Bunch Compression for FELs – Chicanes or Arcs?

LEDS2023

Longitudinal Electron beam Dynamics for coherent light Sources

Peter Williams & Adam Dixon LEDS Workshop
ENEA Frascati

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- Bunch Compressors for XFELs – Chicanes or Arcs?
- Case Study of Arcs – The MAX-IV Linac Bunch Compressors
- Comparing the MAX-IV BCs to Chicane Equivalents
- Upgrading the MAX-IV BCs from Fixed to Variable R_{56}
- Conclusions – Preserving even higher brightness in a future UK-XFEL

Bunch Compressors for XFELs – Arcs or Chicanes?

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- Nearly all XFELs (FLASH, EuXFEL, FERMI, SwissFEL, LCLS-I/II, PAL-XFEL, SACLA) use **chicanes** for bunch compression. This involves accelerating on the **rising** side of RF such that the bunch **tail is higher energy** than the head. A chicane then allows the tail of the bunch to catch up with the head as the **trajectory is shorter for higher energy**.

- Much effort was taken especially at FLASH / LCLS / LEUTL / SDL / UCLA / … in the 1990's / 2000's to justify and understand the best approach for compression, especially how to best cope with emittance degradation from CSR in codes. E.g. the Zeuthen benchmarking chicane from 2002. Arcs not considered as far as I'm aware

- **But why? …** Are chicanes necessarily "better" than alternatives? …

  I don't find any comprehensive comparisons in the literature, just an opinion from John Byrd in a the 2010 USPAS lectures, and comments in Simone Di Mitri & Max Cornacchia's 2015 paper, and 2016 CAS lectures proposing an arc compressor for ERLs

  … let me know if I'm wrong!

Bunch Compressors for XFELs – Arcs or Chicanes?

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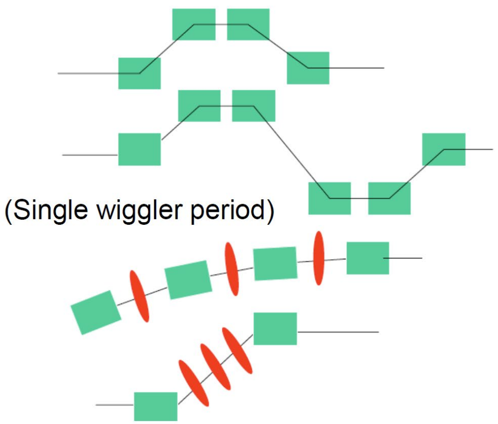
John Byrd – USPAS 2010

Bunch Compressors

John Byrd
(based on a talk by P. Piot)

Short Bunches in Acc

Types of bunch compressors



- Chicane
  $R_{56}<0$, $T_{566}>0$
- S-chicane
  $R_{56}<0$, $T_{566}>0$
- F0D0 arc
  $R_{56}>0$, $T_{566}>0$
- Dog-leg
  $R_{56}>0$, $T_{566}>0$

Short Bunches in Accelerators– USPAS, Boston, MA 21-25 June 2010

Different types of bunch compressors

- **Chicane** : Simplest type with a 4-bending magnets for bunch compression
- **Double chicane** : R_{56} is sum of the R_{56} values for each chicane.
- **Wiggler type** : This type can be used when a large R_{56} is required, It is also possible to locate quadrupole magnets between dipole magnets where dispersion passes through zero, allowing continuous focusing across these long systems.
- **Arc type** : R_{56} can be conveniently adjusted by varying betatron phase advance per cell in the bend plane. The systems chromatic aberrations, introduce large beamline geometry excursions and produce many well aligned components.

Short Bunches in Accelerators– USPAS, Boston, MA 21-25 June 2010

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A Letters Journal Exploring the Frontiers of Physics

March 2015

EPL, **109** (2015) 62002
doi: 10.1209/0295-5075/109/62002

www.epljournal.org

Transverse emittance-preserving arc compressor for high-brightness electron beam-based light sources and colliders

S. Di Mitri[(a)] and M. Cornacchia

Elettra Sincrotrone Trieste - 34149 Basovizza, Trieste, Italy

received 13 January 2015; accepted in final form 17 March 2015
published online 31 March 2015

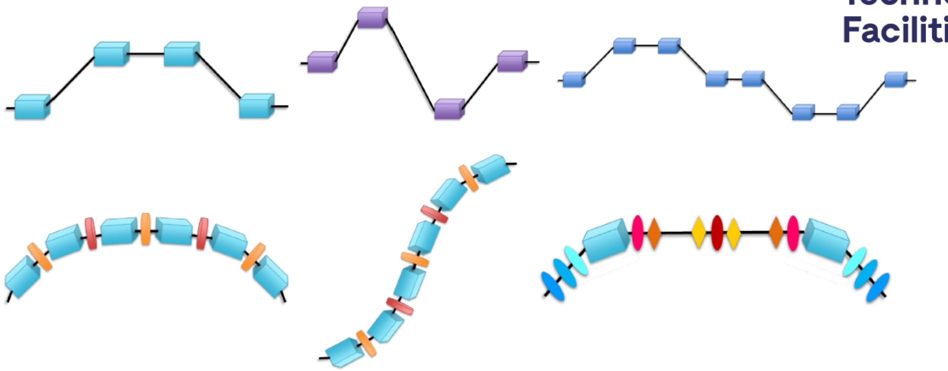


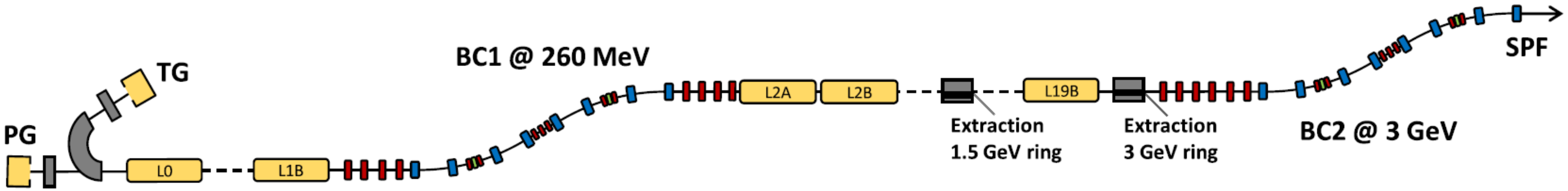
Fig. 6: Most common geometries (not to scale) of magnetic insertions for bunch-length compression. From top, left to right: C-shape, S-shape and double C-shape chicanes; bottom, arc-fodo, dog-leg-fodo and double-bend achromatic cells.

- *Arcs usually provide an R56 term with sign opposite to that of four-dipole chicanes, and are a natural choice for compression in recirculating machines, such as energy-recovery linacs. They may offer the chance of accommodating sextupole magnets for the linearization of the compression process, with a phase advance suitable for the cancellation of geometric and chromatic aberrations.* ***However, additional constraints on the linear optics functions in the bending plane are required in the arcs in order to minimize or cancel the otherwise CSR-induced projected emittance growth.***

- Simone DiMitri CAS FELs & ERLs 2016.

- The system Simone refers to is a full 180(-ish) turnaround arc … not needed for single-pass, so is this still restrictive? …
- … There is one XFEL wannabe that defies the convention of chicanes for compression – the **MAX-IV linac**.

Bunch Compressors for XFELs – Arcs or Chicanes?



- The MAX-IV linac chooses the “wrong” way round! Here compression is achieved using two **arc** compressors. This involves accelerating on the **falling** side of RF such that the bunch **tail is lower energy** than the head. An arc then allows the tail of the bunch to catch up with the head as **the trajectory is shorter for lower energy.**

- **Objection! I hear you cry**… Arc systems are longer, they have many more elements, they are strongly focusing, they lead to an offset in the beamline, … yes these are disadvantages, but do they outweigh the potential advantages? (P.S. See Sara’s talk for higher order corrections in these arcs)

- Why does MAX-IV make this “wrong” choice. Essentially because the linac is **primarily there to inject the 3 GeV and 1.5 GeV rings**! With arc compressors, all you need to do to inject is put a beam through on crest – no magnetic or mechanical change needed, no harmonic RF to get in the way. They are **transparent to ring injection**.

- … Then why are there any compressors at all? Because Mikael Ericsson and his team at the time foresaw a simple way to enable a **short pulse facility** (FEMTOMAX) and later a **soft X-ray FEL** with minimal intervention = additional capability for the facility

Bunch Compressors for XFELs – Arcs or Chicanes?

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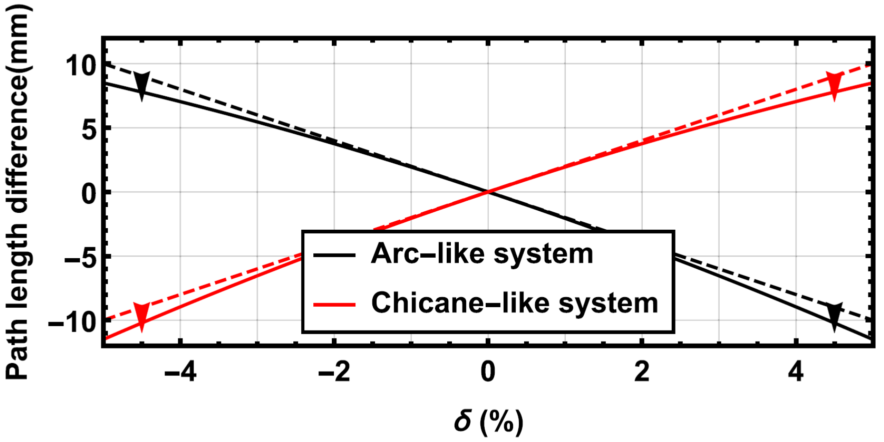
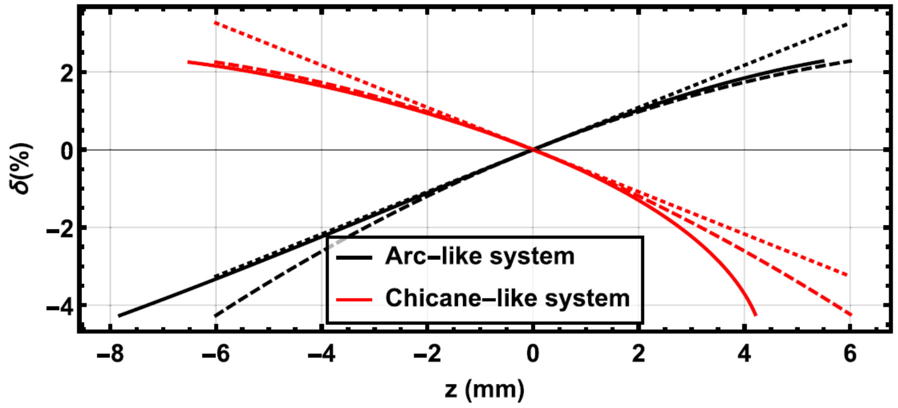
Potential advantages of arc compressors over chicanes:

1. Second order momentum compaction naturally compensates for fundamental RF curvature → no requirement for harmonic RF … this has a second consequence …



Path length deviation from linearity (dashed) in arc-like and chicane-like systems



Longitudinal phase space after chirp-compression in ark-like and chicane-like systems. Comparison with linear (dotted) and curvature from fundamental RF (dashed).

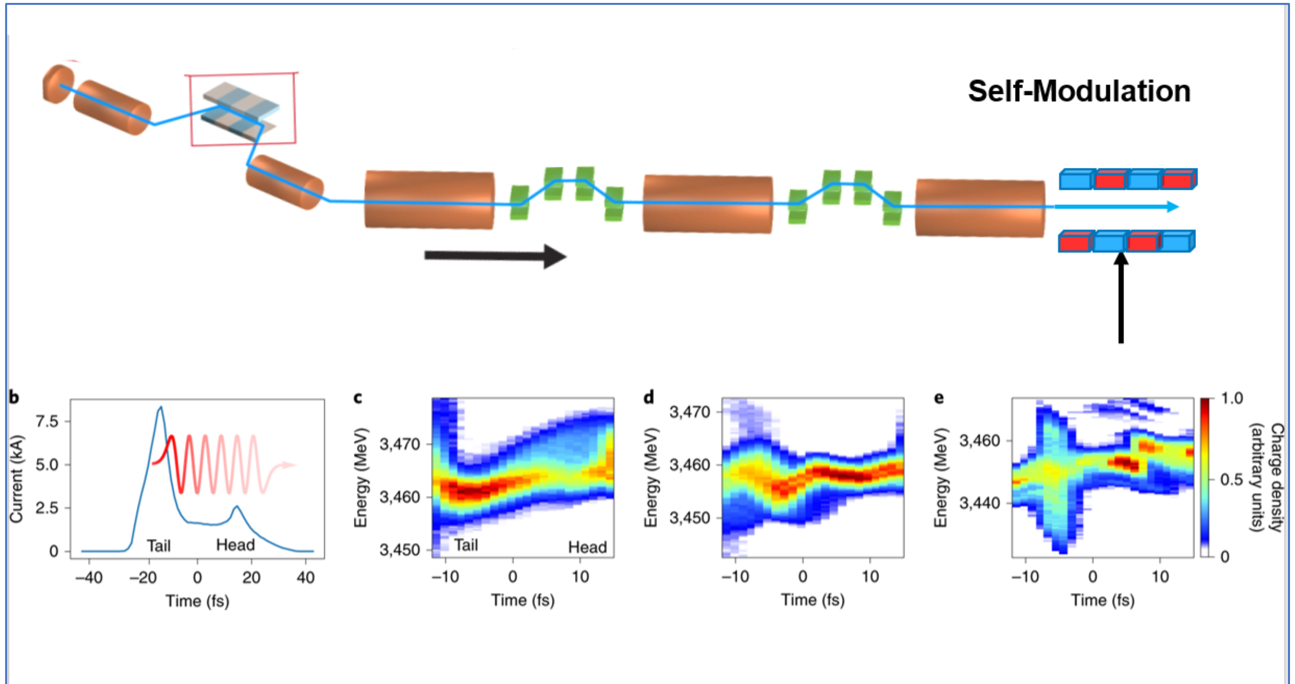
2. Harmonic RF compensates nicely only in the central region of the bunch… it **over-compensates in the tails**, bending them back upon themselves creating the familiar **double-horn current profile** … arc compressors **cannot** produce this

3. Because chicane systems require acceleration on the **rising** side of crest the bunch chirp "**fights" the linac wakefields** which flatten it in energy, this leads to a requirement to run **further off crest in all linacs prior to full compression.** This is unnecessary for arc-like compression where the wakes enhance the chirp, therefore **higher energy is achieved from the same linac.** Particularly S-band and higher frequencies.

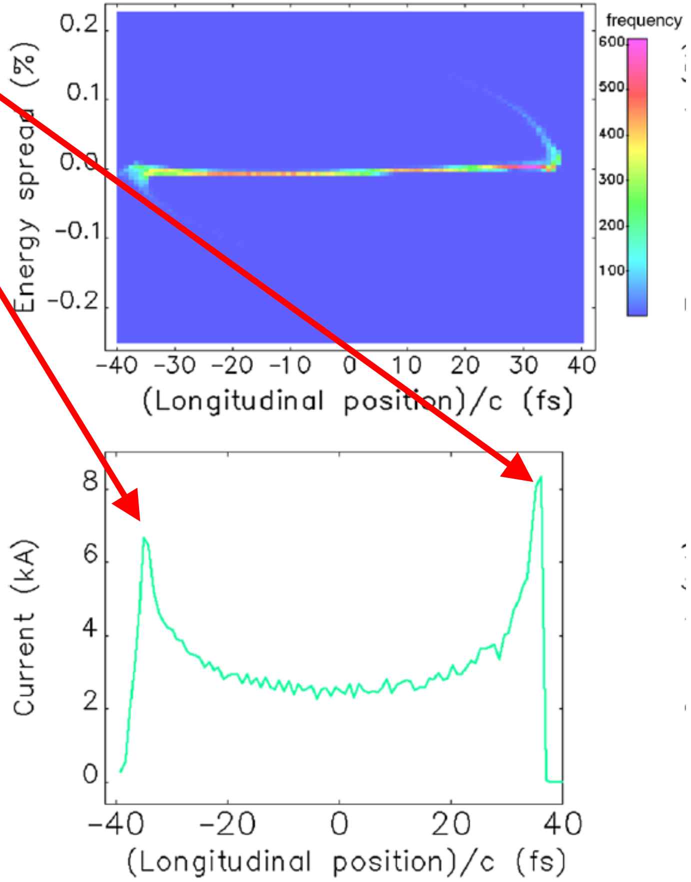
Chicanes Make Double-Horn Current Profiles

- Compression with chicane systems + harmonic RF **always** make "double horns" = towers in the current profile at the head and at the tail…
- The horn at the tail radiates CSR onto the central lasing section altering its energy profile and spoiling its slice emittance (and this is jitter intolerant) – how to deal with this?

1. Make a "virtue" of it! e.g. SLAC XLEAP program's self-modulation scheme to use CSR from tail to modulate the core and generate sub-fs pulses



J. MacArthur., et al. *Physical review letters* 123.21 (2019): 214801
J. Duris, S. Li et al. *Nature Photonics* 14.1 (2020): 30-36.



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- The horn at the tail radiates CSR onto the central lasing section altering its energy profile and spoiling its slice emittance (and this is jitter intolerant) – how to deal with this?

2. Get rid of it! E.g. slotted foil within chicane at Eu-XFEL to spoil head and tail and make short pulses – problem: can’t collimate electrons, can only make them mad → radiation damage at high average power machines

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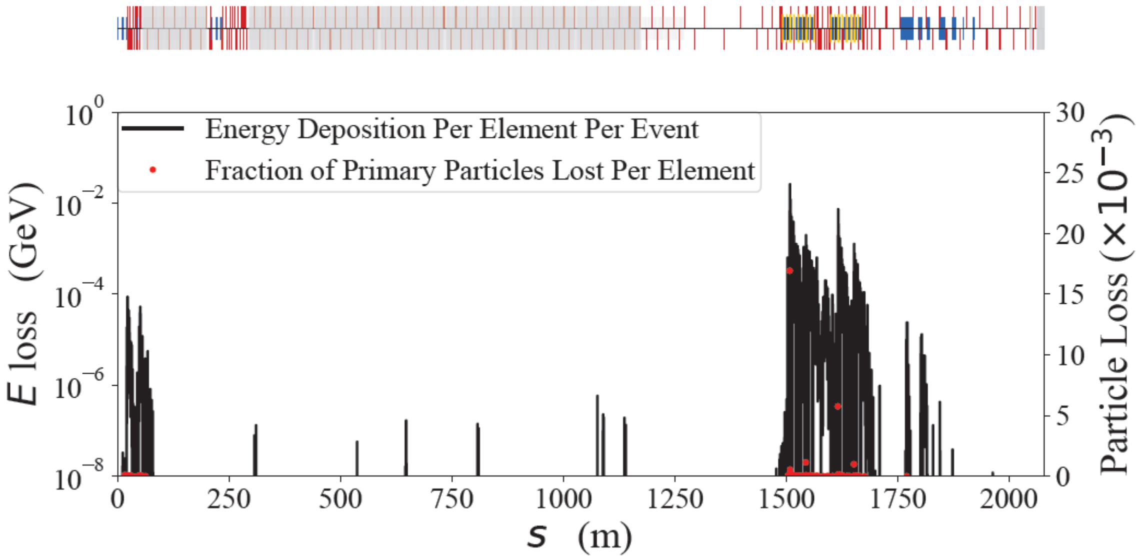
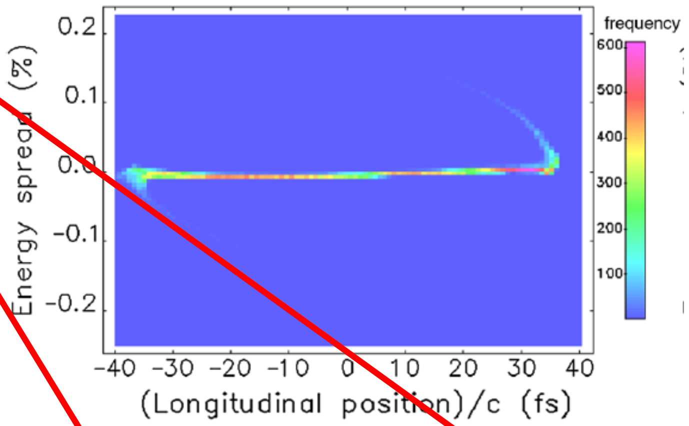
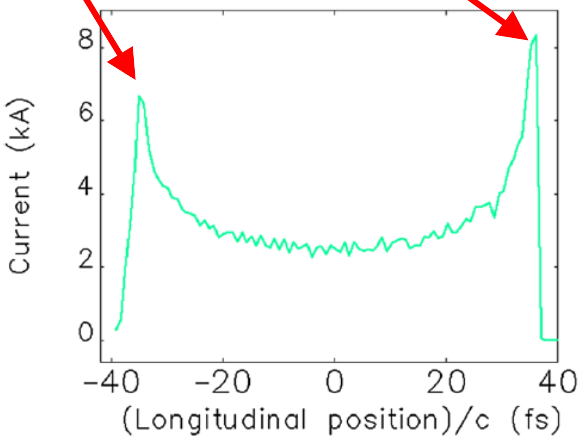
ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-TUPAB125

STUDIES OF PARTICLE LOSSES FROM THE BEAM IN THE EU-XFEL FOLLOWING SCATTERING BY A SLOTTED FOIL

A. Potter, A. Wolski, University of Liverpool, Liverpool, UK
F. Jackson, STFC/ASTeC, Daresbury Laboratory, Daresbury, UK
S. Liu, W. Decking, DESY, Hamburg, Germany







Bunch Compressors for XFELs – Chicanes or Arcs?

Case Study of Arcs – The MAX-IV Linac Bunch Compressors

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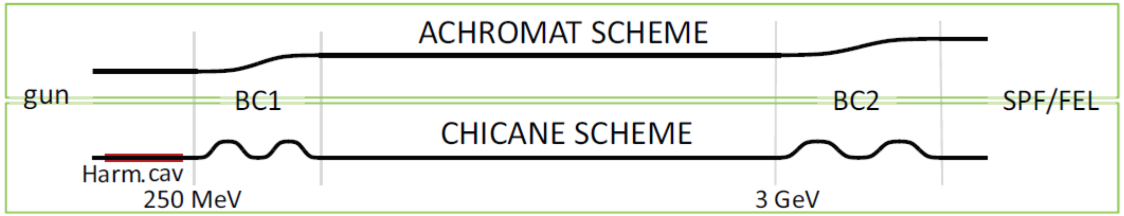
A New Benchmarking - Arcs Vs Chicanes

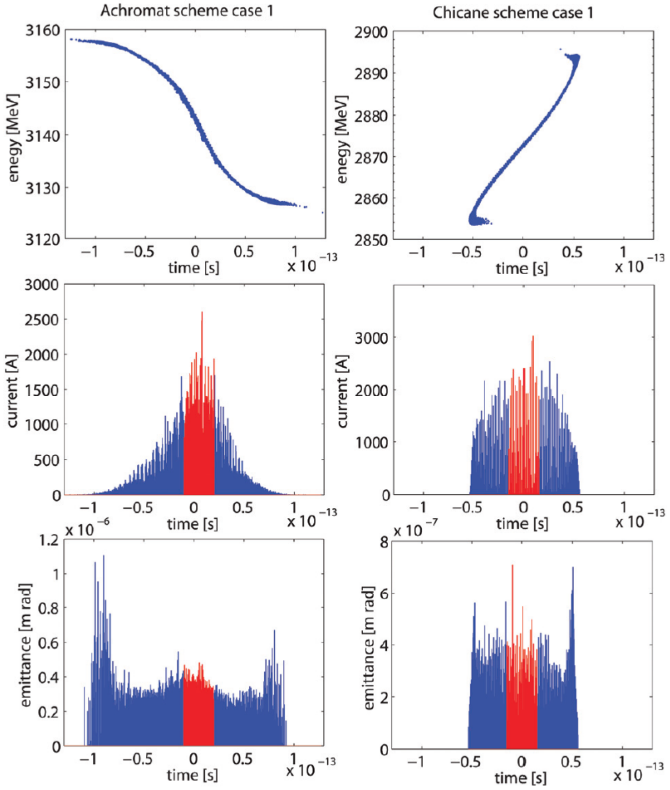
TUPSO35 Proceedings of FEL2013, New York, NY, USA

THE MAX IV LINAC AS X-RAY FEL INJECTOR: COMPARISON OF TWO COMPRESSION SCHEMES

O. Karlberg*, F. Curbis, S. Thorin, S. Werin, MAX-lab / Lund University, Sweden

- Sara Thorin on an advantage of arcs: *“We don’t have any towers irradiating our usable area because the single tower IS the usable peak which makes all the difference.”*
- It makes sense to me to do a new benchmarking comparison of Arcs Vs Chicanes - Olivia Karlberg started this process at FEL2013 – now taken on by Adam Dixon and myself…How to make this a “fair” comparison?





1. Total accelerating gradient available from the linac identical. S-band used.
2. Absolute values (but not signs!) of R56 identical. Two TBA’s per BC = two chicanes per BC
3. Optics within linac nearly identical.
4. Addition of 10 harmonic cavities for chicane scheme.
5. Two values of final compression studied.

- Some features: double horns vs single spike are there. Energy difference of 260 MeV! This is due to harmonic RF (~50 MeV loss) and “fighting the chirp” (~200 MeV loss, a 15 degree phase difference) → arcs save at least an extra klystron / modulator for a 3 GeV S-band case.
- FW energy spreads are higher as we compress at full energy, but slice emittances lower – likely to suit certain FEL schemes and not others – FEL simulations underway

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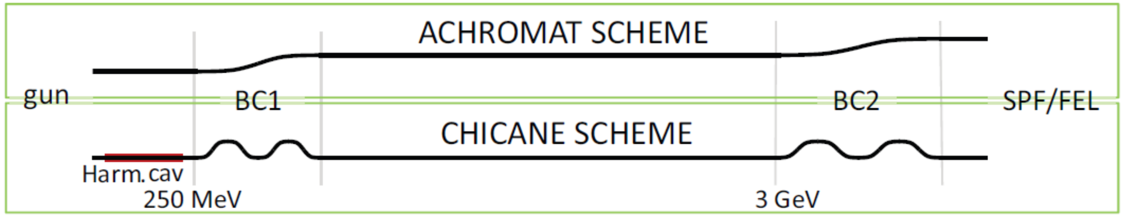

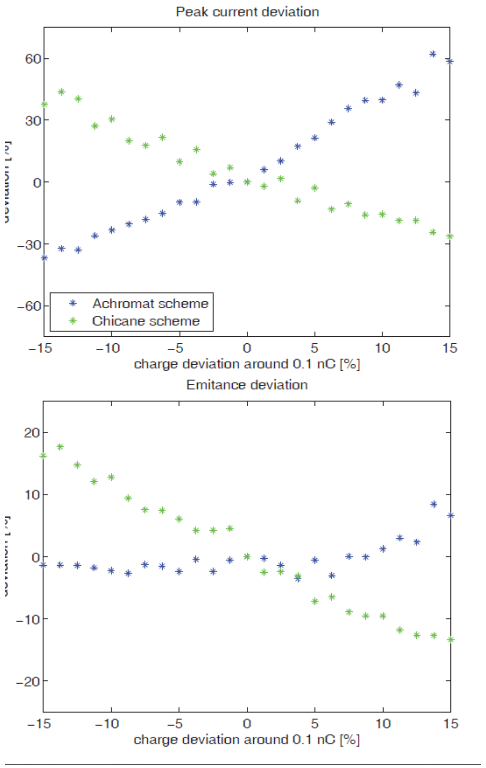

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3. Optics within linac nearly identical.
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- Jitter in peak current with charge is similar between schemes but jitter in slice emittance with charge significantly better in arc scheme

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Arcs Vs Chicanes (4 and 5 dipole variants…)

- Recently LCLS return to considering “non-standard” chicanes to suppress CSR = the 5 dipole chicane. So let’s include this in the comparison…

PHYSICAL REVIEW ACCELERATORS AND BEAMS **25,** 090701 (2022)

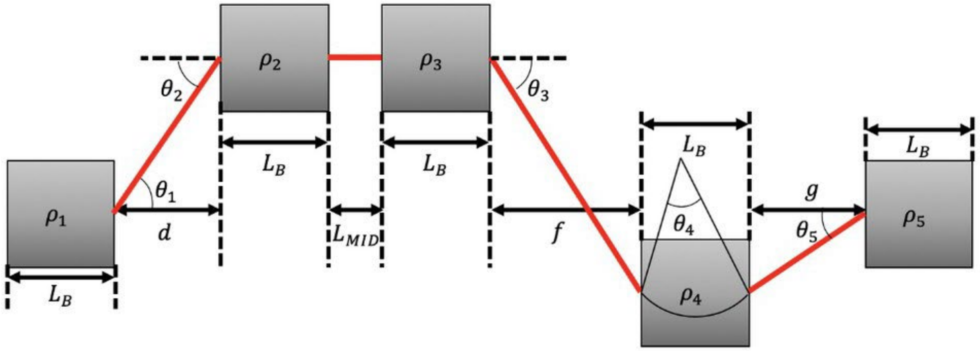
Novel bunch compressor chicane: The five-bend chicane

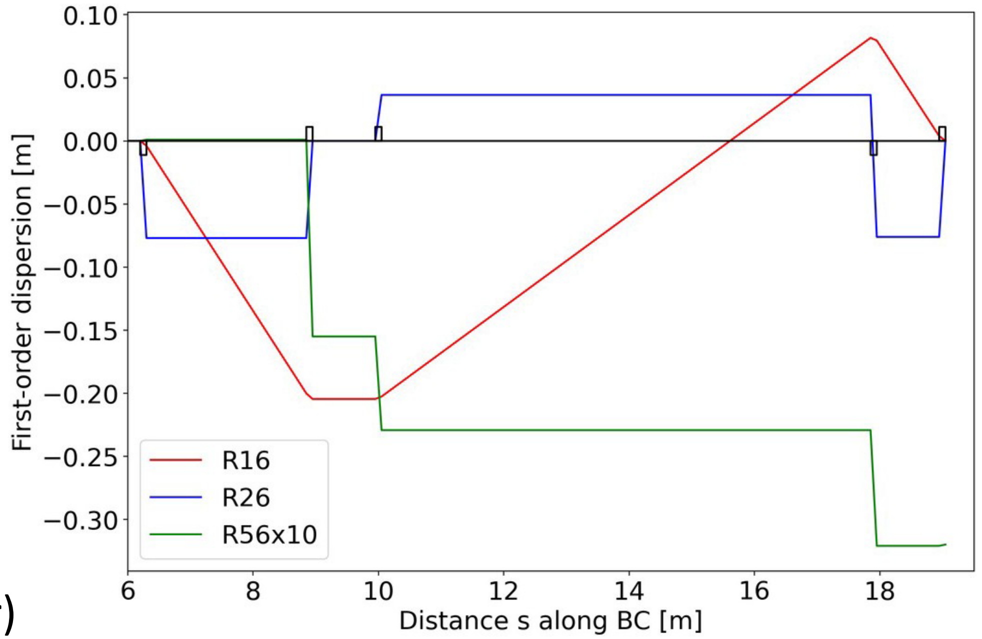
Donish Z. Khan* and Tor O. Raubenheimer†

SLAC National Accelerator Laboratory, Menlo Park, California, USA

(Received 19 May 2022; accepted 22 August 2022; published 7 September 2022)

- Idea is to improve CSR mitigation by making horizontal dispersion of opposite sign at dipole 4 allowing for cancellation of kick from dipole 3

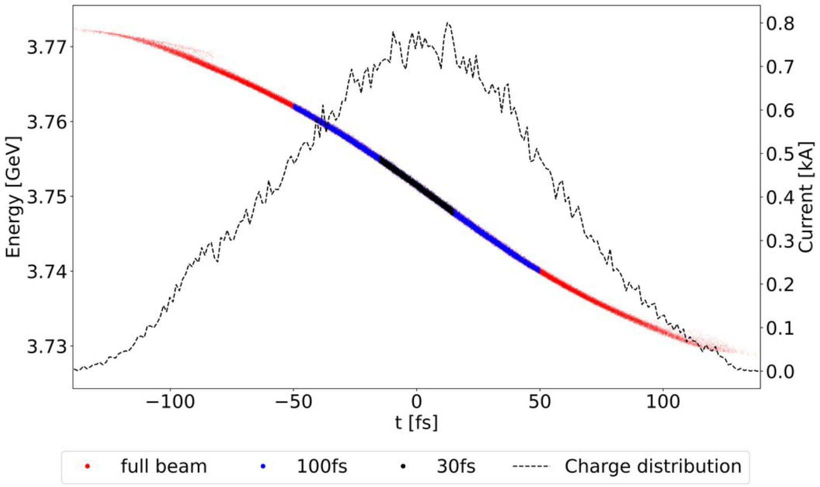




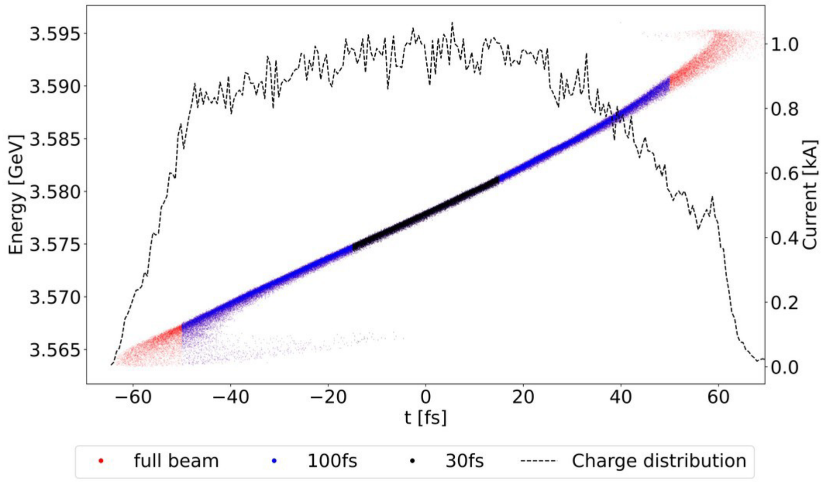
- Personal view – I don’t like it! The kicks from CSR are charge dependent, so the geometry will need to change to properly cancel the kicks for different charges = limits flexibility (also jitter)

Arcs Vs Chicanes for 100 fs FWHM – WIP

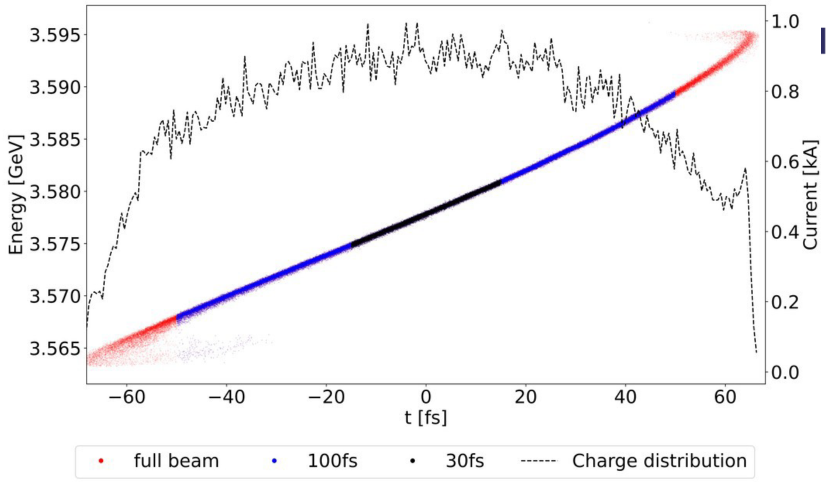
Arc



4-bend



5-bend

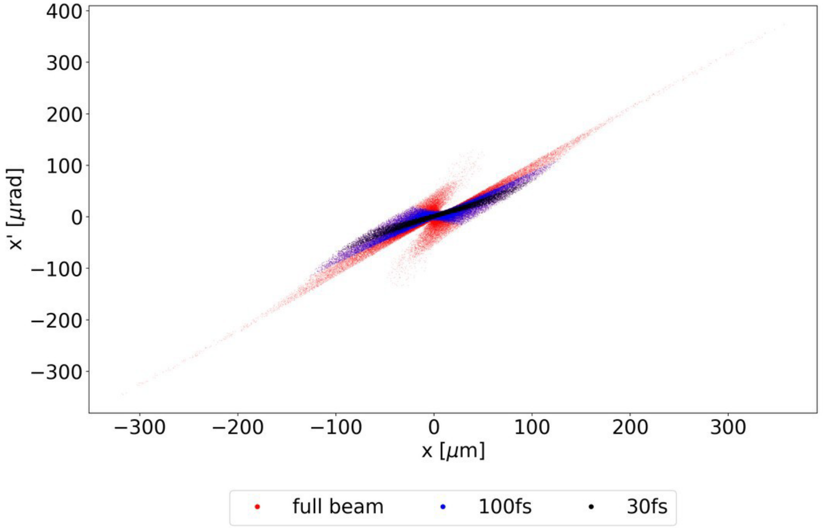


	Arc			4-Bend			5-Bend		
Δt [fs]	Full	100	30	Full	100	30	Full	100	30
Energy [GeV]	3.75	n/a	n/a	3.58	n/a	n/a	3.58	n/a	n/a
Charge [pC]	100	65.29	22.29	100.00	88.93	29.25	100.00	83.00	26.99
ΔE [GeV]	0.041	0.022	0.007	0.031	0.025	0.007	0.031	0.021	0.006
$\Delta(\Delta E)_{csr}$ [%]	0.66	2.93	6.09	-0.95	-1.49	-2.76	-1.21	-7.38	-3.22

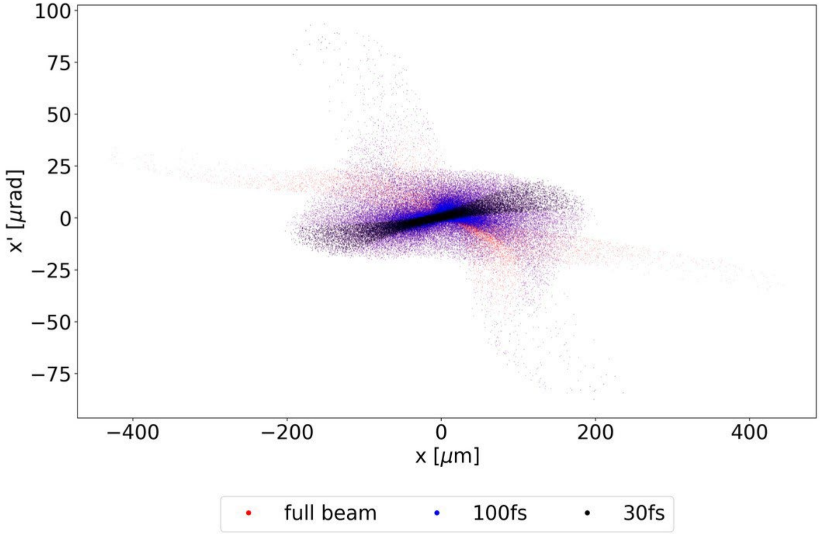
Arcs Vs Chicanes for 100 fs FWHM - WIP

Science and

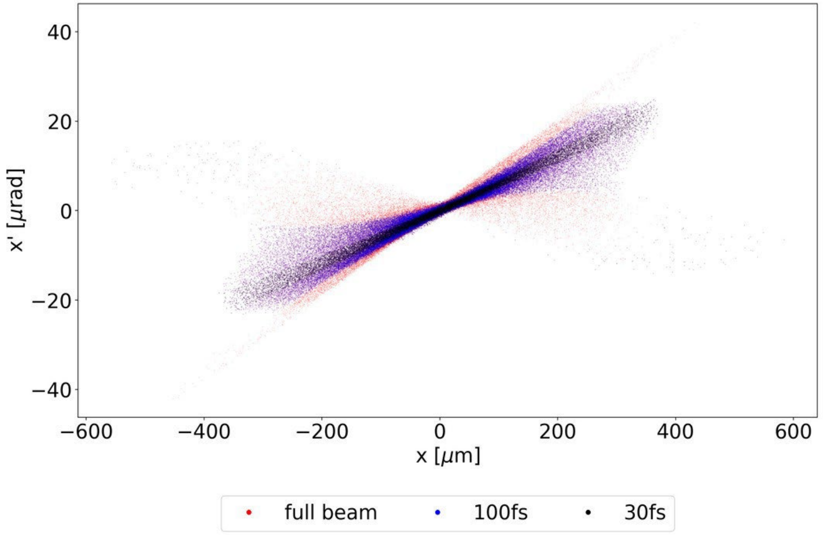
Arc



4-bend



5-bend

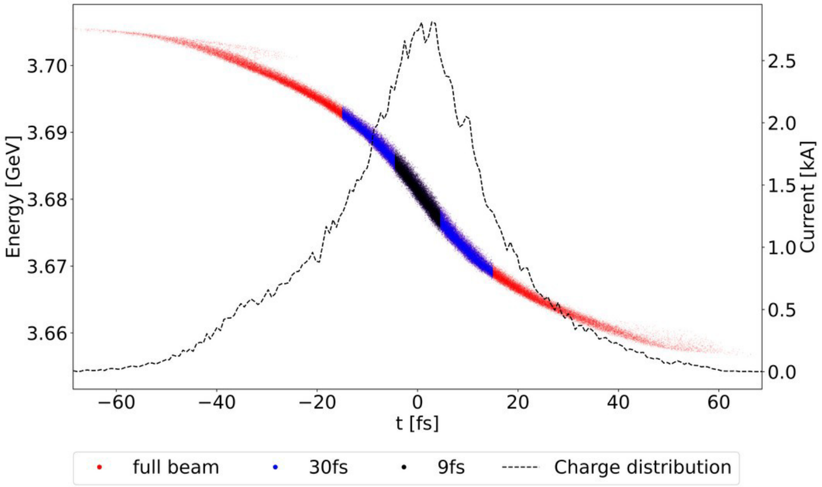


	Arc			4-Bend			5-Bend		
Δt [fs]	Full	100	30	Full	100	30	Full	100	30
ε_{nx} [mm mrad]	4.2	1.87	0.76	3.93	3.26	1.66	3.32	2.38	0.73
$\Delta\varepsilon_{nx,csr}$ [%]	0.34	2.57	4.46	3.15	-1.75	-10.27	-13.88	-23.35	-11.96

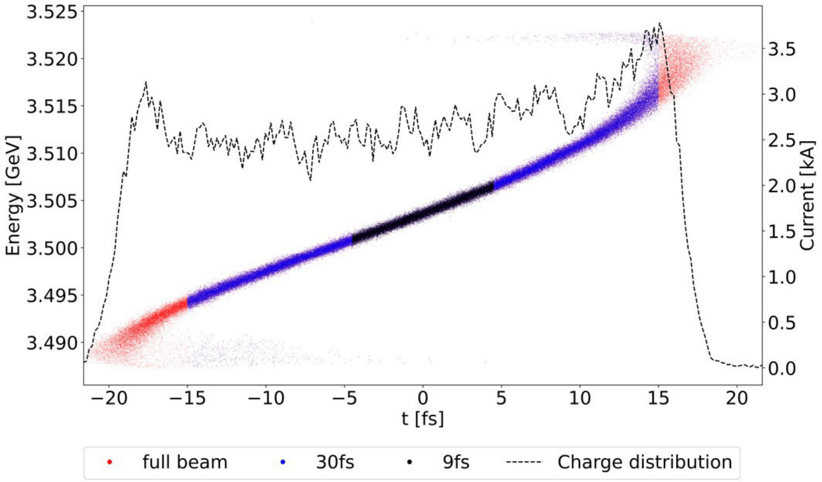
- Mean energy 170 MeV higher in arc compression compared to chicanes. Energy spread for 100fs slice is comparable in all schemes (ΔE = 0.6%). BUT – is this fair? Final compression in most chicane schemes BEFORE final linac – WIP
- ε quoted is with CSR on. $\Delta\varepsilon$ [%] is the change that we see on switching CSR on / off – most negative for 5-bend so it does do what it claims.
- This is using existing MAX-IV photogun – will repeat comparison with a higher brightness injector - WIP

Arcs Vs Chicanes for 30 fs FWHM - WIP

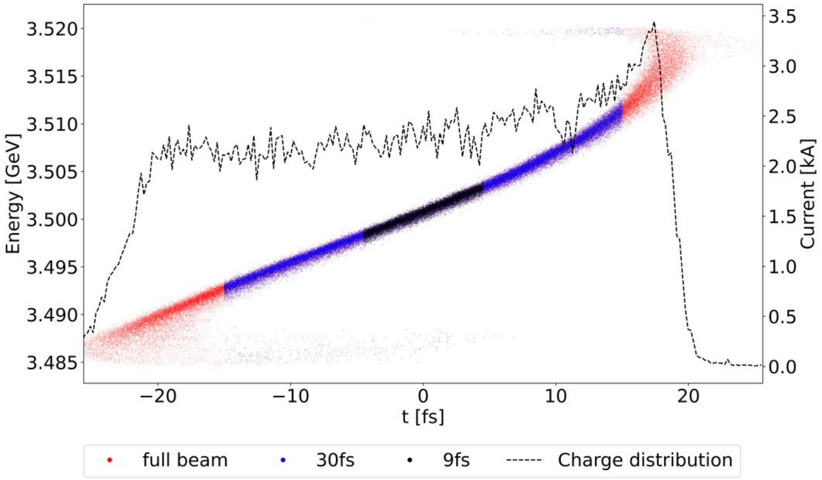
Arc



4-bend

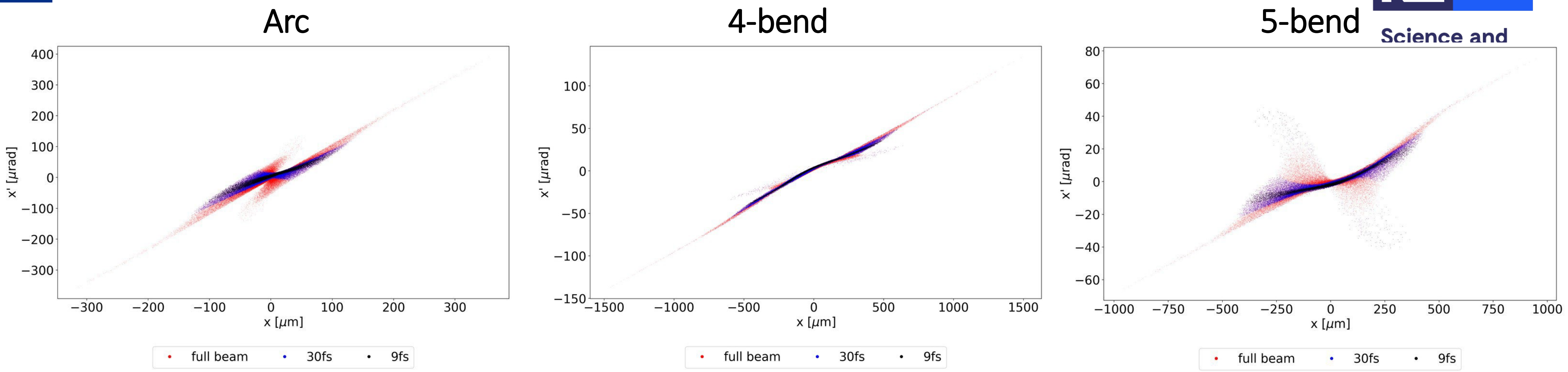


5-bend



	Arc			4-Bend			5-Bend		
Δt [fs]	Full	30	9	Full	30	9	Full	30	9
Energy [GeV]	3.68	n/a	n/a	3.50	n/a	n/a	3.50	n/a	n/a
Charge [pC]	100.00	62.37	23.70	100.00	80.77	23.27	100.00	69.78	20.56
ΔE [GeV]	0.046	0.024	0.011	0.034	0.032	0.006	0.034	0.024	0.006
$\Delta(\Delta E)_{csr}$ [%]	0.92	9.04	20.94	-0.45	15.65	-3.39	-1.33	-5.16	-64.79

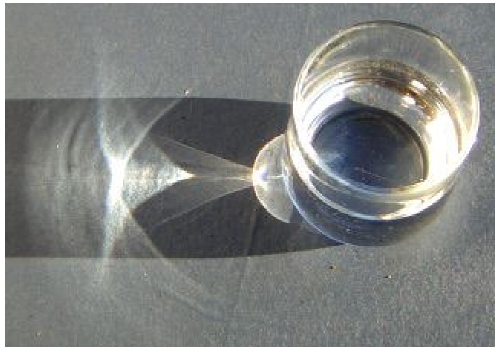
Arcs Vs Chicanes for 30 fs FWHM - WIP



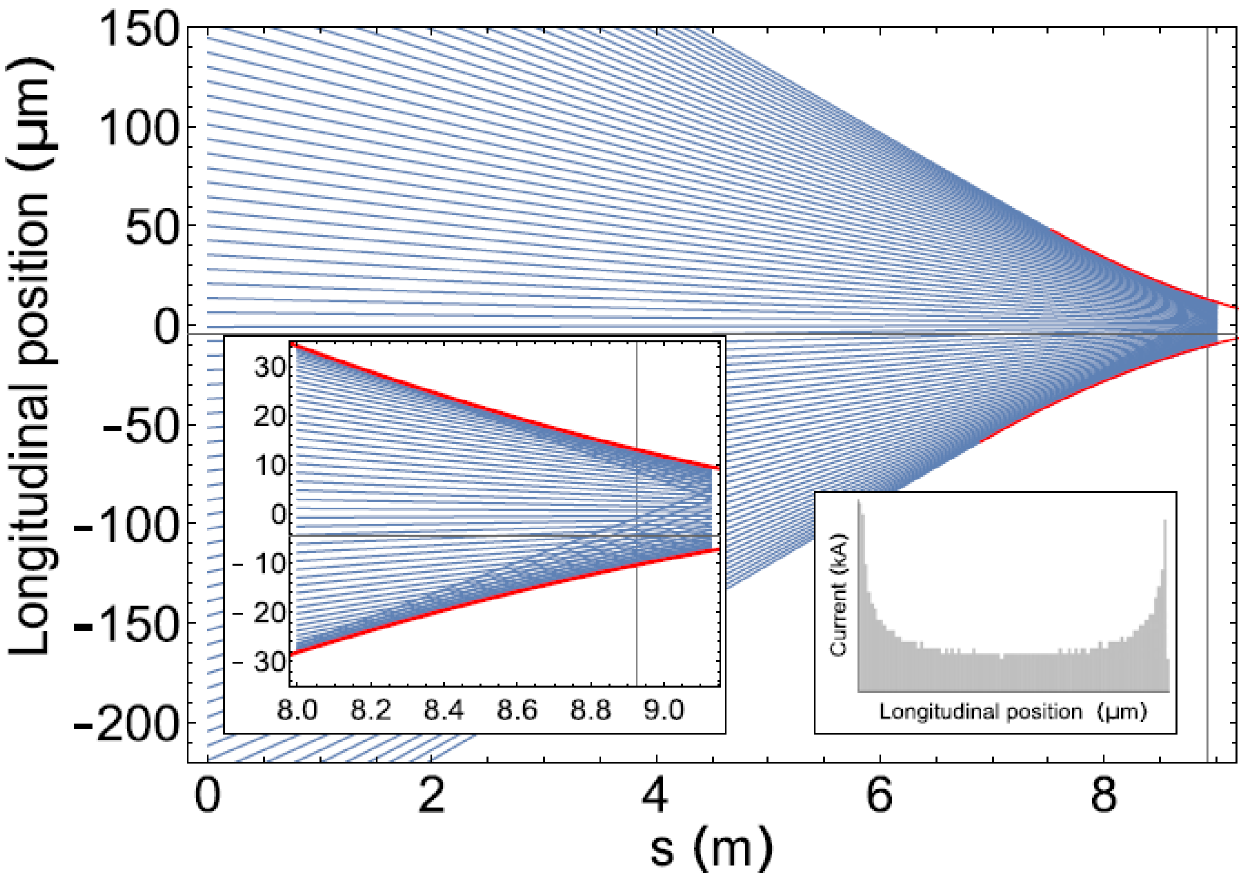
	Arc			4-Bend			5-Bend		
Δt [fs]	Full	30	9	Full	30	9	Full	30	9
ε_{nx} [mm mrad]	4.17	1.96	0.89	3.70	2.86	2.52	5.03	3.59	3.53
$\Delta\varepsilon_{nx,csr}$ [%]	2.39	14.07	19.67	-1.41	13.43	220.27	-20.33	-26.72	-4.33

- Mean energy is 180 MeV higher in arc compression scheme.
- Energy spread for 30fs slice is smallest in arc scheme (ΔE = 0.65%), slightly higher in chicane schemes (ΔE = 0.68%).
- Why is the 5-bend emittance now bigger than 4-bend? I think because kick compensation is compression dependent and requires retuning the dispersion over dipoles 4 and 5 – we didn't do this. Yet it still decreases with CSR on / off ???

Chicanes – Caustic Description



- An elegant way to describe the "folding" of tails is as Caustic formation of the electron trajectories
- Borrowed from light optics, Caustic equations describe the line of singularities in a set of arbitrary ray (in our case electron) trajectories



Blue lines are electron trajectories on passage through a 4-dipole chicane. The caustic equation is the red lines – defined by:

$$\tilde{z}(z_i) = z_i - \frac{\delta(z_i)}{\delta'(z_i)} - T_{566}\delta^2(z_i) - 2U_{5666}\delta^3(z_i)$$

$$\tilde{R_{56}}(z_i) = \frac{-1}{\delta'(z_i)} - 2T_{566}\delta(z_i) - 3U_{5666}\delta^2(z_i),$$

Left inset is close-up as we exit the chicane. Right inset is the resulting double-horned current distribution

PHYSICAL REVIEW ACCELERATORS AND BEAMS **20**, 030705 (2017)

Current-horn suppression for reduced coherent-synchrotron-radiation-induced emittance growth in strong bunch compression

T. K. Charles,[1,2] D. M. Paganin,[1] A. Latina,[3] M. J. Boland,[2,4] and R. T. Dowd[1,2]
[1]*School of Physics and Astronomy, Monash University, Clayton 3800, Victoria, Australia*
[2]*Australian Synchrotron, 800 Blackburn Road, Clayton 3168, Victoria, Australia*
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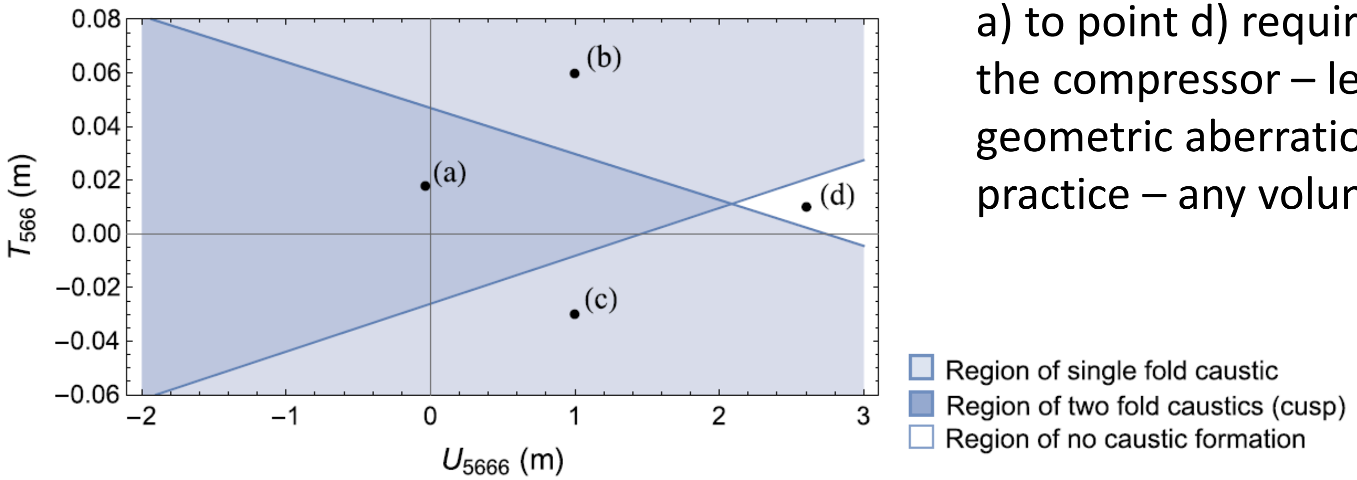
(Received 1 November 2016; published 31 March 2017)

Chicanes – Caustic Description

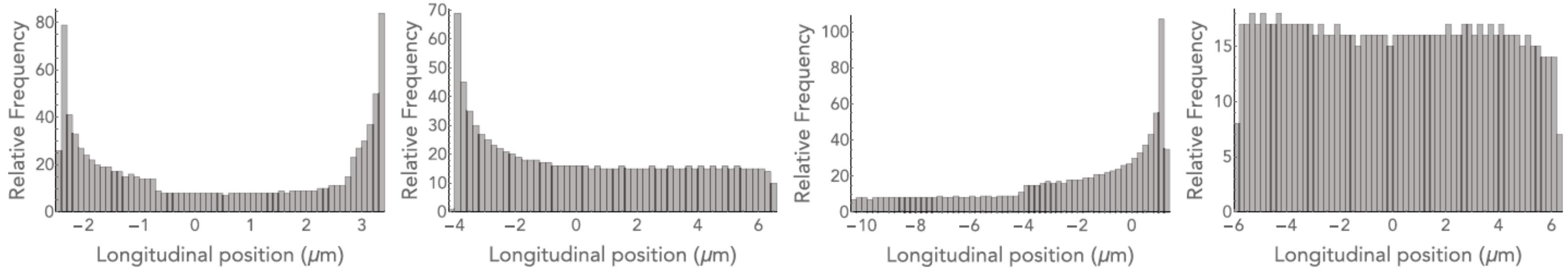
- At the exit of the chicane the condition which identifies if caustics will form is:

$$0 = R_{56}\delta' + 2T_{566}\delta'\delta + 3U_{5666}\delta'\delta^2 + 1$$

- Given a particular R56 we can use this method to find values of T566 & U5666 where two, one or zero caustics will form…



- Unfortunately, for the 4-dipole compressor, in order to move from point a) to point d) requires the insertion of a strong octupole in the centre of the compressor – leading to possible issues with chromatic and geometric aberrations. Nevertheless, my view is this should be tried in practice – any volunteers?

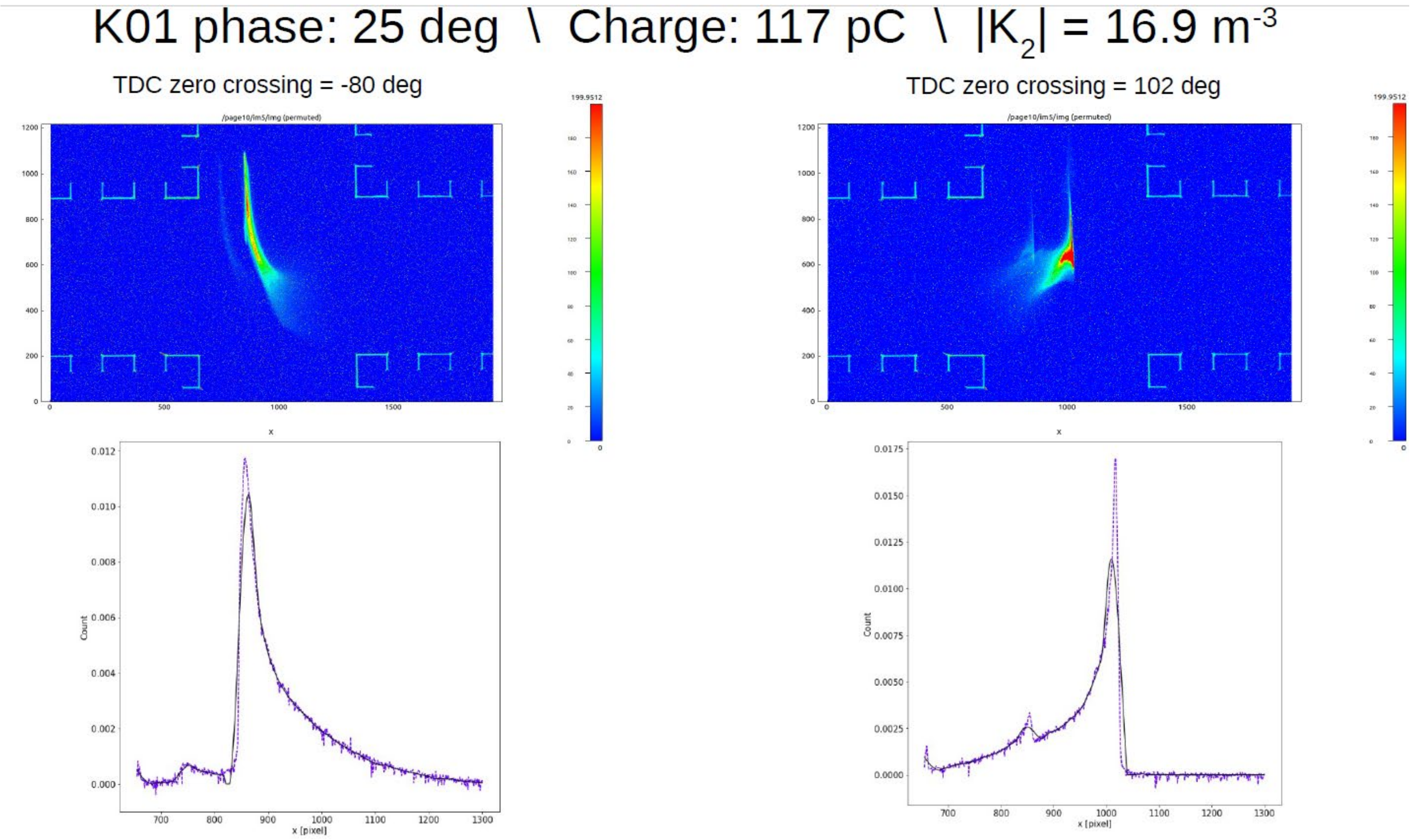


(a) (b) (c) (d)

- To me though, we've caused the cusp with harmonic RF, then "fixed" with a strong oct – surely better not to cause the illness in the first place ☺

- WIP: applying same analysis to arcs (and have taken data on MAX-IV using TDC diagnostics), we expect two-fold caustics far away in U-space, and region of no caustics in the middle.

Arcs Vs Chicanes – Caustic Description



- Work in September 2023 to show movement of caustic line as T566 scanned in MAX-IV BC1, LPS imaged using TDC diagnostics line. Data at different compression under analysis … WIP!
- Data at both TDC zero crossings not consistent with each other … working to understand … trajectory offset in TDC? – simulations indicate not. Leaking dispersion in streak plane? – resulting in a tilt – Paulo's suggestion… TBC
- Also going to independently confirm R56, T566 of each compressor using time-of-flight measurements as a check on the first and second order chirp - WIP – hence my comment yesterday… I think all facilities should do this routinely ☺

General Applicability of Arcs? – Transport of "Plasmons"

Science and Technology Facilities Council

- *"Although the motivation is to introduce flexibility into the MAX IV facility, our observations on these arc-like compressors are generic and have wide potential future applicability in situations where large energy spread beams must be longitudinally manipulated. In particular, any laser or plasma wakefield generated beam would benefit from the deployment of the following proposed schemes for transport and conditioning. Additionally, the schemes hereby proposed are particularly suited to adoption in the rapidly developing field of electron diffraction facilities"*

– Me, PRAB 23 (100701) 2020

- If this assertion is correct, arcs should be better whenever CSR dominates… however crazy the parameter regime is! … recent publication from nanoWA collaboration agrees…
- [Plasmons = quantised version of classical plasma oscillations in conduction band electrons in metallic lattices]

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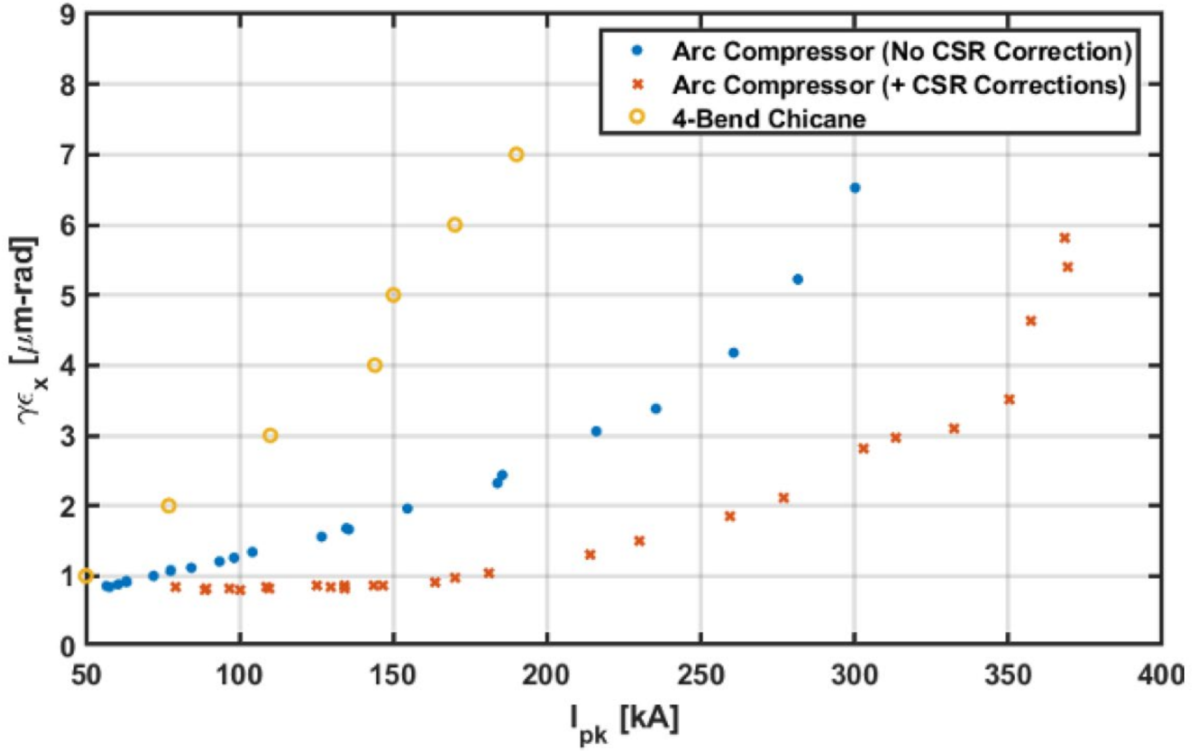
SNOWMASS'2021 ACCELERATOR FRONTIER

PetaVolts per meter Plasmonics: introducing extreme nanoscience as a route towards scientific frontiers

nano^{2}WA collaboration

Aakash A. Sahai,[a,*] Mark Golkowski,[a] Stephen Gedney,[a] Thomas Katsouleas,[b] Gerard Andonian,[c] Glen White,[d] Joachim Stohr,[d] Patric Muggli,[e] Daniele Filippetto,[f] Frank Zimmermann,[g] Toshiki Tajima,[h] Gerard Mourou[i] and Javier Resta-Lopez[j]



Bunch Compressors for XFELs – Chicanes or Arcs?

Case Study of Arcs – The MAX-IV Linac Bunch Compressors

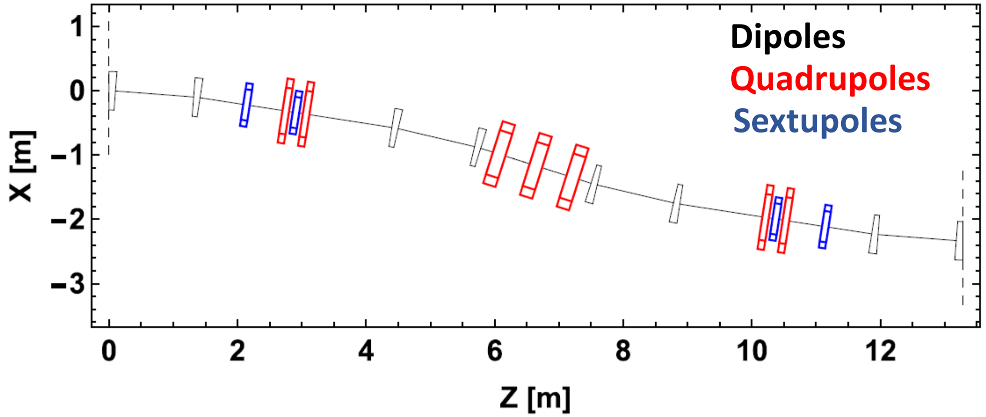
Comparing the MAX-IV BCs to Chicane Equivalents

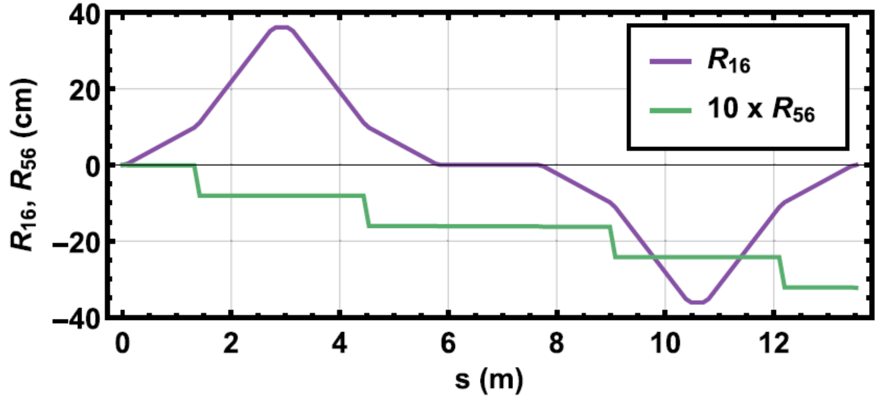
Upgrading the MAX-IV BCs from Fixed to Variable R_{56}

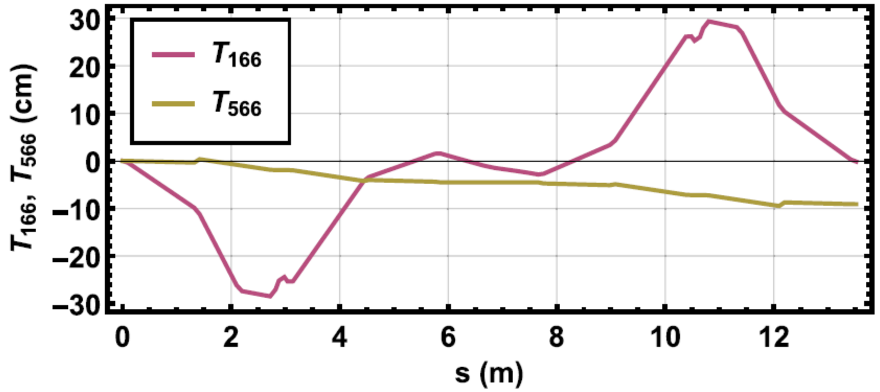
Conclusions – Preserving even higher brightness in a future UK-XFEL

Variable R56 Arc Compressors for MAX-IV – How?

- MAX-IV bunch compressors like most (all?) arc systems have fixed R56! So compression only achievable using linac phase – ok for the SPF, but not to drive an FEL … to get necessary flexibility must enable R56 variability
- Sara showed existing compressor, here it is again: BC1 = 32 mm @ 260 MeV , BC2 = 26 mm @ 3 GeV. We show BC1…

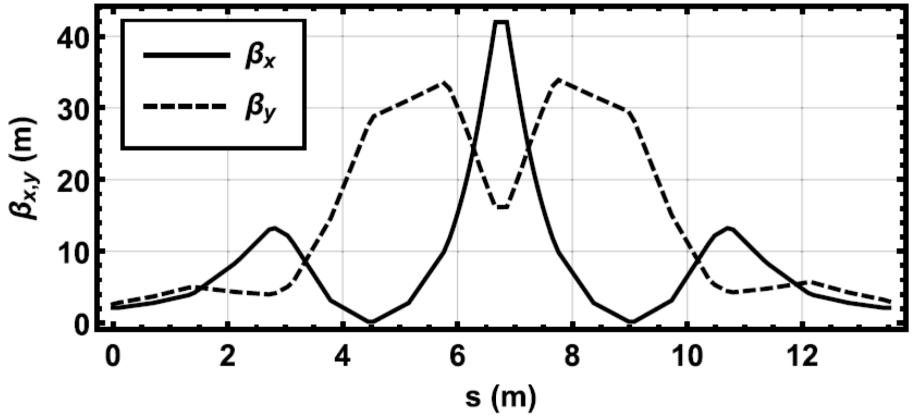






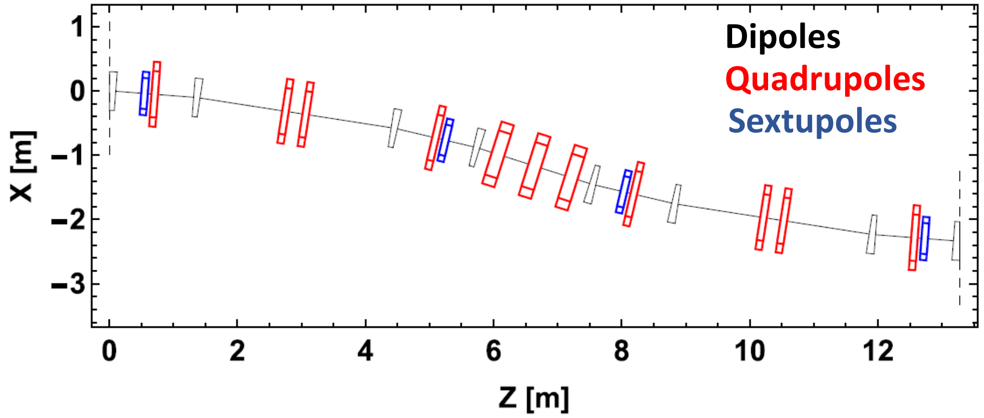
- How best should we make MAX-IV bunch compressors variable R56?

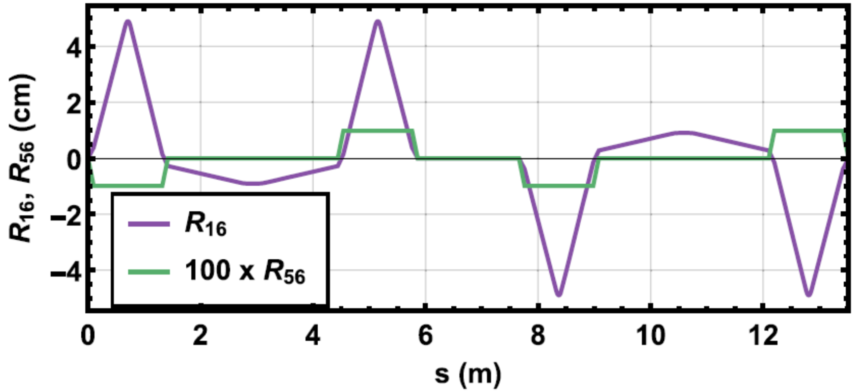
- It should be reducible to the existing scheme
- It should remain transparent to ring injection
- It should be variable at least through to isochronicity
- It should be as simple as possible!

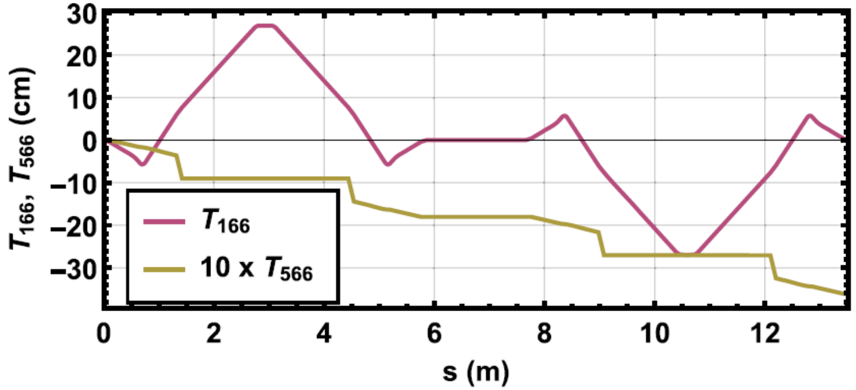


Additional Quadrupoles for Variable R56 ☹

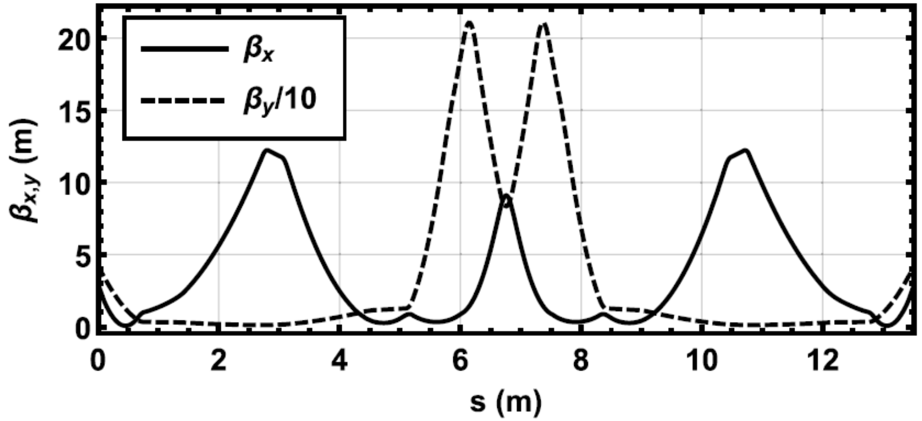
- First try: Use additional quadrupoles!
- Locate within two “half-bends” of each DBA, relocate sexts next to them. Control dispersion at second “half-bend” to produce variable R56. Close dispersion with existing DBA quads. Here we show isochronous tuning:





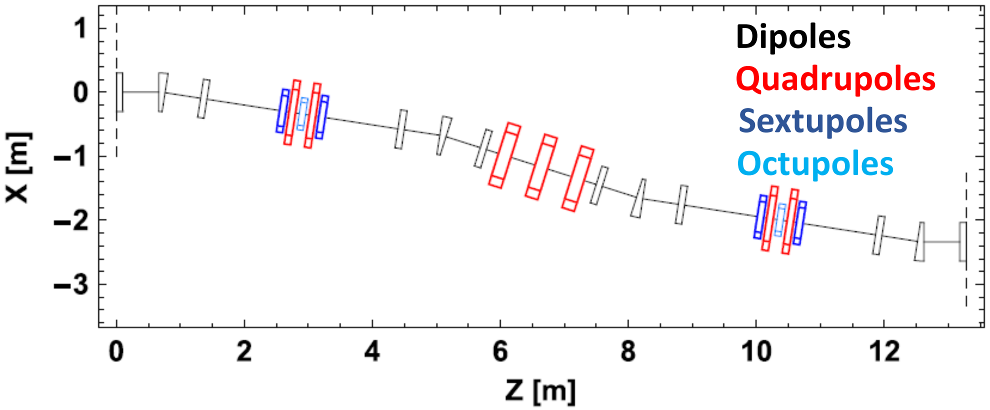


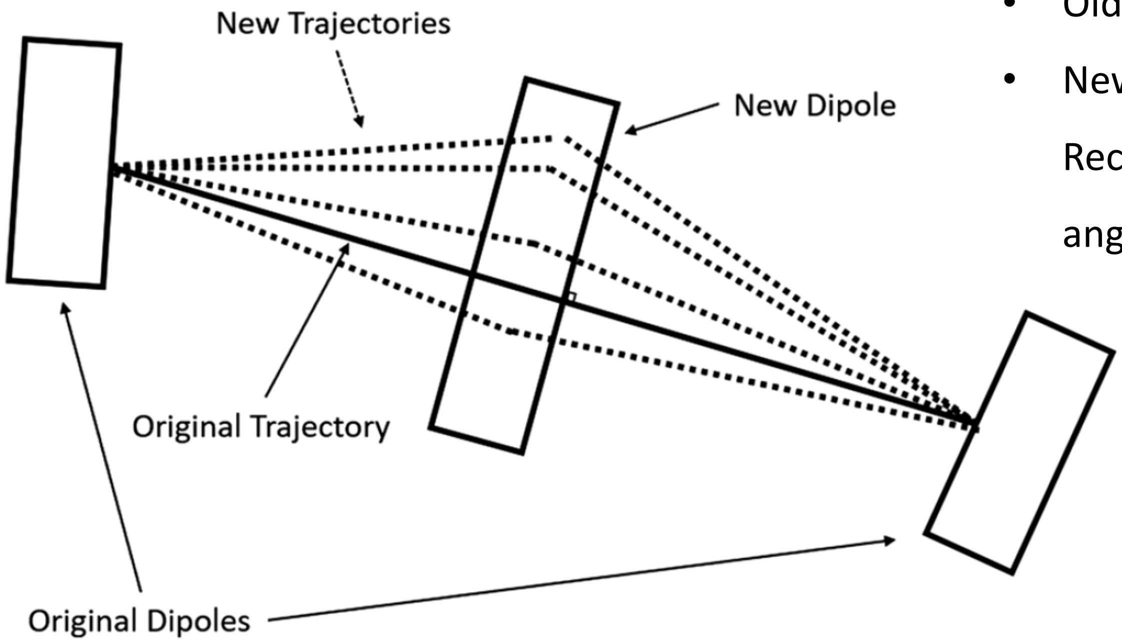
- Additional quads blow up the vertical betas → a highly chromatic solution not suitable for transporting percent level energy spreads ☹



Additional Dipoles for Variable R56 ☺

- Second try: Use additional dipoles!
- Insert a new dipole between each existing "half-bend", **alter the trajectory** through this dipole, using the dispersion here to get the R56 you want according to $R_{56} = -\int \frac{R_{16}}{\rho} ds$
- Inspired by reverse bends in storage rings





- Old dipoles keep their original finite θ/k_1 and θ/k_2
- New dipoles rectangular and have no quadrupole (to start with!).

Rectangular → $e_1 = e_2 =$ Bending Angle/2 where e_1 & e_2 are the edge angles

PHYSICAL REVIEW ACCELERATORS AND BEAMS **23**, 100701 (2020)

Arclike variable bunch compressors

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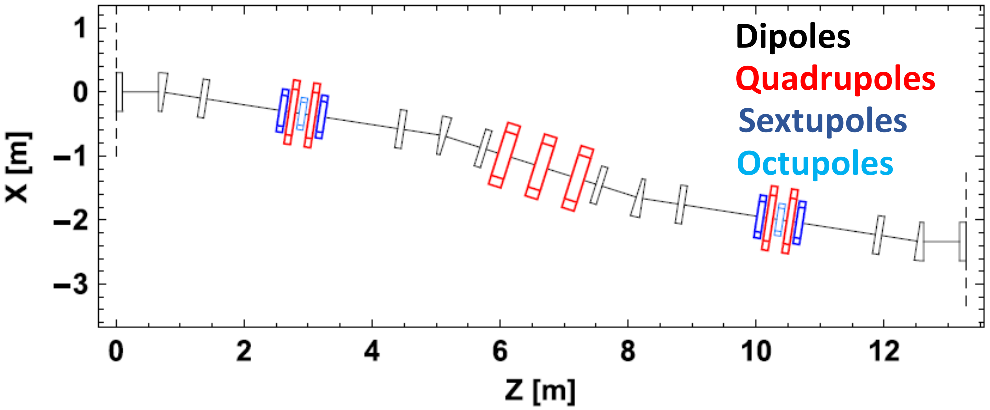
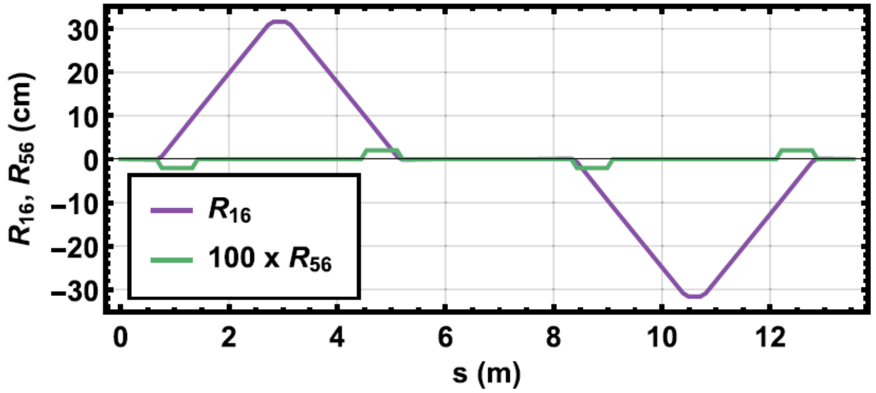
(Received 26 June 2020; accepted 28 September 2020; published 13 October 2020)

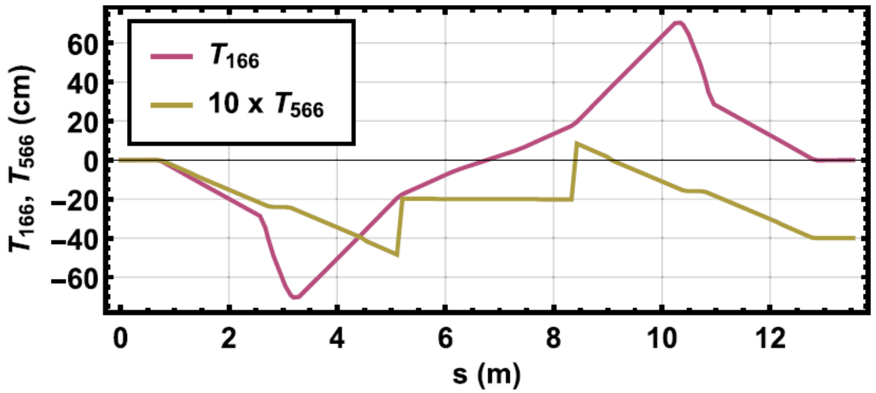
Additional Dipoles for Variable R56 ☺

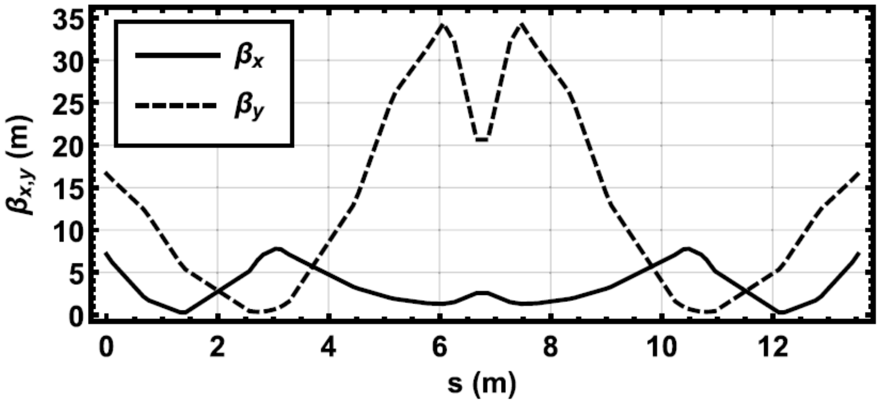
- Second try: Use additional dipoles!
- Insert a new dipole between each existing "half-bend", **alter the trajectory** through this dipole, using the dispersion here to get the R56 you want according to $R_{56} = -\int \frac{R_{16}}{\rho} ds$
- Again, we show the isochronous tuning





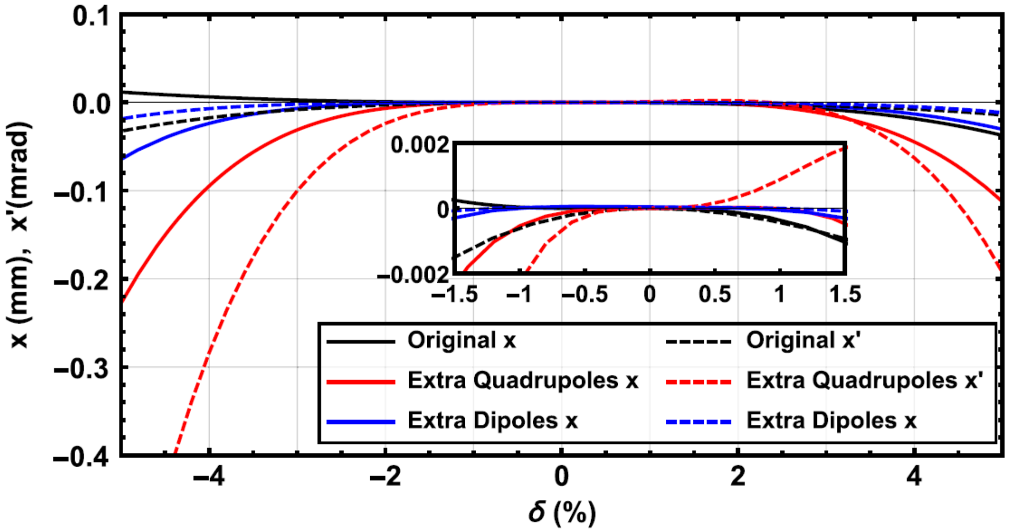
- Only small correction to dispersion function of existing compressors is made, just enough to accumulate R56 to the desired value – "gently does it" ☺
- Due to focusing from additional dipole edges, at isochronous tuning shown this system is actually **less chromatic** than existing compressors, allowing easy correction to higher order – third shown here (best to move sexts slightly)

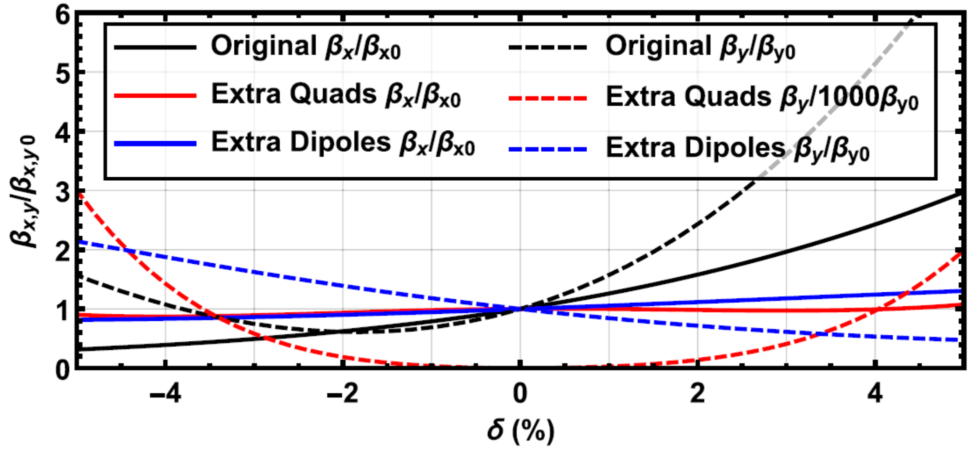




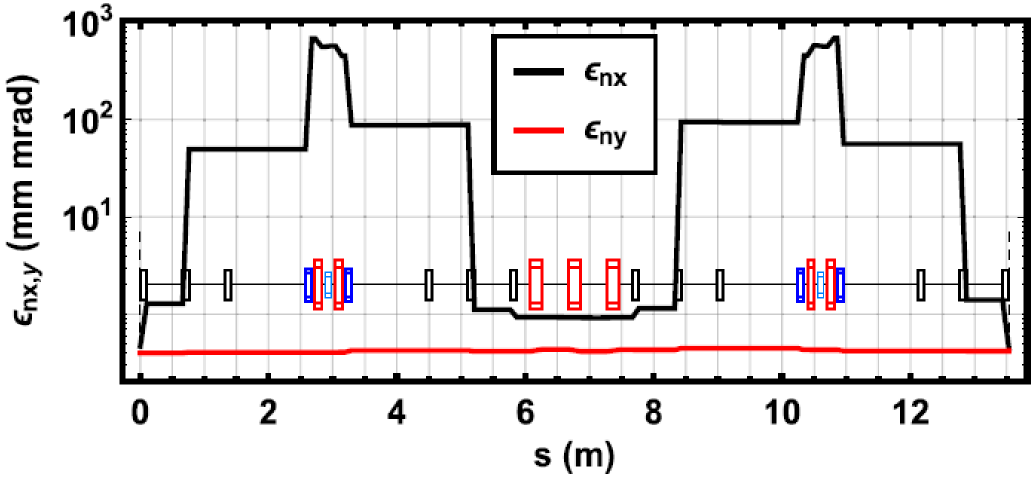
Additional Dipoles Vs Additional Quadrupoles

- Comparing the momentum acceptance (top) and chromatic dependence of beta (bottom) shows the difference

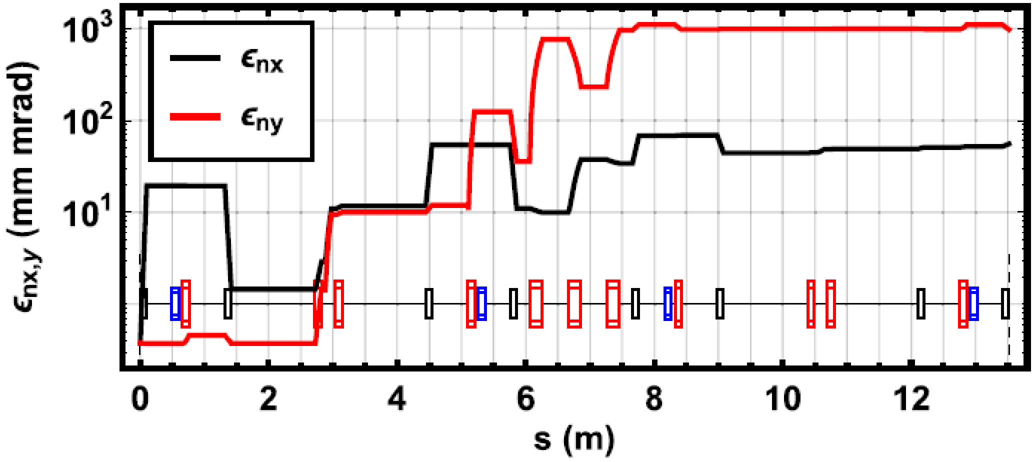




- Tracking through the isochronous systems confirms no emittance growth in the additional dipole case (top) vs additional quads (bottom) – dispersive contribs. not subtracted



(a)



Additional Dipoles for Variable R56 – Further Work

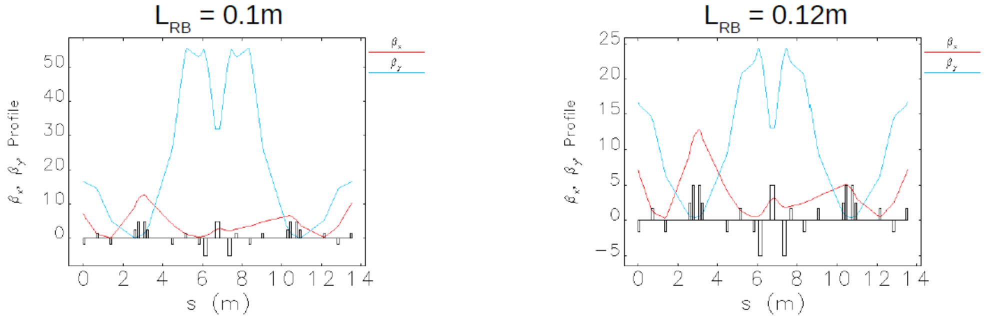
- R56 is variable in our existing design from the original +32 mm continuously down, through isochronicity, to –18 mm

Sara asks for more!!! To make -32 mm (i.e. turn the arc into a "chicane"). This is too much – requires us to make the additional dipole graded gradient to control beta_y and increase its length, and we lose linearisation control… going to try variational bends = make a problem for the magnet designer, not the accelerator physicist ☺. Alternatively we ask Sara to moderate her demands!

Variable BC1

In BC1 the RB dipole length is 0.1m – B_{max}=1.75T – max chicane-like R56 achievable is 18mm. Increasing the RB length to 0.12m allows us to reach chicane-like R56 = 32mm for the same dipole field.

- No change to first-, second- or third-order horizontal dispersion.
- No change in emittance due to CSR.
- T566 increases from 8.5cm to 10.5cm with horizontal dispersion closed.



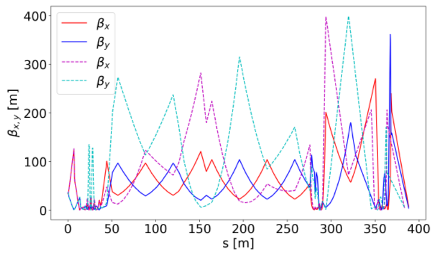
Variable Bunch Compressor – SXL

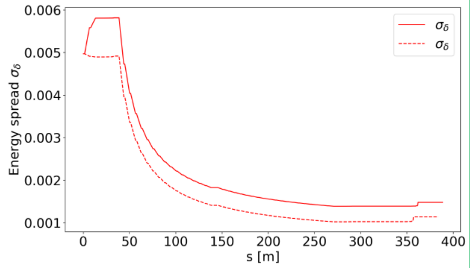
Existing

Location	ϕ_{RF} [°]	R_{56} [cm]	T_{566} [cm]	U_{5666} [cm]
Linac 1	24	n/a	n/a	n/a
BC1	n/a	3.23	10.73	-29.11
Linac 2	21.5	n/a	n/a	n/a
BC2	n/a	2.60	-8.60	87.16

Variable BC

Location	ϕ_{RF} [°]	R_{56} [cm]	T_{566} [cm]	U_{5666} [cm]
Linac 1	19	n/a	n/a	n/a
BC1	n/a	4.01	15.01	-48.20
Linac 2	19	n/a	n/a	n/a
BC2	n/a	2.60	5.99	-24.14





Elegant tracking of sxl with variable bunch compressor for case 2. Increased R56 in BC1 to 4.01cm (from 3.23cm), R56 of BC2 unchanged.
Beta functions were increased in the bunch compressors and main linac for the variable bunch compressor scheme.
Energy spread reduced due to smaller accelerating phase.

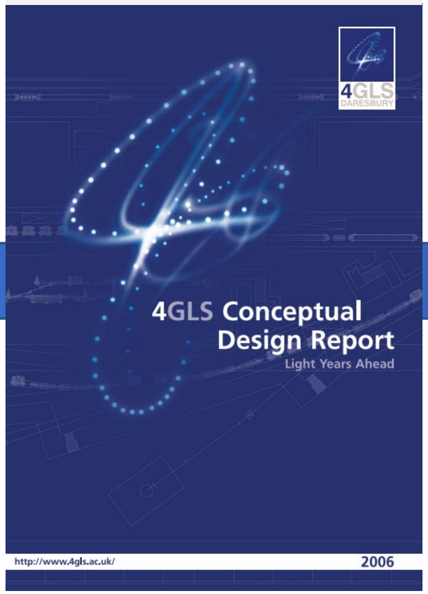
- Detailed CSR and microbunching studies at a range of compression settings – benchmarked on MAX-IV as much as possible. Sara particularly interested in setting the R56 such that the linac can operate on 19 degrees and produce the same bunch for SXL as with original compressors – this is easy ☺. Why 19 degrees? Ask Sara!

- Bunch Compressors for XFELs – Chicanes or Arcs?
- Case Study of Arcs – The MAX-IV Linac Bunch Compressors
- Comparing the MAX-IV BCs to Chicane Equivalents
- Upgrading the MAX-IV BCs from Fixed to Variable R_{56}
- Conclusions – Preserving even higher brightness in a future UK-XFEL

Science and Technology Facilities Council

Why Am I So Interested? – UK-XFEL Conceptual Design & Options Analysis Project

2006



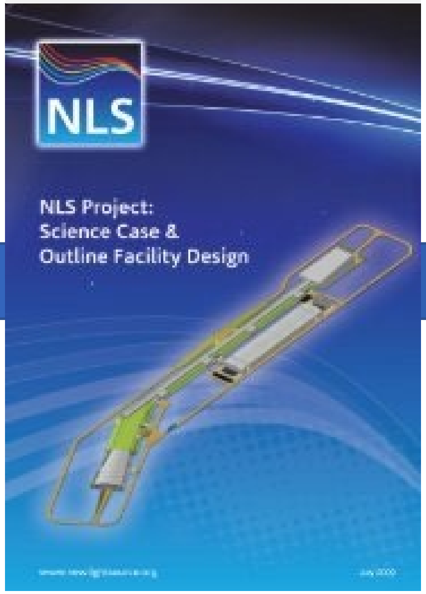
4GLS

Conceptual Design

VUV FEL,
600MeV @ 1.3GHz
XUV FEL,
950MeV @ 1kHz
+ IR FELs

Led to the ALICE ERL FEL

2010



NLS

Conceptual Design

FEL-1: 50-300 eV
FEL-2: 250-850 eV
FEL-3: 430-1000 eV
2.25 GeV, 1 kHz to 1 MHz

Led to the CLARA facility

2016

FELs

Strategic Review

Not a facility design but highlighted a SwissFEL-like option + increased international engagement

2018

European XFEL

Eu-XFEL + UK

UK becomes a member of Eu-XFEL

2020

UK XFEL

Science Case

Soft x-rays @ 1 MHz
Hard x-rays @ 1 kHz to 1 MHz

UK-XFEL CDOA Objectives

By October 2025 we will have:

- mapped out how best to deliver advanced XFEL capabilities identified in the Science Case
- explored a Conceptual Design for a unique new machine that can fulfil all required capabilities
- examined other investment options and collaborations in existing XFELs
- updated the Science Case to feed into the process and inform future decisions
- held multiple Townhall Meetings around UK engaging with the user community (like this one)
- investigated the socioeconomic impact of a next generation XFEL

- The conceptual design of a greenfield machine will involve injection proposals with ambitious brightness to drive ~20 keV FEL with ~8 GeV linac. My interpretation is we will need to work hard to preserve that brightness – hence exploring alternative (better?) ideas for compression & transport

Conclusions & Acknowledgements

- My view is arc compression schemes are generally better at preserving brightness than chicane schemes – **discuss**! (this is a workshop, so please take this talk in that spirit ☺)

- To be sure there are cons as well as pros, and I haven't proven my assertion yet, but in the context of a potential new greenfield XFEL, and for general interest, I think this is worth pursuing, and it shows promise. A proper, fair proof will necessarily need / develop our understanding of compression for FELs

- MAX-IV may upgrade their arc compressors to variable R56 as part of the SXL project – an ideal testbed for these ideas

- Thanks to the organisers of LEDS 2023 for this opportunity, and thanks to collaborators who contributed to this talk…

- Adam Dixon (Liverpool), Tessa Charles (Liverpool → Australian Light Source)

- Sara Thorin, Erik Mansten, Johan Lundquist (MAX-IV), Jonas Bjorklund Svensson (MAX-IV → DESY), Bill Kyle (MAX-IV → ISIS)

- Gustavo Perez-Segurana (Lancaster → CERN), Ian Bailey (Lancaster)