36th AWAKE Technical Board
19 November 2019

All presentation can be found on Indico at: https://indico.cern.ch/event/863684/

Present: Allen Caldwell, Seong-Yeol Kim, Joshua Moody, Stefano Mazzoni, Valentin Fedosseev, Livio Verra, Francesco Velotti, Anna-Maria Bachmann, Pablo Guzman, Steffen Doebert, Edda Gschwendtner, Harsha Panuganti, Eduardo Granados, Fabian Batsch, Patric Muggli, Ishkhan Gorgisyan, Mariana Moreira, Rebecca Ramjiawan, Ben Woolley, Michele Bergamaschi, Giovanni Zevi Della Porta, Matthew Wing, Jan Pucek, Kookjin Moon, John Farmer, Franz Roeder, Amrutha Gopal

Introduction and Matters Arising (Edda Gschwendtner):

Edda begins by discussing our regular meetings: the Run 2 meetings have been on pause for a few weeks, but will resume after the BE review on November 28; the simulation meetings, which had stopped after Marlene's departure, will resume next week, coordinated by John Farmer. In terms of AWAKE schedule, this week is taken by Machine Learning studies of the electron beam, and the following three by plasma/laser studies.

The run plan for 2020 is being discussed, so if people have ideas for 2020 please bring them up as soon as possible with Giovanni. So far only Josh and the Machine Learning group have expressed interest. Edda asks Francesco to summarize the progress and plans for the Machine Learning group in the next TB.

Regarding Run 2 funding and review schedule, the situation has not changed since the last TB, and the plan is still to have a cost and schedule review in 2020.

Edda then focuses on the plan for the BE intermediate project review on November 28th, listing the panel members and describing the mandate and the draft agenda. The review is motivated by the move of the AWAKE experimental team to the Beams department, and it will cover the description of the project management structure and of the milestones and timescale for 2020 study phase, as well as the list of external resources, and a prioritization of the critical aspects of the physics program. The review will not show schedule and costs for Run 2, and will focus on the study phase, and on any showstoppers and critical issues that we are already aware of. Allen suggests to adapt the wording of our goal, from "electron acceleration before LS3" to "electron acceleration program before LS3", to clarify that we will need more than a handful of days of beam time at the end of 2024.

Edda concludes that the precise timeline for Run 2 design, procurement, installation is currently taking shape, and we should be able to internally share a version in the coming weeks.

Actions:

- Francesco: summarize machine learning studies in next TB

Bunch length measurement in Summer run (Seongyeol Kim):

Seongyeol motivates the bunch length measurements, based on previous disagreements between the UV pulse duration and the electron bunch length, as observed both at the beginning and the end of the electron beam line. The most recent measurements, made before the plasma cell (BTV 50) using the streak camera, vary the UV pulse length (between 0.7 and 1.6 ps), the OD filter (0 and 0.5) and Iris aperture (50 and 250).

A set of simulations, using ASTRA (electron gun) and ELEGANT (beam line), was used to compare with the measurements. The ASTRA simulation includes the effects of beam size differences due to Iris aperture, and the effect of space charge. The ELEGANT simulation includes coherent synchrotron radiation, but it does not include space charge. In order to check the effect of space charge in the beam line, one simulation point with PARMELA is included in the comparison.

The experimental data show a gaussian beam for the shorter bunches, while the longer bunches have a flatter top. The profiles of the streak camera images are fitted with a gaussian after jitter correction, and the σ_z value is reported. Both data and simulation show a significant increase of electron bunch length with respect to the UV pulse length, and this increase is larger for higher charge. This is a large effect, in both data and simulation, with the electron bunch a factor of 3 to 7 longer than the UV pulse. In the measurements, the length of the electron bunch is independent of the UV fluence illuminating the cathode, and independent of the UV pulse duration, while it is affected by the total charge in the electron beam, supporting the hypothesis that lengthening is due to space charge. In the simulation, the bunch significantly lengthens when the charge increases from 160 pC to 225 pC, but remains approximately stable at higher charges. The beam line, whether simulated with ELEGANT or PARMELA, does not introduce any lengthening of the bunch.

After considering corrections for the point spread function and the streak camera resolution, the data and simulation beam lengths agree at low charge (160 pC), where both data and simulation show a ~300% lengthening with respect to the short UV pulse. But the agreement is spoiled at higher charge, with the data showing more lengthening than the simulation. Seongyeol explains that this could be due to simulation assumptions, for example the simulation does not currently consider the fringe fields of the dipole magnet.

Seongyeol concludes by reminding everyone that the original data/simulation discrepancy, which motivated our study of bunch length, was one in bunch size. Now that the beam length measurements are complete, further measurements of beam size at the pepper-pot screens are planned in order to understand those effects.

A discussion follows, focusing on both the measurement and the simulation.

- Regarding the measurements, Steffen asks if the data analysis will change because of additional corrections, and Stefano and Eduardo reply that any residual corrections would have percent level effects, so they would not change the result.
- Regarding the simulation, Michele asks whether the simulation also shows distorted profiles (sloped flat top) as the data, Seongyeol answers that this can be checked.
- Patric and Francesco argue that fringe fields are not a good candidate for explaining the discrepancy, since we would not observe agreement at 160 pC if the fringe field were incorrect.
- Steffen brings up another possibly incorrect assumption in the simulation, based on the effect of iris aperture changes, which might not be taken into account correctly. Giovanni replies that the experimental data shows that aperture changes do not affect bunch length, when they are compensated by filter changes to provide the same total charge. So, at least in the data, this is not a significant effect.
- Francesco asks about the bunch length difference from the beginning to the end of the beam line. Steffen replies that the measurement at the beginning of the line, while being limited because of the low light, points to the bunch length not increasing. Additionally, simulation gives confidence that there is no beam lengthening in the line.
- Edda asks what this means for Run 2. Steffen replies that there is no issue, except that we will need a very reliable bunch length measurement, so that we can tune the buncher element. Stefano adds that we are developing a dedicated tool for these length measurements.
- Giovanni points out that one important lesson, from both data and simulation, is that space charge is responsible for a 300% or more lengthening of the UV pulse. This effect is so large, and takes place in such a short distance, that perhaps a small difference in initial beam distributions might justify the observed difference in data and simulations.

Actions:

- Seongyeol: check the beam profile in simulation to see if it shows flat top profiles as seen in data.
- Steffen, with Giovanni (electron beam), Barney (pepper pot data analysis), Seongyeol (simulation), Stefano (reinstall pepper pot camera): define which measurements are needed at the pepper pot, make the measurements, analyze the data.

Rb vapor source for Run 2 (Jan Pucek):

Jan relates that design studies for the Run 2 vapor source are ongoing. The current design has both electrical heaters and a heat exchanger in the first cell, and only heat exchanger in the second cell. For the first cell, the heaters will be grouped in triplets of 5/40/5 cm, in order to guarantee sharp edges between them. WDL simulations showed that electrical heating could provide fluctuations below 0.2 C. Regarding windows, the plan is to include both sapphire and diamond windows, depending on location/purpose. The windows will be double-layered, with argon gas between the two layers to ensure lack of oxygen contamination if the inner window breaks. The temperature difference due to each window, as expected from simulation and to be verified in a prototype, is 0.04°C

The prototype should arrive in mid-February and it will be installed in EHN1. It will allow to test temperature uniformity with electrical heaters, and possibly also to test the effect of windows.

In November, EHN1 was cleaned to create space, but the prototype of the first vapor source is still there, and should be decommissioned before we take out the Run 1 vapor source (this would be a good learning opportunity for decommissioning the Run 1 vapor source).

In terms of decommissioning, the first step will be recycling (i.e. removing) the Rb. The safety documentation concerning recycling will be delivered to CERN in January, and commissioning of the glove box will start in February. Following this step, the remaining decommissioning is planned for Summer 2020, to give time for the additional safety documentation to be developed and approved.

John asks about the possibility to have density gradients in the first plasma cell, Jan answers that the current plan provides flexibility in the first half of the cell, with 6 to 8 temperature zones that can generate several shapes, but does not allow gradients in the second half of the first plasma cell.

Stefano asks about the plan for the OTR screen tests in Rb vapor in the CLEAR facility, and Jan and Patric reply that these tests are planned for 2020 and the plan is currently being put together.

Edda asks how much Rb is left, Patric and Fabian reply that there is only enough until the end of the year, so a refill will be needed in order to run in 2020.

Actions:

- Fabian: refill the Rb in time for Josh's experiment in 2020.

Electron line design for Run 2 (Rebecca Ramjiawan):

The design of the new electron line presents several challenges, especially in the injection region, where the parameters at the injection point (particularly $\sigma_{x,y}$ = 5 µm) are difficult to achieve given the space constraints (1 m maximum distance between the plasma cells, and a limited tunnel size). These considerations result in a distance between the dipole and the nearest quadrupole of 1.9 m, and a bending angle of the last dipole of 10 degrees. The deflection of the proton bunch through the dipole, 0.004 degrees, can be easily corrected in

the chicane before the first plasma cell, and the laser beams will have to be aligned to match the proton direction in each cell.

Given the space constraints, 2 designs for the injection dog-leg are presented, one based on 2 dipoles, and one based on 4 dipoles ('double achromat'). The former is shorter and narrower (14.5 m x 2.5 m), and might provide the required parameters, even if not completely isochronous (R56=-0.0059 instead of R56=0). The double achromat would be too wide (4.5 m) to fit in the tunnel, so it is not considered further. Focusing on the 2 dipole design, the effect of R56 on the bunch is small (5% shorter beams). However, the dog-leg in the x-dimension results in a significant growth of beam size in y, originating from the initial 0.5% momentum spread. This results in a minimum beam size (with no errors on any of the beam line elements) of 10 µm instead of the required 5 µm, in the y dimension. Overcoming this limitation would require introducing sextupoles in the high dispersion regions to reduce the chromatic effects.

To include static errors and study the effectiveness of a correction system, simulations were performed with the 2 dipole design, adding 8 BPMs and 7 correctors to the beam line. The model, which includes static errors, BPM resolution, and correction errors (but no dynamic errors), resulted in position stability (x/y) of 0.1 mm (RMS of positions). The beam sizes resulting from the simulations, based on 100 seeds with static errors modeled from a Gaussian distribution, ranged from 5 to 36 µm for σ_x and 18 to 176 µm for σ_y, with a large dependence on the initial momentum spread. Both these ranges are beyond the required 5 µm.

The next steps will move in two directions: solving the issues already uncovered (for example introducing sextuples to minimize the chromatic effects), and adding more realistic effects (dynamic errors on beam trajectory, momentum jitter, parasitic dispersion from the correction system, coherent synchrotron radiation, space charge). Additionally, the discussion with BI to optimize the diagnostics will continue.

Patric asks about the possibility of a chicane at the plasma exit, in order to extract the electron beam without affecting its properties. This would not be easy, is the reply, given that the energy at the plasma exist is not well known.

Steffen asks about the chromatic effects of the 4-dipole chicane, Rebecca replies that they are actually similar to the 2-dipole option.

Edda asks if there is space for the sextupoles, Rebecca replies that there is room in the high dispersion regions.

Steffen points out that the existing sextupoles in the CERN Linear Collider Test Facility (CTF) might have the right specifications, so we should check whether their designs could be used for AWAKE.

Edda asks if there are any showstoppers, Rebecca replies that this will depend on whether sextupoles are able to get back to the design 5 µm beam size in y.

Actions:

- Rebecca: check specifications for CTF sextupoles.

AOB:

Minutes of last TB are discussed, several action items having been addressed. Some leftover action items (leaving aside the ongoing long-term developments) are:

- Eugenio: Analyze electron beam BPM data
- Seongyeol: Continue trying to understand beam size discrepancy with simulation
- Valentin, Ans: check integration of the laser system in the facility.

The status of the BI developments towards a new digital camera DAQ system is discussed. Stefano reports that two meetings took place, one with Giovanni and BI people (Enrico, Athanasios, Michele) to define the desiderata, and one only among BI to discuss the implementation. In the short term, Athanasios will have a couple of weeks before Christmas to define the FESA class for the digital camera.

Summary of actions:

- Francesco: summarize machine learning studies in next TB
- Seongyeol: check the beam profile in simulation to see if it shows flat top profiles as seen in data.
- Steffen, with Giovanni (electron beam), Barney (pepper pot data analysis), Seongyeol (simulation), Stefano (reinstall pepper pot camera): define which measurements are needed at the pepper pot, make the measurements, analyze the data.
- Fabian: refill the Rb in time for Josh's experiment in 2020.
- Rebecca: check specifications for CTF sextupoles.

Next Meeting:

The next Technical Board will take place on January 23, 2020, 14:00.

Giovanni Zevi Della Porta, 20 November 2019