

Observation of Optical Synchrotron Radiation from Ultra-low Charges Stored in a Ring Operating at 425 MeV

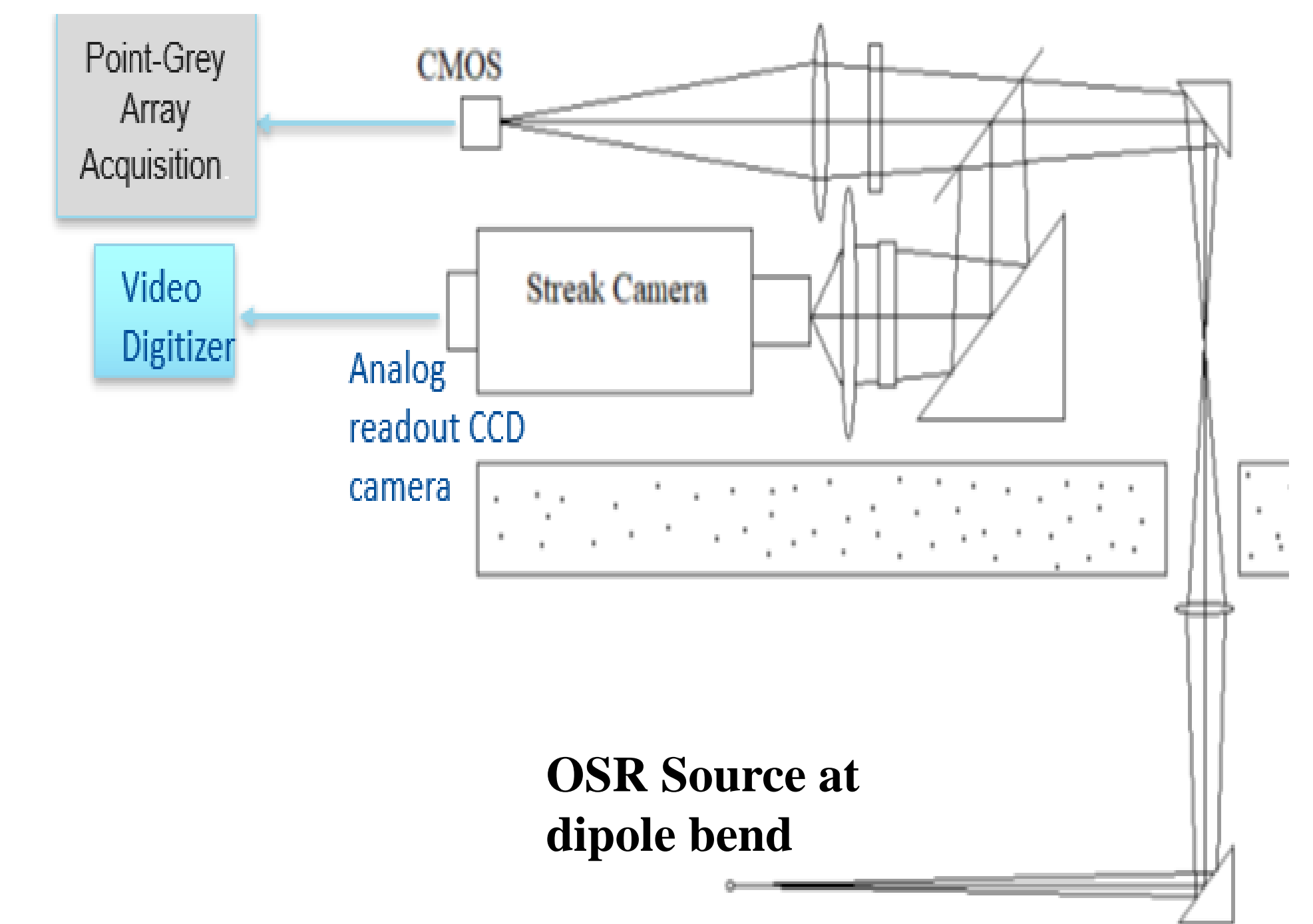
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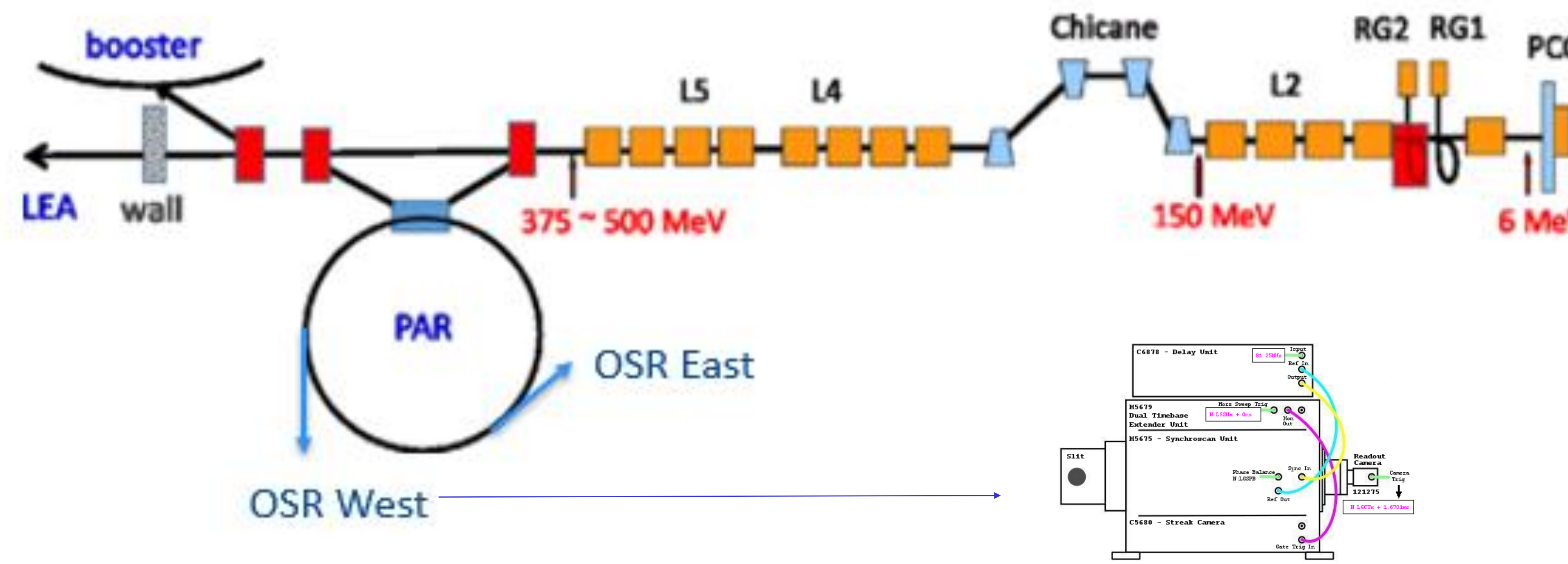
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ABSTRACT

The initial observations of optical synchrotron radiation (OSR) emitted over millions of passes from a few electrons circulating in the Particle Accumulator Ring (PAR) at the Advanced Photon Source have been done with a digital CMOS camera and a synchroscan streak camera operating at 117.3 MHz. The discrete changes of integrated counts in the CMOS image region of interest are ascribed to single electron steps at ~ 3500 counts per e^- . Circulations of a single electron at 375 MeV and at 425 MeV were demonstrated in the 12-bit digital FLIR USB3 camera images. The Hamamatsu C5680 streak camera operating at the 12th harmonic of the fundamental revolution frequency of 9.77 MHz was used to measure the bunch length from 0.5-nC circulating charge down to 10s of electrons or <10 aC.

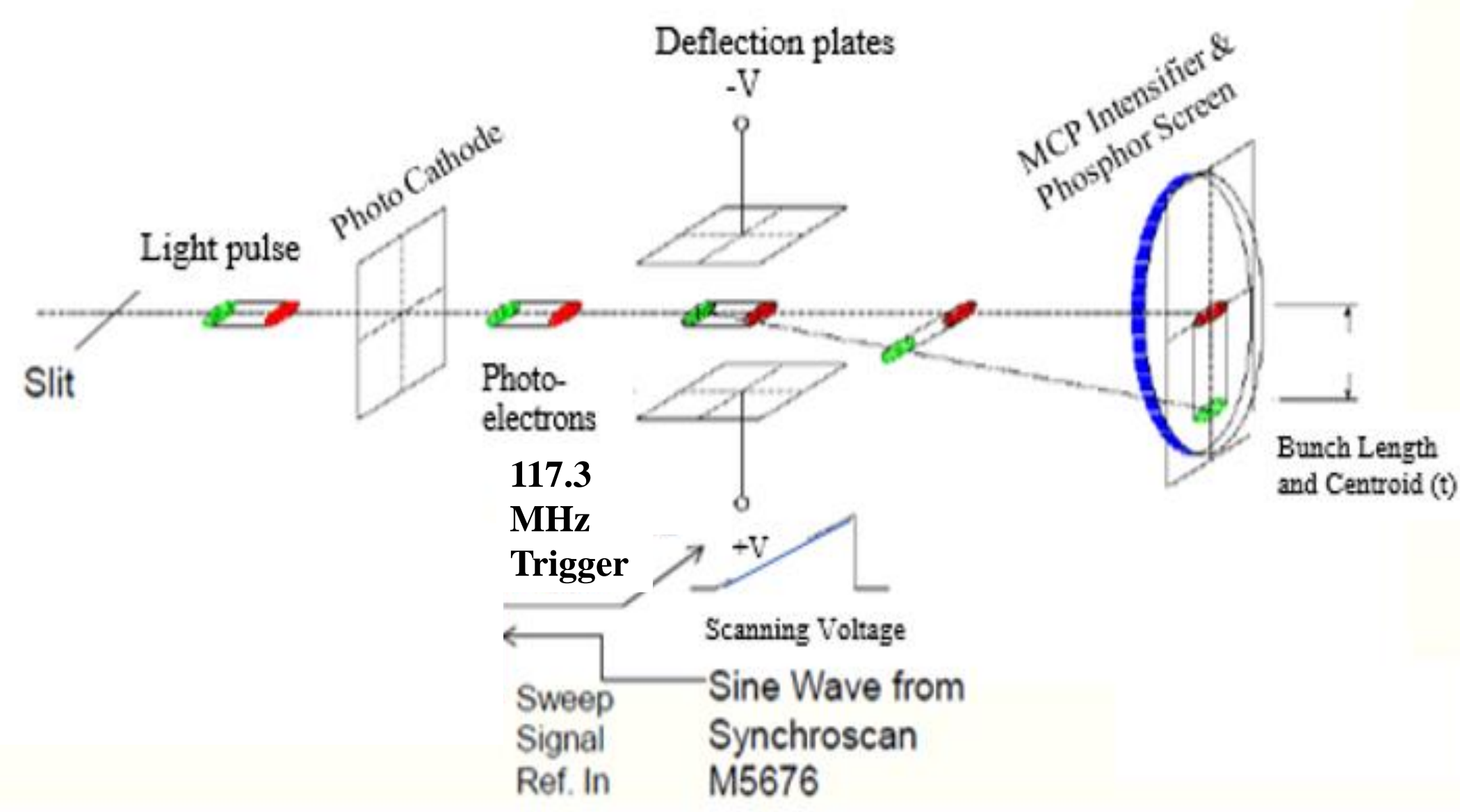


Schematic illustration of the PAR West optics table with the CMOS camera and the streak camera.

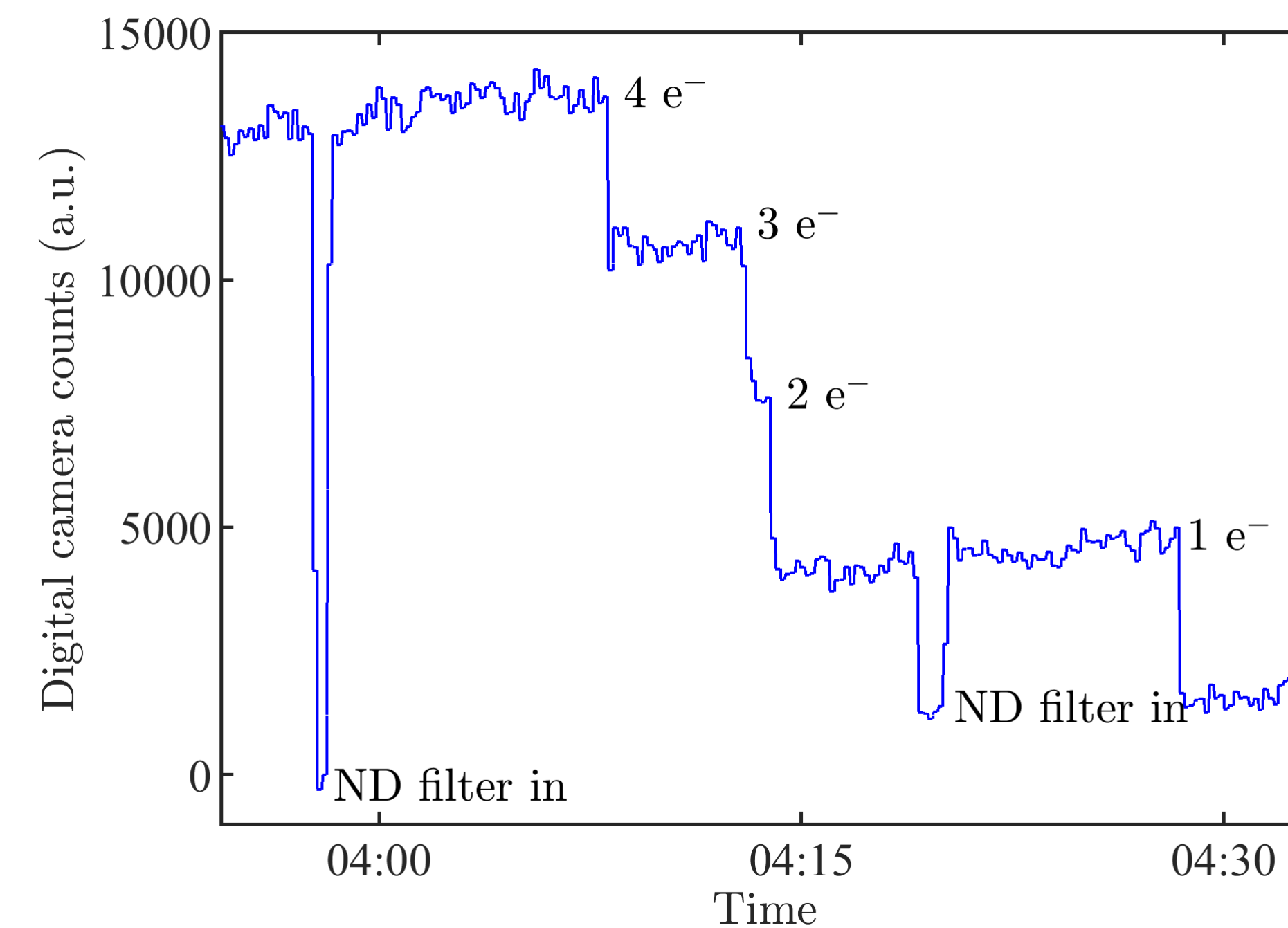


Schematic of the APS linac showing the path to the PAR and the path to the streak camera.

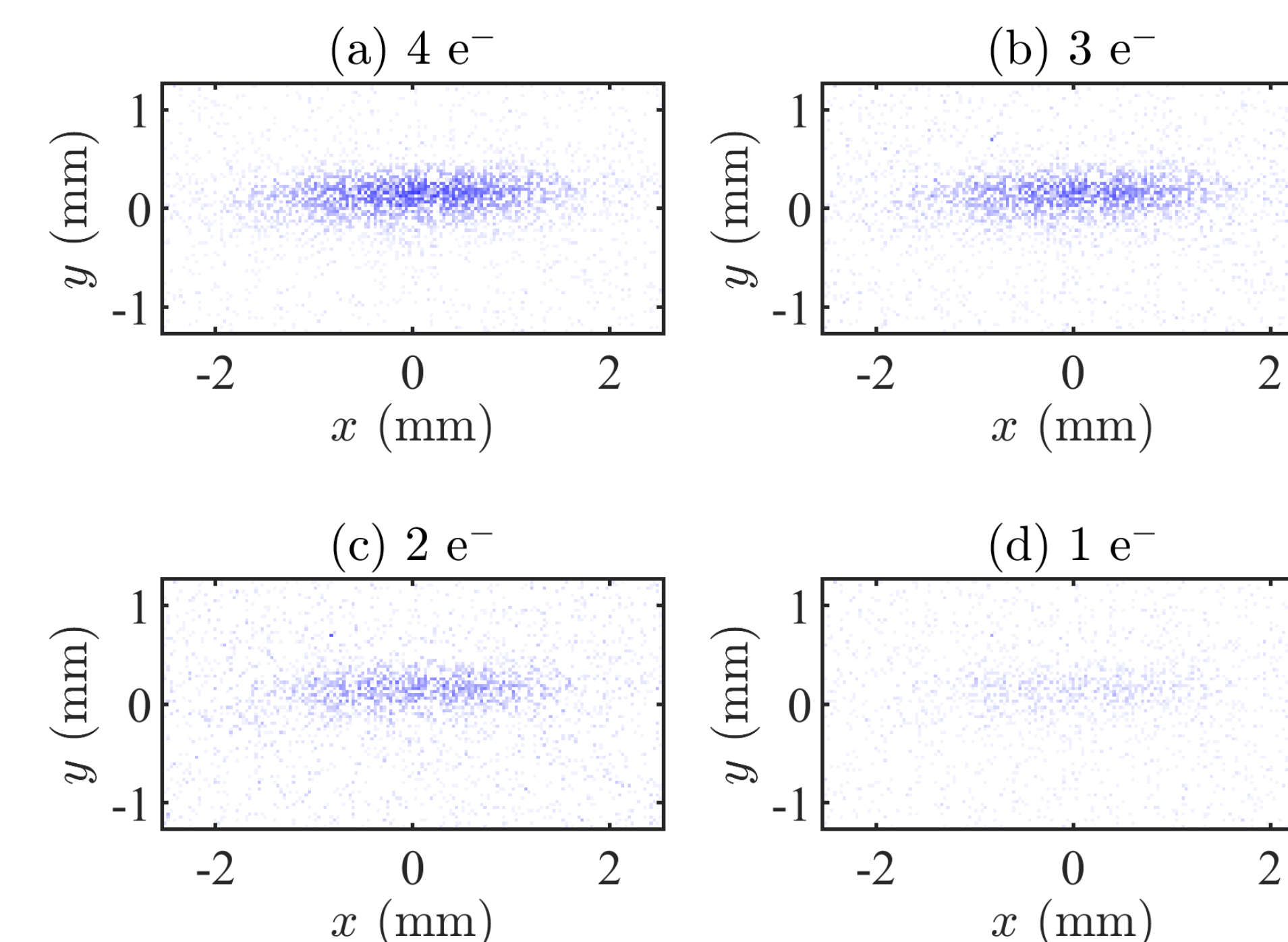
Dual sweep C5680 streak camera with MCP gating feature and phase locked at 117.3 MHz.



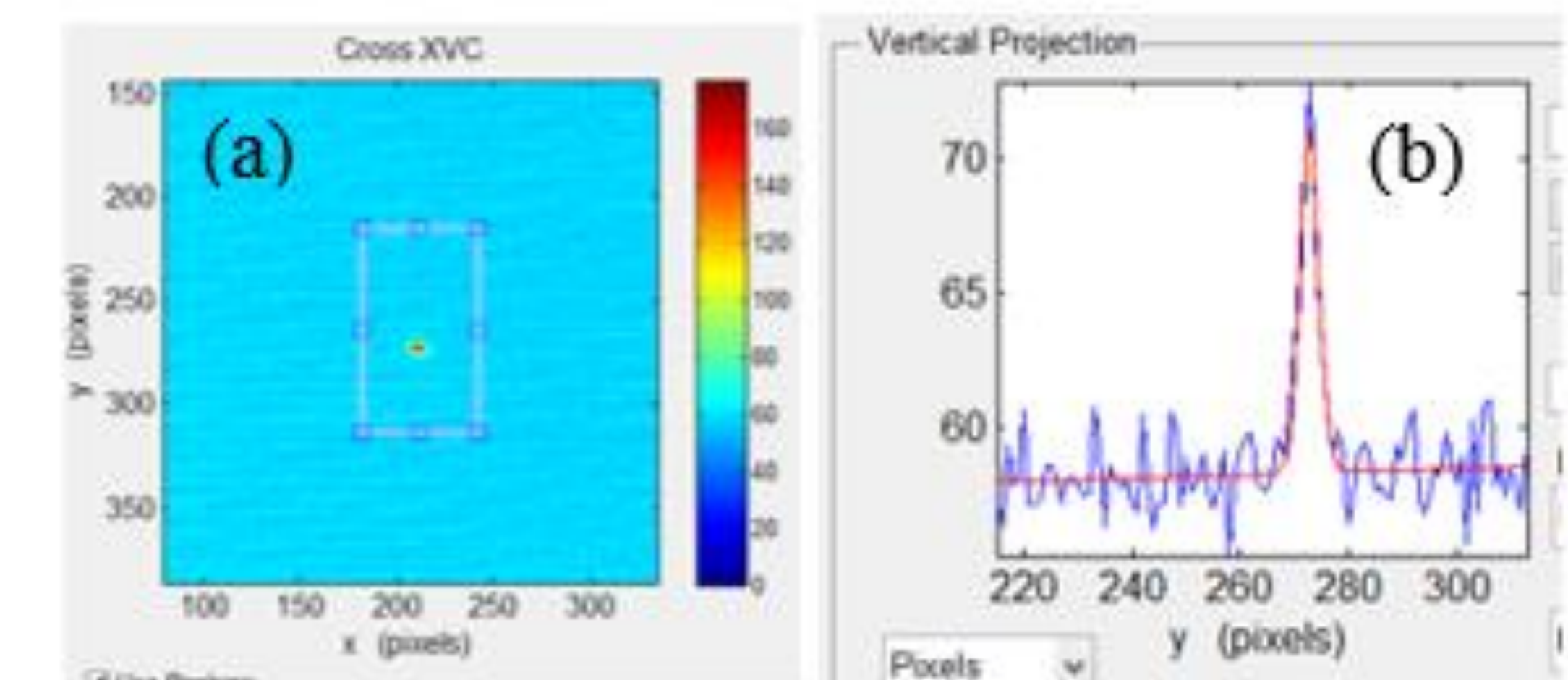
OSR intensity in the west synchrotron light monitor (PAR:SLM1) versus run time. The discrete intensity steps are at 3,500 counts/ e^- . A single e^- was stored.



A set of 4 CMOS camera 2D images. These are background subtracted for the four stored-electron-number cases indicated, 4 to 1. This is at 375-MeV.

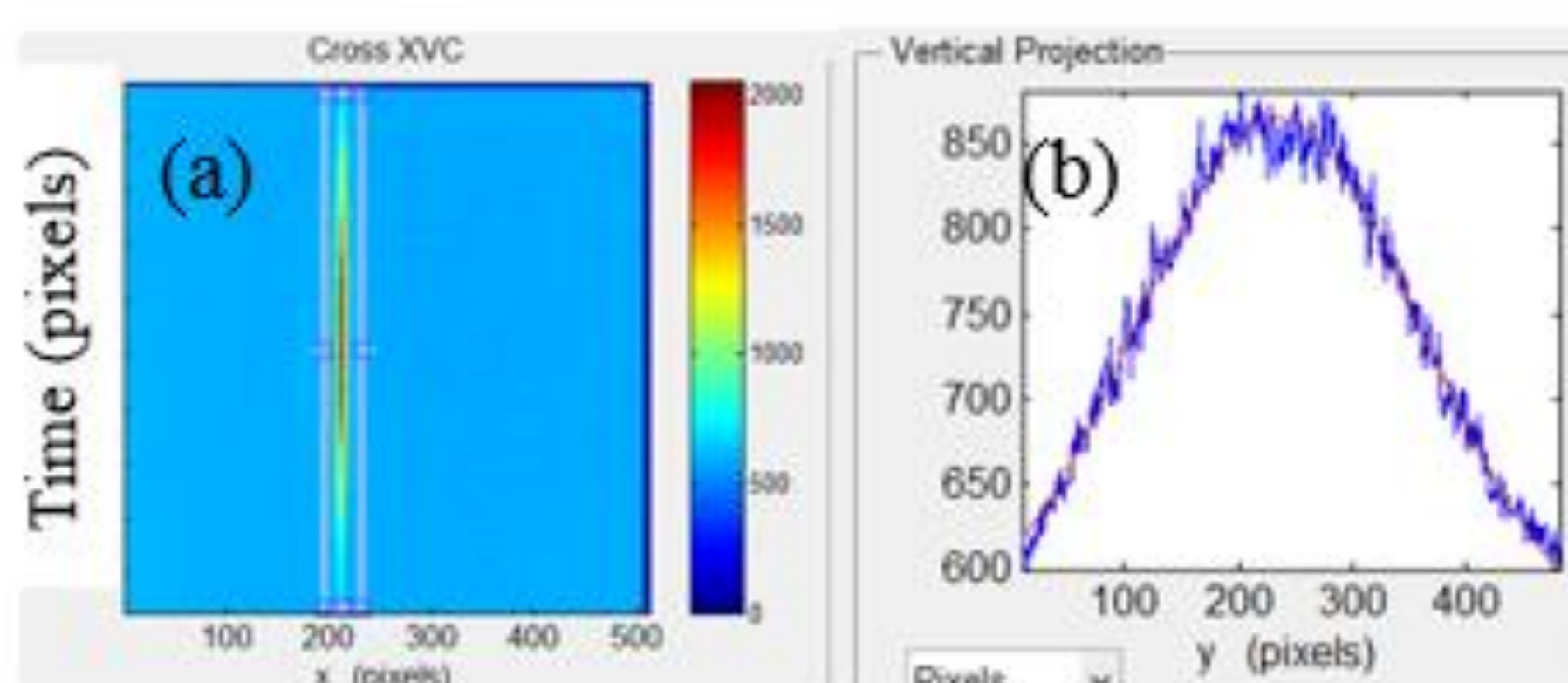


Streak camera focus mode image at 0.32 nC (a) where slit is opened so beam focus vertically sets limiting size at 1.7 pixels in (b).

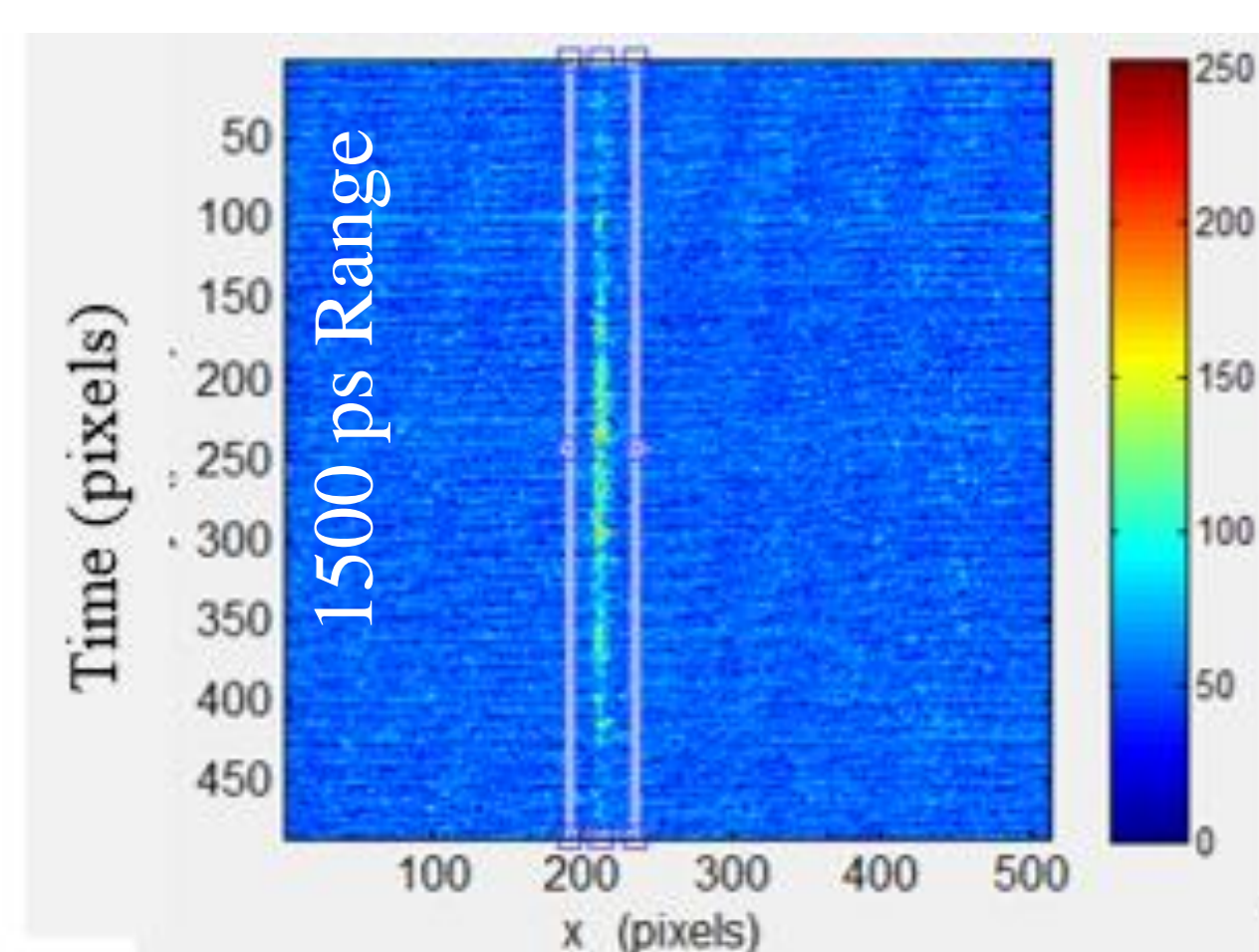


SUMMARY

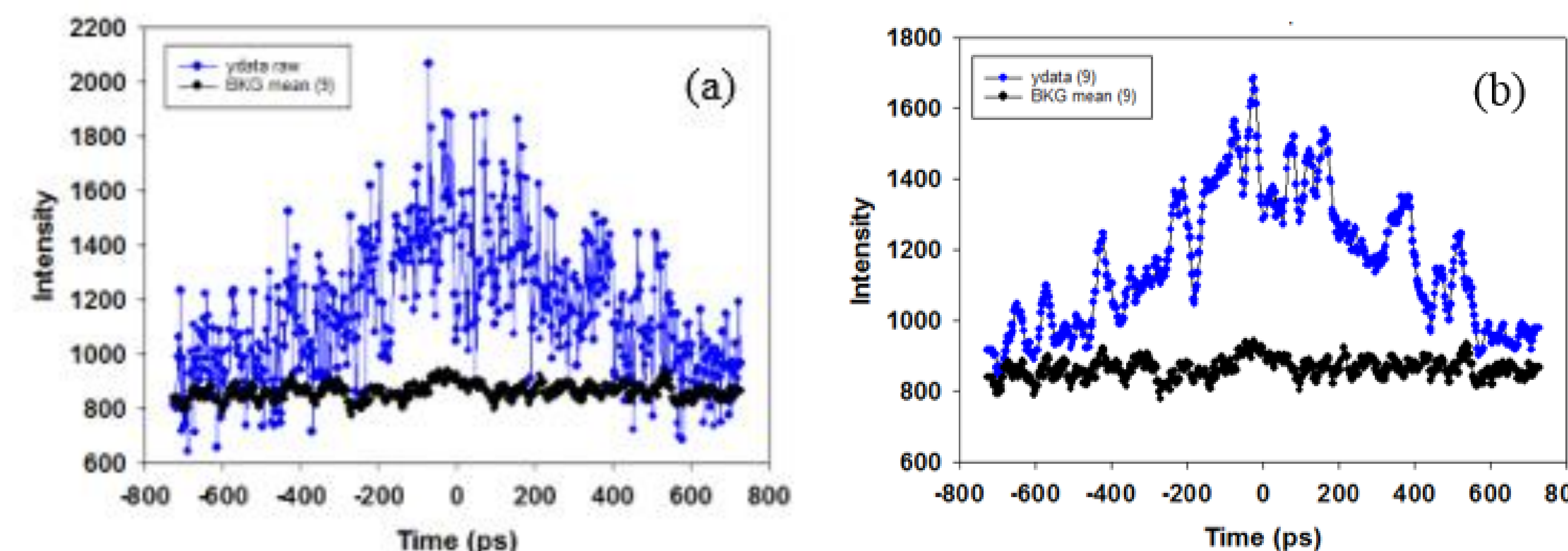
(a) Streak mode image on Range 4 and (b) time profile with bunch length of 373 ± 12 ps at 0.32 nC. The vertical scale time range is 1500 ps. The energy was 425 MeV.



Streak Image from 57 e^- stored with 200-image sum and background subtraction of 200-image sum. The fit is 276 ± 36 ps.



(a) Projected raw time profile of Streak Image for 57 e^- stored at 425 MeV and (b) results of a 9-channel sliding smooth and background profile.



In summary, we performed initial investigations of OSR emissions from a few electrons stored in the PAR at 375 and 425 MeV with a digital CMOS camera and with a synchroscan streak camera. We measured a bunch length of 285 ps at 0.5-nC stored charge as a reference at 325 MeV and 372 ps at 425 MeV. We were able to identify OSR from a single electron stored using the CMOS camera and OSR from 10s of electrons stored using a streak camera for the first time. The latter bunch length for 57 e^- stored was observed to be 25% shorter than the reference at 425 MeV. We are reviewing our results in the context of existing models on the PAR, OSR, and streak tubes. Further investigations are planned.