a single shift mode, 9 hours per day from Monday to Friday; this schema allowed us to accomplish successfully the development task in 2008 and 2009 Runs. We treated more than 3500 ECC up to now (equivalent to 200,000 emulsion thin foils) without major problems.

We routinely apply dedicated quality checks to developed films in order to monitor emulsion thickness and fog (random grains) density. All the parameters fit the specifications and no ageing or chemical contamination effects were observed up to now. The alpha tracks density due to the lead radioactivity is measured as well and it turns out to be as expected for OPERA lead (< 30 $\alpha/cm^2/day$).

The 2010 run activity will be organized in single shift mode as well and we plan to run the facility for 6 months with a “small” team and for 6 months with an “enlarged” team as reported in the Table below.



ECC processed per week (2008 +2009 Run).

	Maximum Weekly job (9 h/day Five days)	Supervisors	Trained operators	OPERA shifters
Small team	240 CSD + 60 ECC	2	3	3
Enlarged team	240 CSD + 150 ECC	2	6	3

Run 2010 shifts planning.

From electronics detectors to neutrino vertices

From December to May 2010 the scanning activity has been mainly focused on studies related to the first tau candidate event. Therefore, the overall speed was affected by this extra work.

The electronic detectors provide the prediction of the brick where the neutrino interaction occurred. The position and the slope (for the possible muon track) are provided with an accuracy of about 1 cm in position and 20 mrad for the slope. The brick is then extracted and its CS scanned and analyzed. The brick is developed if a signal is found in the CS. In the analysis of the 2008 run, the

CS was developed if at least one track matching the electronic detector hits was found after the CS analysis. The matching criteria were defined either as a 60 mrad cut on the muon slope or, for non muon candidates, as 3 hits on a road of a cylinder of 1 cm radius extrapolated in the electronic detectors. With the above cuts, 77% of the events had a brick developed after the analysis of the first two probable CS. In a subsample of about 150 events where up to 4 CS per event were analyzed, this fraction increased to 83%.

The previous criteria on hadron tracks turned out to have an impurity of about 12%. This impurity was evaluated through the analysis of the success rate in the CS track connection within the brick. This result has motivated a different strategy for the CS analysis of the 2009 and 2010 runs. If the event is a muon-less interaction or no muon track candidate is found, there must be at least 2 tracks found in the CS scanning with a convergent pattern. A single track is accepted only if isolated target tracker hits are visible along its extrapolation. The fraction of brick identified with this new procedure is 72% after the CS analysis of the two most probable bricks. The measured inefficiency in the CS to brick connection with 2009 data is about 4% showing a significant reduction of the impurity in the brick selection.

We are evaluating the efficiencies of our analysis procedure with a full Monte Carlo simulation. The overall location efficiency (including brick finding, CS tagging and vertex location) is defined as the number of located events divided by the overall number of reconstructed events. Events in the dead material and those with high fog (preventing the scanning) CS films are subtracted from the denominator. We have found out that the overall location efficiency is 47% and 76% for 0μ and 1μ events, respectively. A detailed simulation of the different analysis steps from brick identification to CS scanning and event location is in progress to assess the major contribution to the inefficiency.

The fraction of bad quality CS films (6% in 2008) has been significantly reduced in the 2009 run (below 2%) after the CS replacement campaign. There is interplay between the brick identification rate and the location fraction so that only the product of the two is relevant. A full Monte Carlo simulation will disentangle the two contributions and the geometrical acceptance effect.

The electron neutrino search was carried out on a subsample of the data. This sample is made of 691 events on which the decay search procedure was performed. We have found 6 electron neutrino candidates consistent with the expectations from the electron neutrino contamination in the beam.

We have completed the CS scanning of the first CS for all the events of 2008 and 2009 run. The CS analysis is now devoted to the second probable bricks of the 2009 run. Meanwhile we are also analysing the CS of the 2010 run in lower priority.

The total number of located events so far is 1921 corresponding to 61% of the total 2008 and 2009 statistics. The decay search was performed for 1331 interactions (42% of the statistics). About 30 charm candidates were found in the analyzed sample. The scanning laboratories are now concentrating on the event location and decay search and we plan to complete by the end of 2010 the analysis of the first two physics runs.

Physics studies

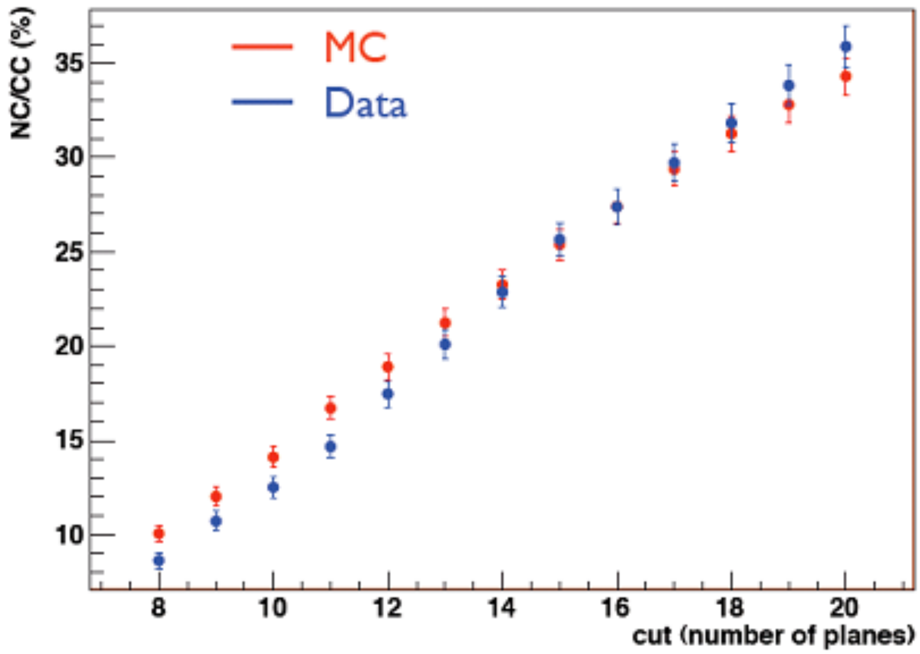
Large part of the analysis activity in the last 5 months was focused on the first tau candidate event. We will just provide complementary information on a few points and mention other aspects of the analysis not related to the tau candidate.

Electronic detectors performance

The analysis of the electronic detectors (ED) data was finalized reaching a good understanding of the NC/CC ratio, the muon spectrum and the hadronic showers reconstruction. All these results on a month time-scale will be the subject of a publication reviewing the OPERA ED performance. The NC/CC ratio reflects the muon identification performance. This was not optimized in order to reach the best purity on the NC and CC samples but to reach high efficiency on low energy muons for the rejection of the charm background and the reconstruction of muons from tau decays.

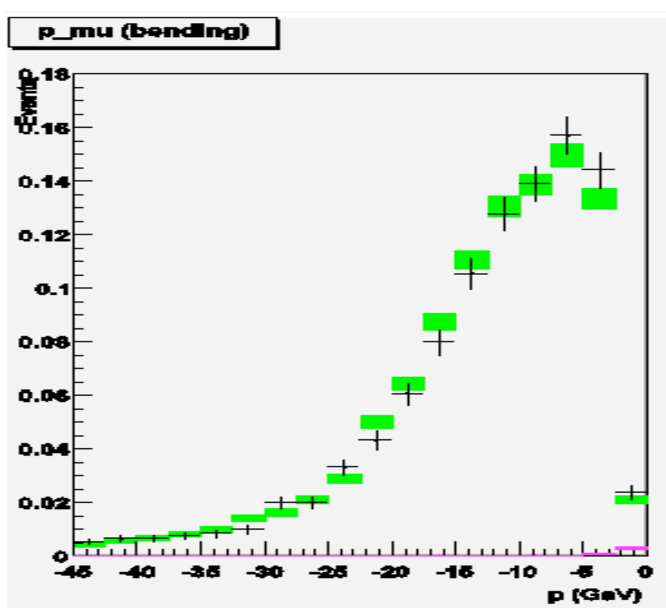
The NC/CC ratio is also affected by the contribution due to neutrino interactions occurring in the materials (rock, mechanical structures) surrounding the target and producing neutral particles re-interacting in the bricks. These events appear as soft NC candidate events. We performed a detailed simulation and we optimized the fiducial cuts to select candidate interaction in the target and reject external events. Given the performance of the algorithm (OpCarac) to identify internal and external events, we expect to measure a NC/CC ratio of 22.8%±0.8% (stat). This value is lower than the canonical 30% mainly due to NC events classified as fake CC. This is a consequence of the muon identification cuts aimed at maximizing the efficiency at low energy.

A track is identified as muon when able to cross at least 14 walls. The NC/CC ratio measured in the data is 23.4%±0.8% (stat) in good agreement with the MC expectation. We evaluated a systematic error of 2% by varying the cut on the number of walls and checking how the NC/CC ratio measured in the data was reproduced by the MC simulation.



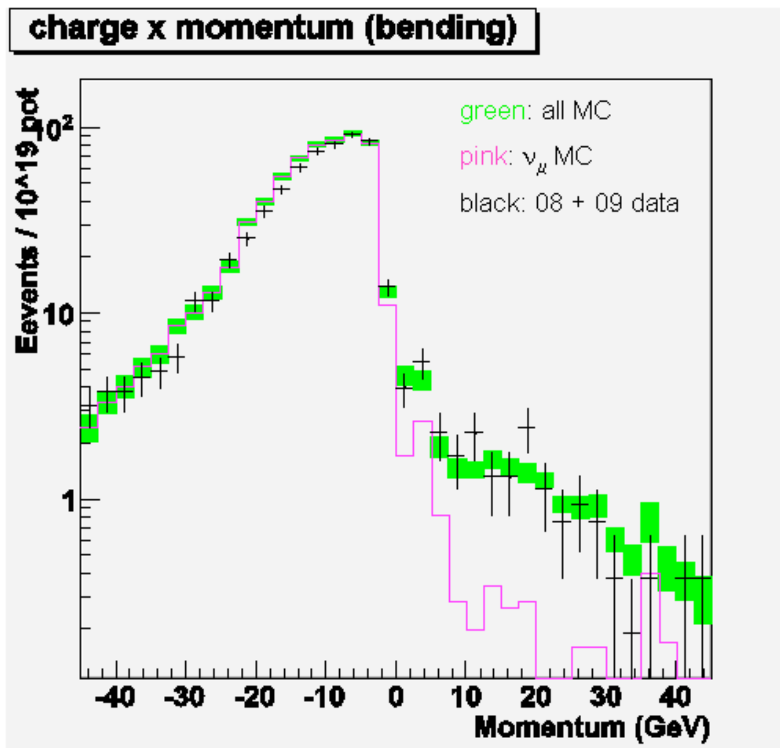
NC/CC ratio in data and MC as a function of the cut on the number of planes.

Given the progress in the spectrometer alignment and reconstruction also for the muon spectrum and the muon charge distributions a good level of understanding in the data/MC comparison has been achieved. The following plot shows the momentum distribution for muons reconstructed in the spectrometer. This sample is more pure (<0.4% NC contamination) than the one defined by simply applying the muon identification criterion being just based on the range. The contamination of NC events affects mainly the lowest energy bin (p<2.5 GeV/c) and is represented by the purple line.



Muon momentum spectrum for data (crosses) and MC (green boxes).

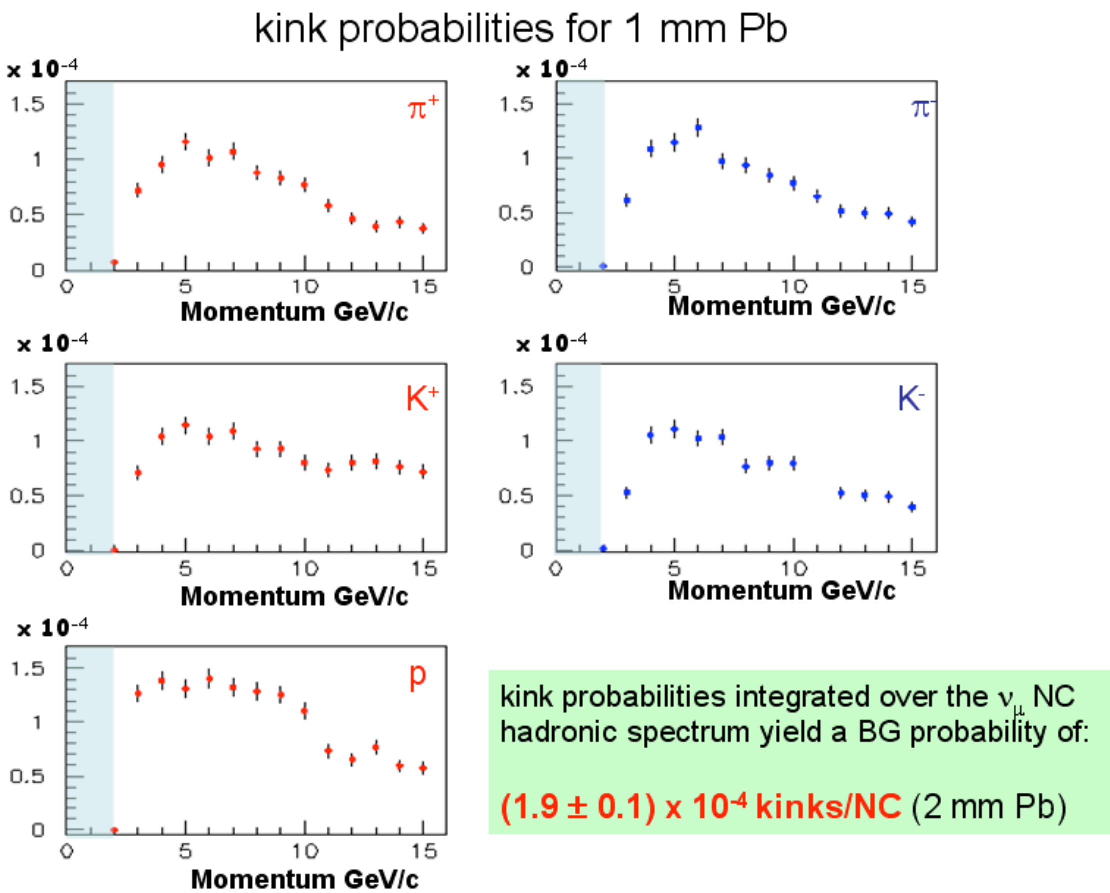
The absolute number of ν_μ CC events reconstructed in the data agrees with MC expectation within 6%. This result is well within the uncertainties on the beam fluxes and cross-section. The next plot shows the momentum*charge distribution for muon candidates reconstructed in the spectrometer. Data are compared to the MC whit just the ν_μ CC contribution or also including the anti-ν_μ CC ad NC interactions.



Data/MC comparison for the muon charge*momentum distribution.

Hadronic re-interaction background

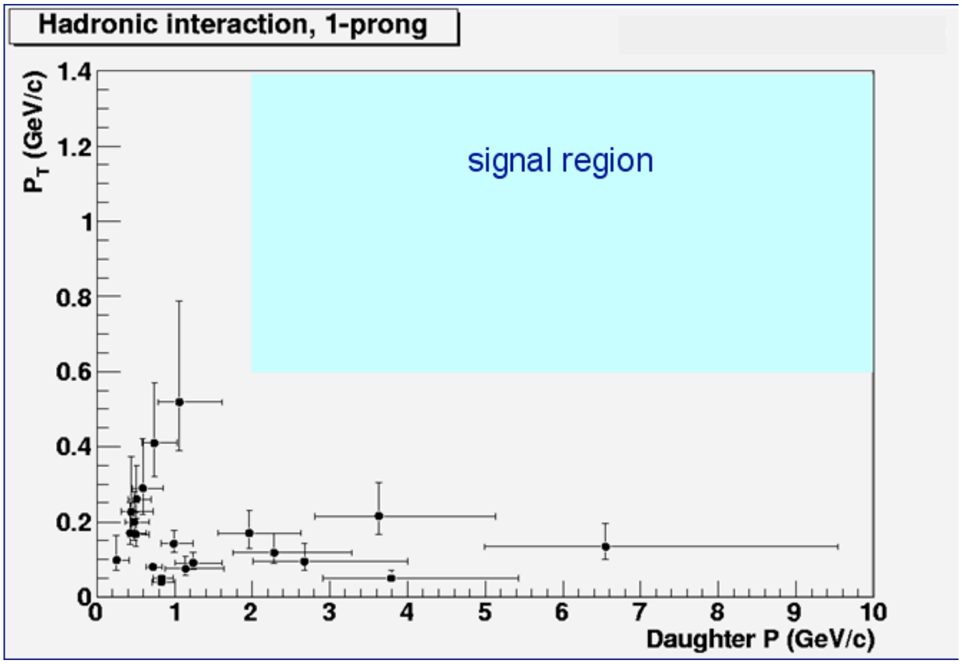
The analysis activity on the first tau candidate event implied a large effort in understanding hadronic interactions (and re-interactions) for both data and MC events. A large simulation sample of 160 millions of events was generated with FLUKA by shooting pions, protons and kaons on 1 mm lead. These samples were generated by using the most precise FLUKA settings for hadronic interactions (the "PRECISION physics set" and some ad hoc settings on the PEANUT hadronic data model and the single Coulomb scattering discussed with the authors). All particles produced in the interactions were recorded in the output and this allowed to perform dedicated calculations by applying the same topological cuts as in the single hadronic prong tau decay channel and to compute the kink probabilities shown in the figure below.



Probabilities as a function of particle momenta to obtain the kink topology selected for the tau->1h channel on simulated hadronic interactions.

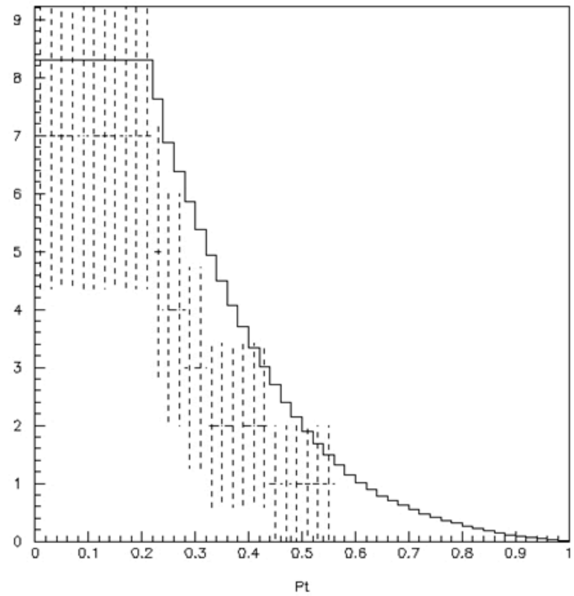
This FLUKA MC production, useful for many aspects of the OPERA analysis, was also used for the calculation of the background to charm decays and also in order to compare with data in the scan-forth sample. Results from the MC simulation were also compared to a sample of hadronic interactions collected in a brick exposed to a negative beam at 4 GeV/c momentum at the PS.

The OPERA scan-forth sample amounts actually to a total of 9 m of track length, along which 23 single prong hadronic interactions were located. The distribution on the plane P(daughter), Pt(daughter) is shown in the next figure.



Distribution of kink candidates on the P,Pt plane for kink candidates in the scan-forth sample.

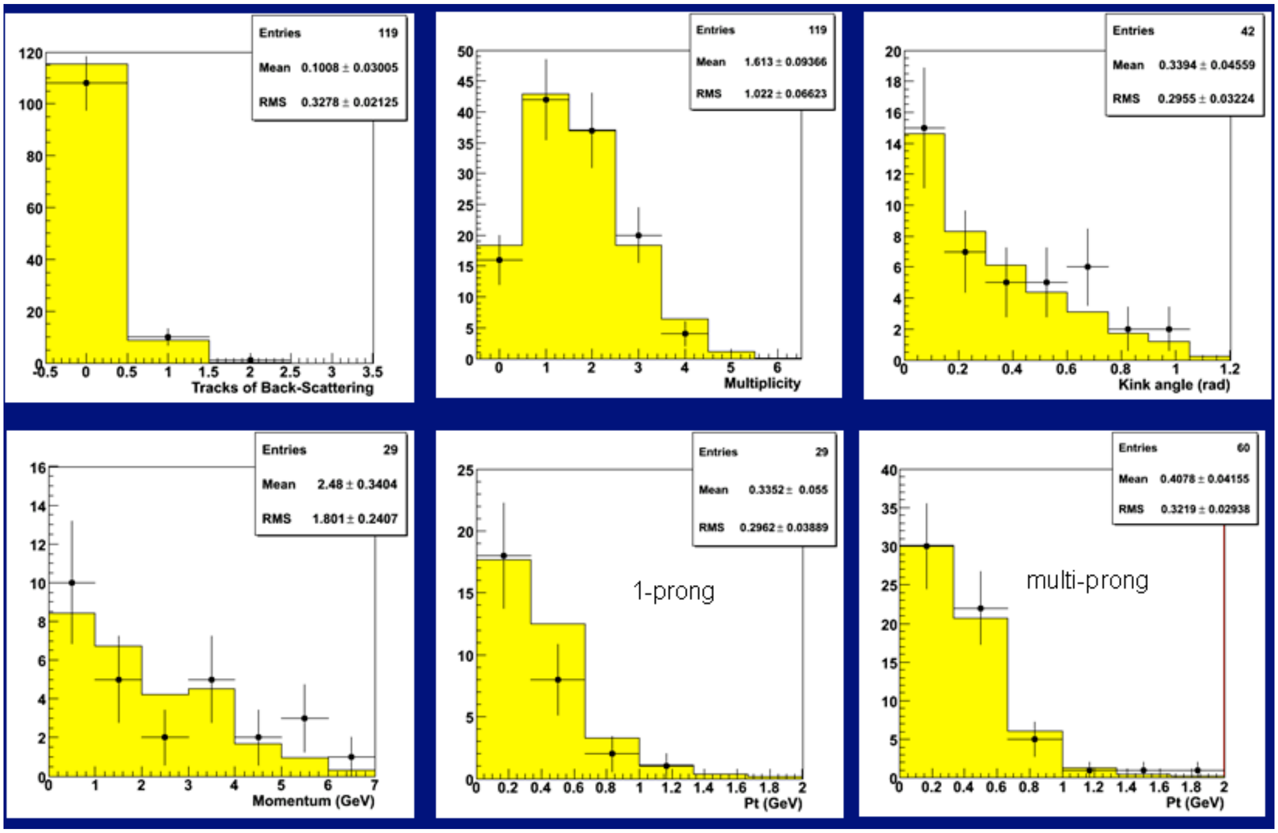
Since no events were found in the signal region, this measurement allowed setting an upper limit on the kink probability of 1.54E-3 kinks/NC event over 2 mm Pb. This limit is one order of magnitude larger than the kink probability evaluated from the simulation. We foresee to complete the measurement of the hadronic background from the data themselves within 1.5 years. For this task a sample of about 100 m of hadronic track length will be needed. By taking the subsample of the kink candidates closer to the signal region at Pt>200 MeV we cross-checked the expectations of the FLUKA simulation (8 events expected) with the number of events found in the data (7 events). The number of events and the shape of the Pt distribution (see next figure) are in reasonable agreement with the MC, although with a large (about 30%) statistical error.



Data/MC comparison of the integral Pt spectrum in the scan-forth sample.

A brick exposed to the 4 GeV hadronic test-beam provided a data sample for which actually 20 m of track length have been scanned. 119 hadronic interactions with at least one prong greater than 20 mrad were found out of 564 incoming pions. The fraction of hadronic interactions is 21.7±1.7% in good agreement with 22.1±0.4% expected from the FLUKA simulation. Out of the 119 events 42 events showed a single prong topology (7.4±1.1%) to be compared to the MC expectation (7.6±0.3%). For 29 out of the 42 kinks it was possible to measure the daughter momentum and determine the interaction kinematics.

A comparison with the FLUKA simulation is reported below including several variables, including the number of backward going tracks, the daughters' multiplicity, the kink angle, the momentum and Pt for kink events for which the kinematical measurements were possible, and the Pt of each single prong for multi-prong events. All these variables are in good agreement with the simulation showing the capability of FLUKA of well reproducing the general features of hadronic interactions. These results are preliminary; the analysis of these data is still in progress in order to increase the statistics.



Data/MC comparisons for several distributions obtained with the hadronic interaction sample reconstructed in a brick exposed to 4GeV/c hadronic beam.

The analysis of the first tau candidate event brought us to improve our understanding of hadronic interactions both from the point of view of the simulation and the data. First cross-checks of the simulation were performed on the scan-forth sample and dedicated test-beam data showing a good agreement with the simulation, although still statistically limited. We plan to continue and improve this comparison at higher statistics with the progress of the scan-forth activities and get to a direct measurement of the background from the data themselves.

Decay search

The decay search procedure (DS) was defined and put in operation at the end of 2009. It has been applied so far to 1331 events from the 2008 and 2009 data samples. The DS is aimed not only at the reconstruction of tau events but at getting the maximal efficiency for all decay topologies in order to guarantee also good reconstruction efficiency for charm decays. Charmed hadrons have a longer flight length than taus, include also decays of neutral particles and have a richer multi-prong sample than tau events. The DS procedure has been fully simulated in computing the MC expectations for charm events. Given the experience acquired during 6 months of operation, we reviewed some aspects of the DS in order to make it lighter from the point of view of the scanning load and less time consuming, with minor changes in the efficiency.

The application of the DS procedure can take, depending on the event topology, a time going from few tens of minutes to few hours. A time consuming aspect of the DS concerns the in-track decay search where loose cuts were defined in order to study small angle kinks (<20 mrad). This implied the verification of all kinks having a R_max value (significance with respect to the RMS of all other angular deviations along the track) greater than 3. This criterion required performing frequent manual checks on track segments showing small angular deviations. Given the data accumulated so far the in-track DS will be performed only for deviations greater than 15 mrad, with an R_max>5 and after an automatic check on the coherency of the single angular deviation with respect to the rest of the track. In addition, the in-track DS will be applied only to muons in CC events while, as originally decided, it will be still applied to all particles in NC events.

The extra-track DS procedure, looking for decay topology among tracks disconnected from the primary vertex, was also reviewed by adopting tighter cuts on the maximal impact parameter that a track may have to be taken into account, typically going from 800 to 500 microns. This will reduce the number of background tracks to be investigated at the expense of just 1% efficiency loss. The size of the volume scan around the vertex was also optimized by reducing the number of upstream plates from 5 to 2 in case of multi-prong primary vertices. The goal of all these changes is to keep the scanning time needed for the execution of the DS procedure at the level of 1 hour/event at most.

Charm decay search

The search for charm decay topologies provides a control sample for validation of the efficiency of the DS procedure. It was fully implemented in the MC simulation and used in order to evaluate both the charm efficiency and the backgrounds from hadronic interactions and the decay of strange particles. The charm search analysis was applied to a sample of 26 events selected as decay topologies with minimum bias criteria at the level of the scanning laboratories. An idea of the different efficiencies in reconstructing the charm decay topologies before the kinematical cuts used to suppress the background can be obtained from the following table:

	0	1	2	3	4	tot	+/-
D^+		0.47		0.81		**0.59**	**0.06**
D^o	0.00		0.78		0.83	**0.66**	**0.07**
D_s^+		0.64		0.84		**0.71**	**0.08**
Λ_c^+		0.24		0.60		**0.37**	**0.04**
tot						**0.58**	**0.06**

D_S efficiencies for decay topology reconstruction of charmed particles.

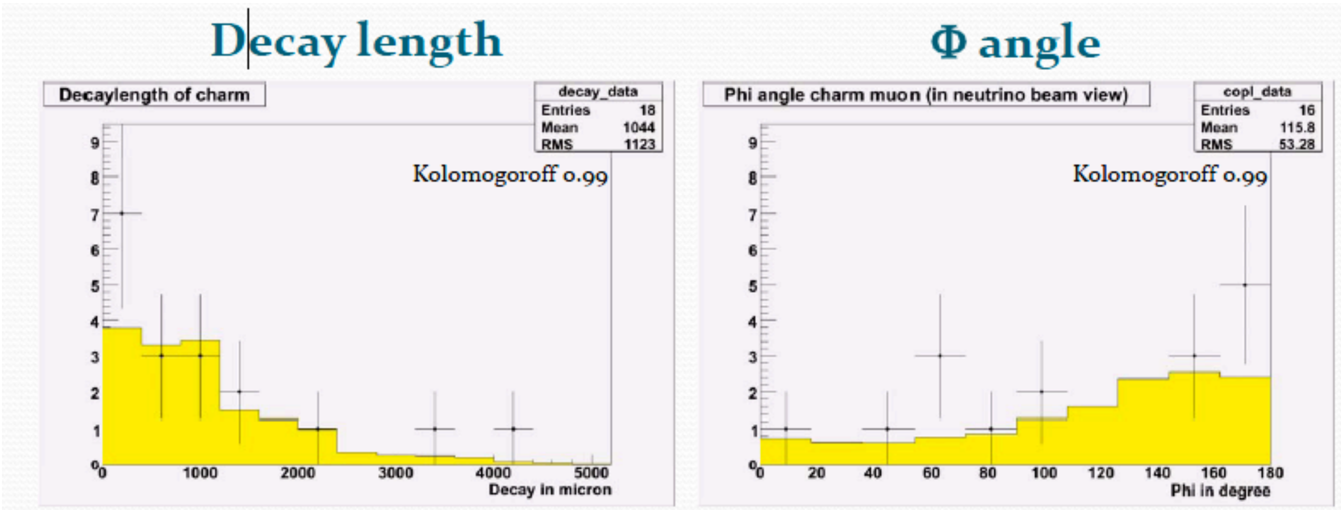
The efficiency, averaged on the populations of the different particles expected in ν_μCC events on the basis of the CHORUS data, amounts to 58%. Kinematical cuts on the Pt of the decay and the momentum of the daughters aim at removing the background from hadronic interactions, mainly affecting decay channels with 1 prong topology, and the one from the decay of strange particles present in the V0 sample. Cuts are optimized for the different decay topologies and for short and long decays. The hardest cuts are applied for the kink channel requiring a daughter with momentum greater than 2.5 GeV/c and a Pt greater than 0.5 GeV/c.

The data sample after kinematical cuts is reduced to 18 events (3 kink candidates). The corresponding efficiency for charm in the MC sample is 39.4% (see next table) with 15.5±2.8 events expected (0.79 kinks), while the expected residual background amounts to 1.72±0.31 events (0.79 events for the 1 prong topologies including short decays).

	0	1	2	3	4	tot	+/-
D^+		0.20		0.66		**0.36**	**0.04**
D^o	0.00		0.57		0.74	**0.51**	**0.06**
D_s^+		0.32		0.69		**0.45**	**0.05**
Λ_c^+		0.13		0.35		**0.20**	**0.02**
tot						**0.394**	**0.039**

DS efficiencies for decay topology reconstruction of charmed particles after kinematical cuts.

Data are in good agreement with MC expectations. The kinematical analysis is still in progress and will be further optimized. A comparison between data and MC (charm signal only) for the decay length distribution and the angle on the transverse plane between the muon and the charmed particle can be seen in the next plot.



Data/MC comparison for charm candidates after kinematical cuts.

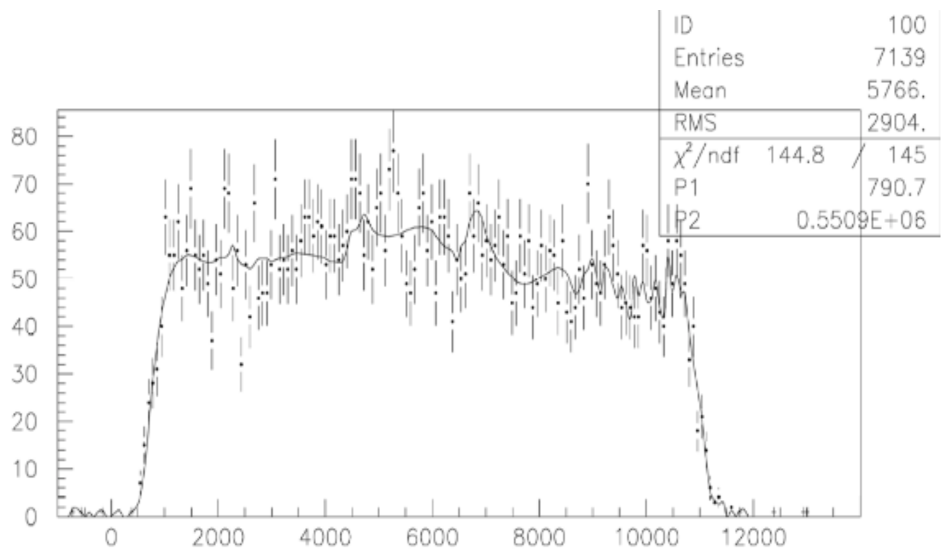
Status of the software

The OPERA simulation and reconstruction softwares at the CCIN2P3 computing center were ported to Scientific Linux 5 at 64 bits. The offline emulsion reconstruction software OpEmurec was completed including the Data Navigation Map which allow treating in a coherent way different scanning data sets extracted from the central DB, like CS, scan-back, scan-forth and as many as total scan volume as needed as well as the electronic detectors data. The MC interface was also finalized for what concerns the incorporation of base-tracks reconstruction efficiencies and the mixing with background from real data scanning volumes.

The use of OpEmurec for the offline reconstruction of real data and MC samples, after this first phase of implementation and debugging occurred during the last months, will become a systematic tool for the understanding of reconstruction and analysis efficiencies at the level of the ECC and at the global event level. The flow of data from scanning laboratories to central DB's is steady. The current size of the scanning data has already exceeded 9 TB. The data sharing technology implemented in OPERA has been upgraded in the last months to overcome problems of transfer interruptions due to network errors: the upgrade had a positive effect, reducing administrative interventions to recover incomplete transfers to less than a handful per month.

Non-oscillation topics

The activities related to the neutrino velocity measurement are in progress. The analysis of the 2009 data sample of on-time interactions (about 21000 events) showed that the measurement of the time of flight of neutrinos could be performed with about 12 ns statistical accuracy, representing an improvement of a factor 5 with respect to the MINOS measurement. The next figure shows a typical time distribution of neutrino interactions during the second CNGS extraction. OPERA events times are superimposed to a global proton current distribution as a function of time obtained by summing proton current measurements corresponding to the individual spills with neutrino interactions recorded in OPERA. The proton current is measured at CERN for each spill with a fast waveform digitizer connected to a BCT and time tagged by the GPS system. The time distribution of events in OPERA clearly follows the shape of the protons current during the spills. The two distributions are superimposed via a fitting procedure that measures the TOF, the time axis does not take yet into account all delays included in the timing chain.



Time shape of the neutrino interactions in OPERA superimposed to the CNGS protons current (ns).

The analysis was then focussed on systematic aspects in order to bring them at the same or better level than the statistical error. A new campaign of calibrations of the timing chain at CERN was performed in February by injecting a reference signal with a Cs clock in various points of the chain. The inter-calibration (at 1 ns level) of the GPS systems at CERN and LNGS was performed by analysing the data in common view mode of the two twin systems GPS-Cs clock installed at CERN and LNGS on top of the existing GPS systems. A new campaign of geodetic measurements has been defined at LNGS in order to measure the relative position of OPERA with respect to the CNGS target within 1 m accuracy. These measurements to be performed in the next months in the highway tunnel will allow transporting underground the external GPS measurements with high accuracy.

Finally, the measurement of the atmospheric muon charge ratio with the OPERA detector has been completed and published in May 2010 **(EPJC Volume 67, Issue 1 (2010), Page 25)**.

Summary performance tables

We show in the following a few tables summarizing the various efficiencies affecting the global analysis chain, from a trigger in the electronic detector, down to the decay search. We remark that the event publication is mainly relevant for specific studies, such e.g. those related to the availability of fully analyzed data for the tuning of the MC and for the re-evaluation of efficiencies and backgrounds.

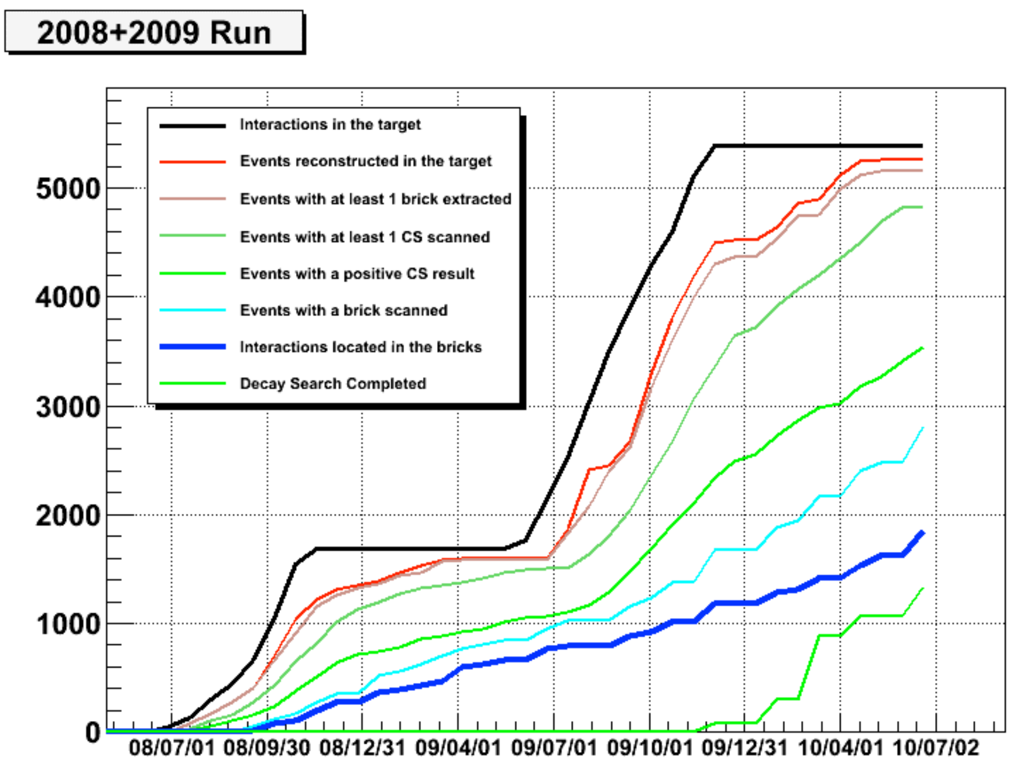
Events	All	0μ	1μ
Triggers	**1698**	**406**	**1292**
Interactions in the bricks	93%		
Reject bad quality CS films	94%		
Brick identification by electronic detectors	78%	65%	82%
Location fraction	88%	72%	93%
Located interactions	**1017**	**166**	**851**
Decay searched events	873	145	728

The Table above shows the breakdown of the different steps in the analysis of the 2008 run. Since for 2009 the vertex location and the decay search are still in progress it is not possible to prepare a Table similar to the previous one. Indeed, being the numbers in the Table data-based, the overall location fraction (the overall location efficiency is being computed with a full MC simulation) can only be computed once all steps are concluded for all the events.
For 2009 run, we can only report the fraction of events analysed so far and an estimate of the time needed to complete the analysis. The present status of the 2009 analysis is reported in the Table below.

	0mu	1mu	All
Events predicted by the electronic detector	1097	2460	3557
Extracted bricks	1062	2407	3469
Found in CS	564	1632	2196
Located in ECC	177	773	950

Located in dead material	3	12	15
Interactions in the upstream brick	4	23	27
Decay search performed	85	373	458

As it is visible from the plot below, the rate of located and decay searched events has increased significantly in the last month, reaching the maximum speed of more than 200 located events per month. We expect to complete the analysis of the 2009 run by the end of 2010.



The black line shows the number of triggered events in the target region, while the red one the reconstructed ones. The difference between the two curves (about 100 events) is due to events difficult to reconstruct. The events with at least one brick are slightly less than the number of reconstructed events due to a delay (about 2 months) between the two steps of the analysis. The forth and the fifth lines from the top (dark green and light green) show the number of events with at least 1 CS scanned (note that the 2008 run has been completed) and the number of events with a positive CS results, respectively. The ratio of events with a positive CS result over those with at least 1 CS scanned is 69%. The brick finding efficiency dominates it. For the 2009 run data, the analysis refers mainly to the first brick per event.
The light blue and the blue lines show the number of events with at least one brick scanned and the number of located events in the brick, respectively. The

delay between the CS result and the brick scanning includes the brick development and its delivery to the scanning laboratories.
The progress in the decay search is shown in the last curve. The decay search together with a careful study of all the events with a secondary decay topology explains the slope of the event location curve in the last few months.

Conclusions

As a general conclusion, we can state that the experiment is performing well, according to the design expectations. After a few years of running we have reached a rather good understanding of the detector and optimized most of the operations. In addition to the successful finding of the first signal candidate event, a major achievement of the Collaboration, we can state that all detectors and facilities are in very good shape.

The analysis chain, from trigger to decay search is under control. In many respects we are improving the various efficiencies that contribute to the overall one.

The analysis of the candidate event pushed us very much towards the re-evaluation of the detection efficiencies and backgrounds (notably for the hadronic decay channel). We are in the process of extending these studies to all the tau decay modes.

Our next analysis goal is to complete as much as we can (and in the shortest time) the decay search for already located events with the goal of assessing the possible presence of additional signal candidate events in the available statistics.

We count on a successful 2010 run that, according to expectations, should bring us very close to a nominal run. This is a very good prospect in view of the decisive 2011 and 2012 data taking campaigns.