Linac4 Beam Commissioning Above 12 MeV

1.0 rf phase & amplitude

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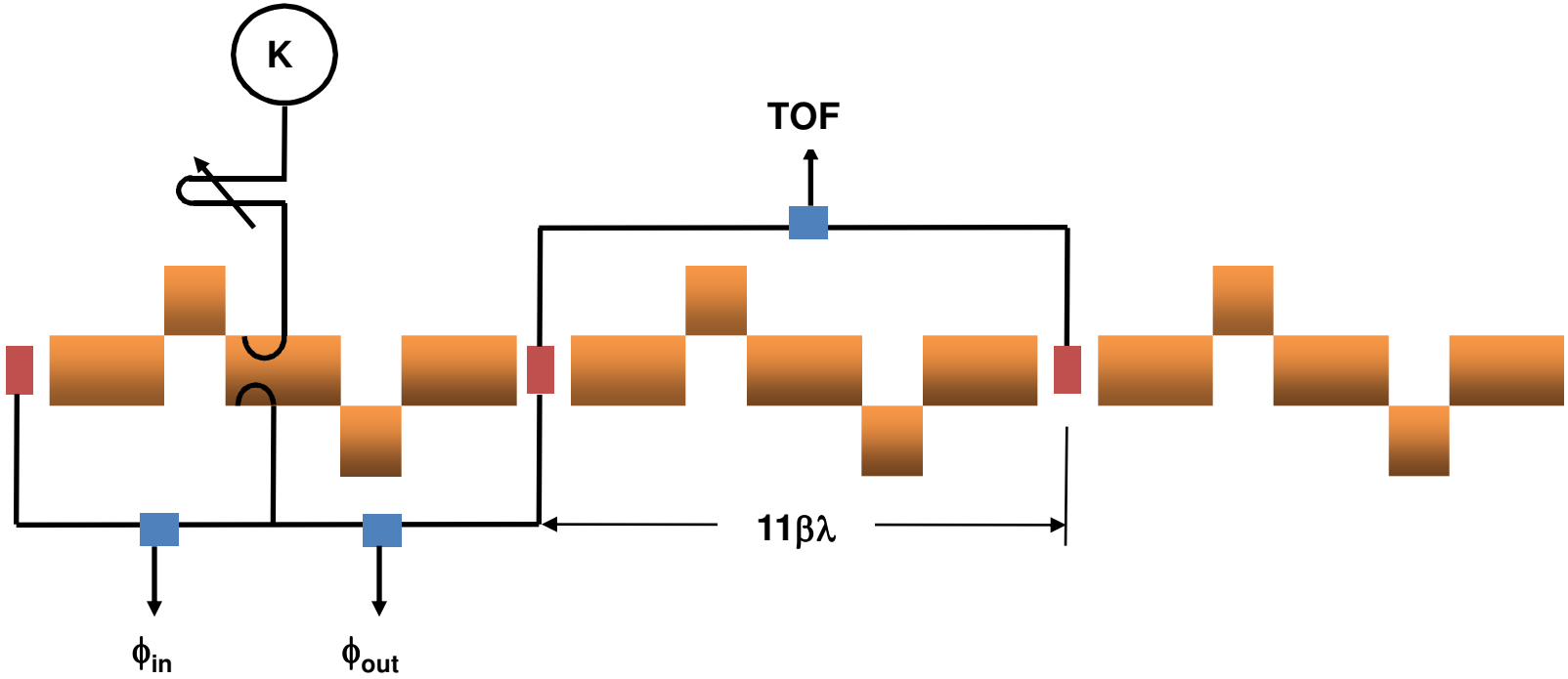
CCDTL longitudinal diagnostics

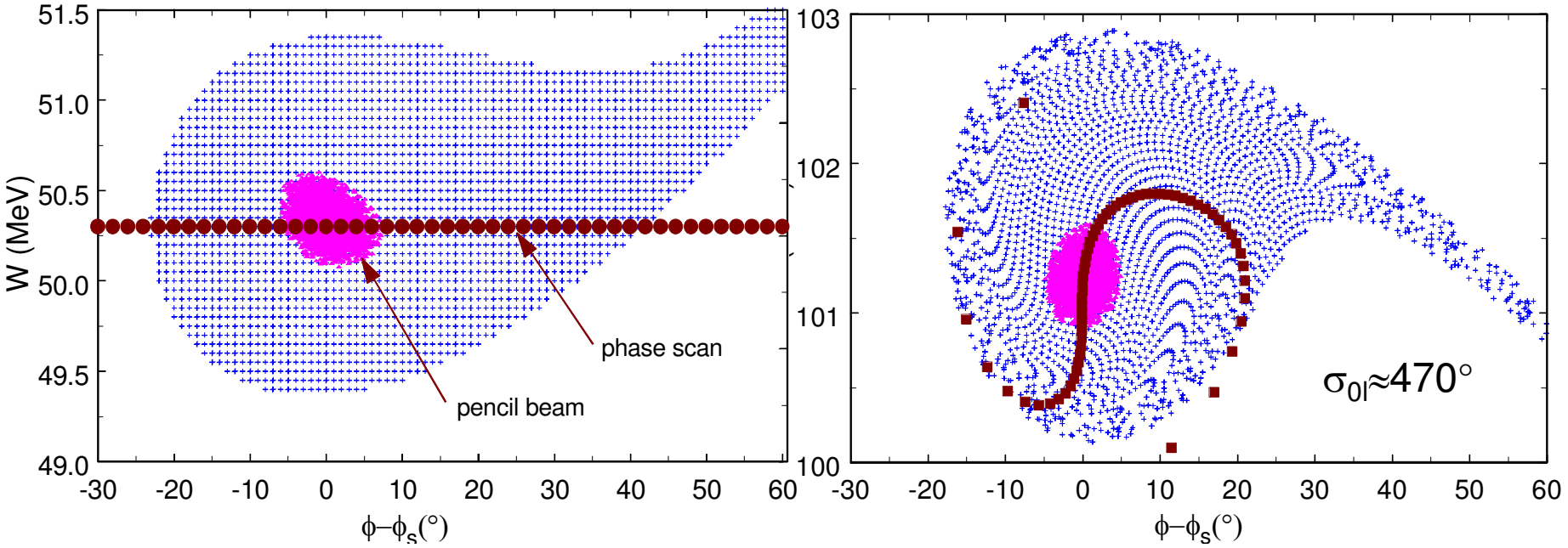


$$\frac{\Delta W}{W} = 2\frac{\Delta\beta}{\beta} = 2\sqrt{\left(\frac{\Delta L}{L}\right)^2 + \left(\frac{\Delta t}{Nt + t_{scope}}\right)^2}$$

ΔL≈1mm, Δt≈1°(352 MHz) ≈ 8 ps

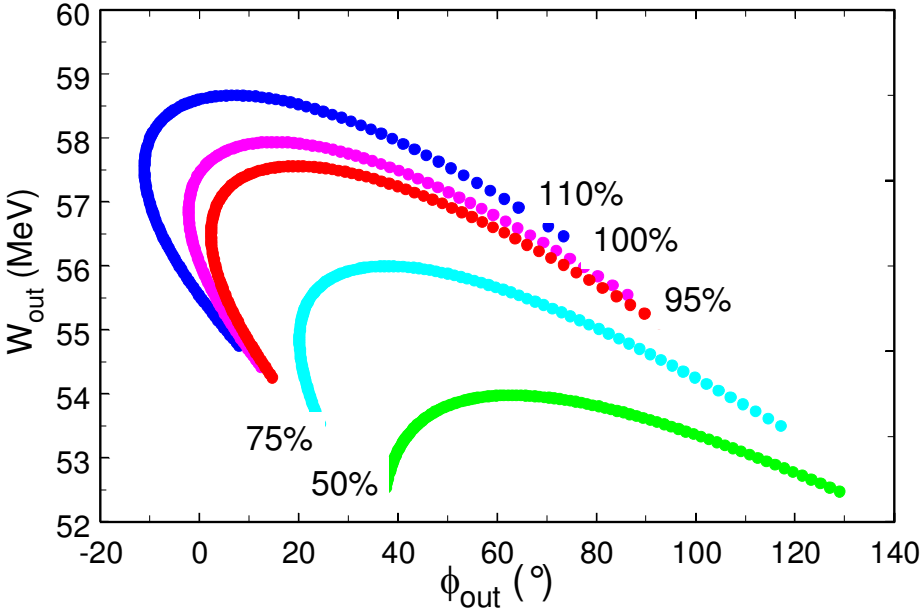
$$\frac{\Delta W}{W} \approx 1‰ \approx 50keV$$

CCDTL longitudinal acceptance



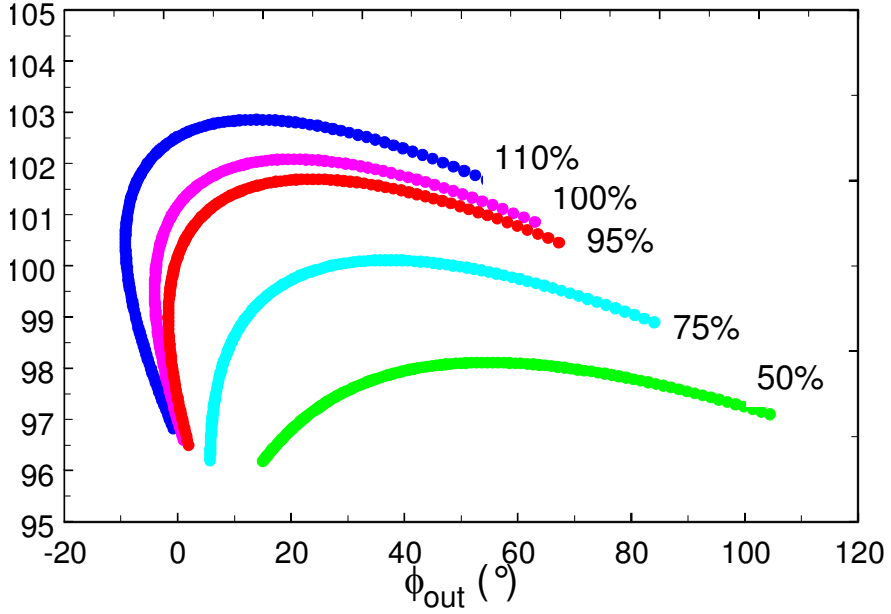
- Pencil beam
  - I≈1 mA
  - $\varepsilon_{99\%}$. ≈0.25π mm-mR
  - Δx = ±1 mm
- σ_{0l}≈67°/module

CCDTL "output" amplitude scans have no distinctive identifiable features: ϕ_{out}-W_{out}



Module 1

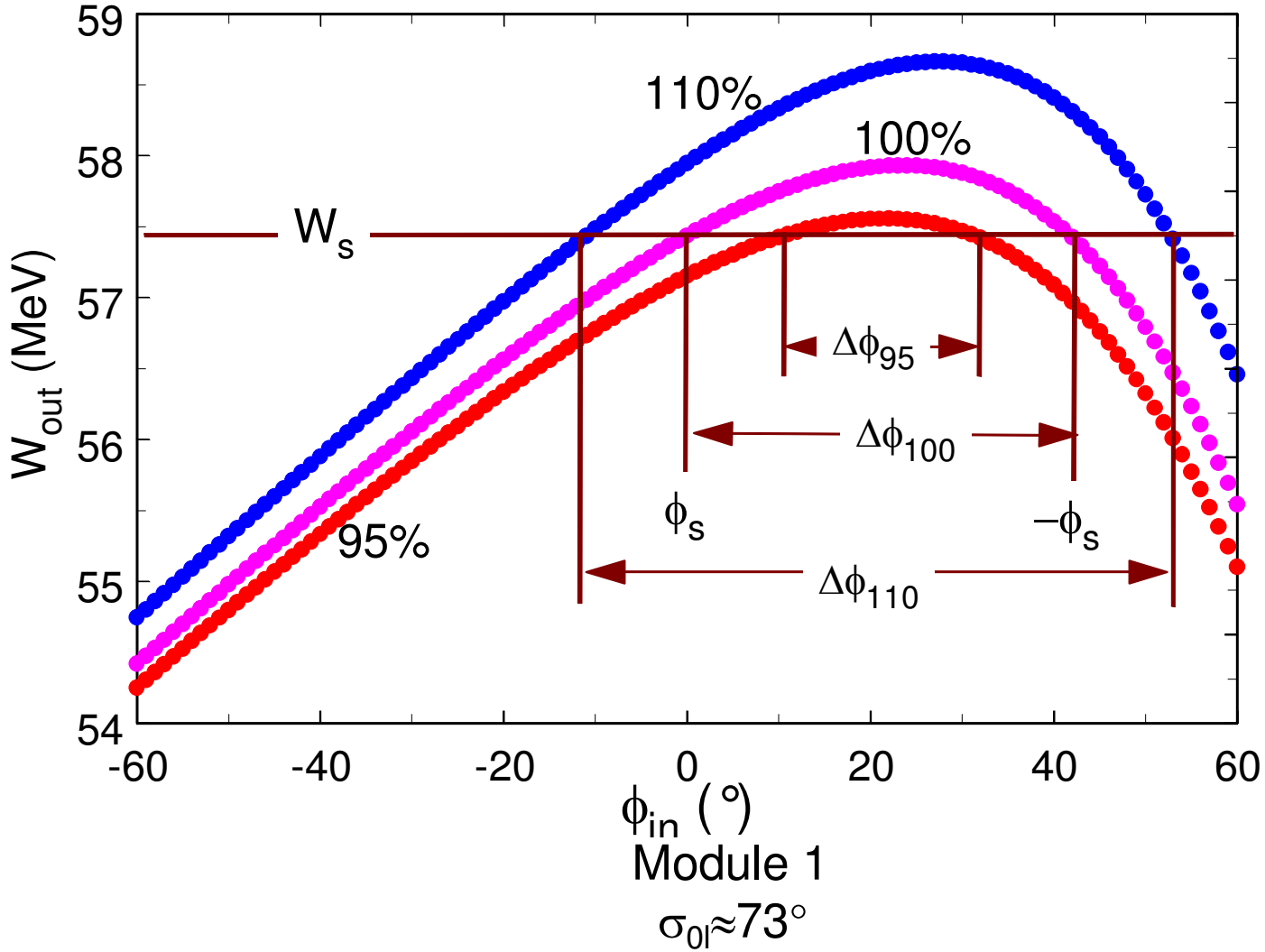
$\sigma_{0l} \approx 73°$



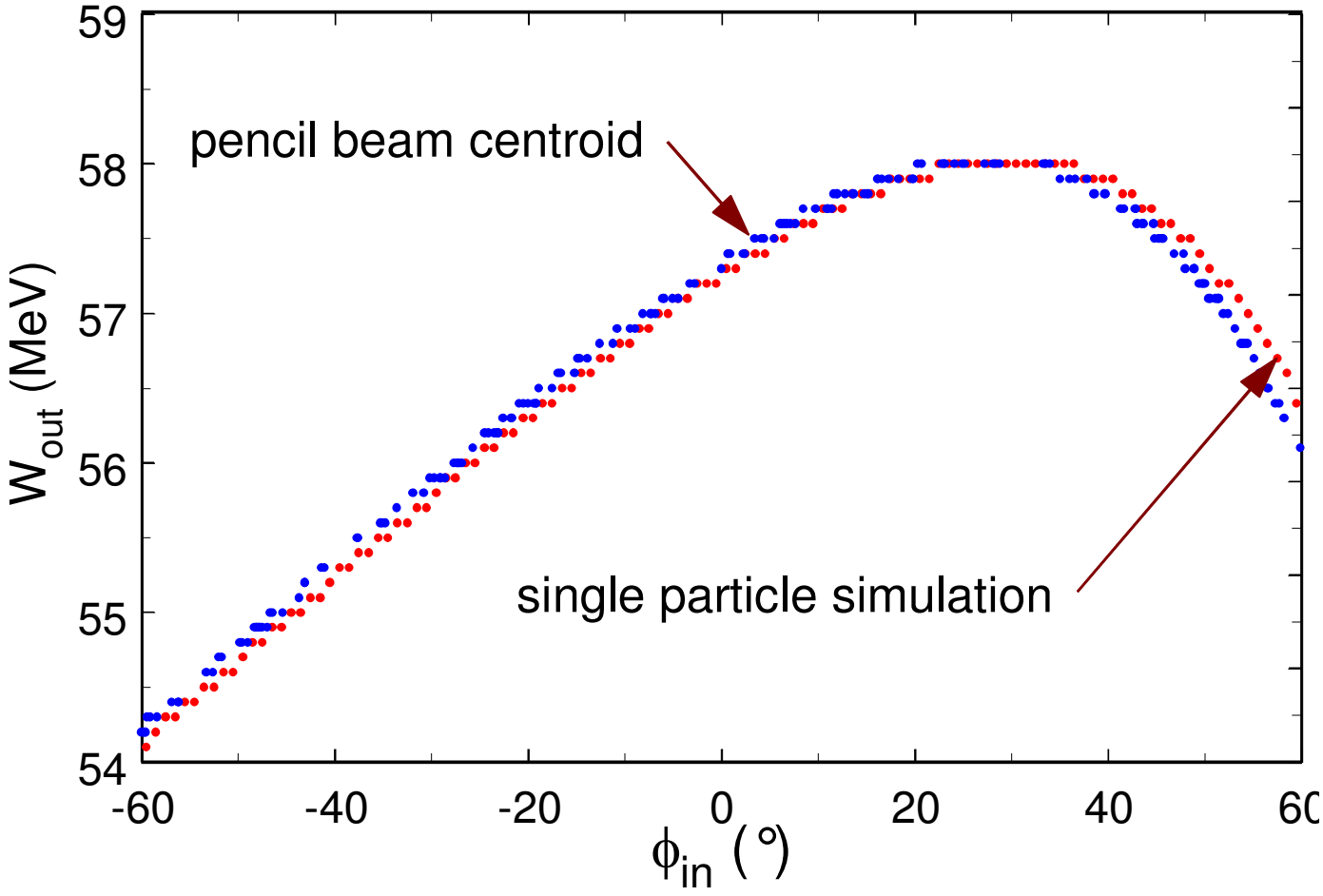
Module 7

$\sigma_{0l} \approx 61°$

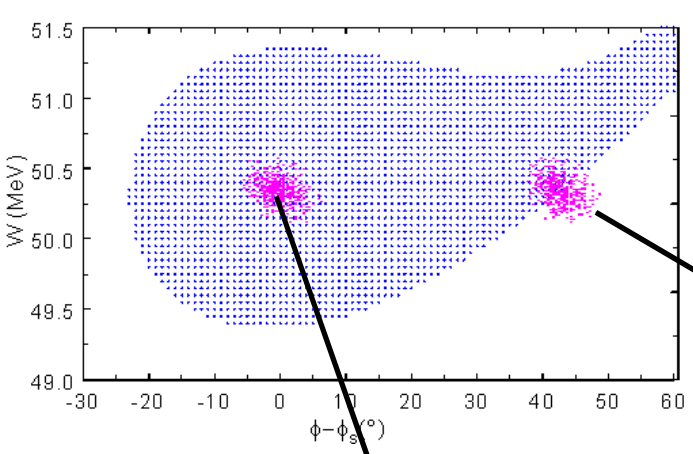
CCDTL "input" amplitude scans have distinctive peaks & phase widths : ϕ_{in}-W_{out}

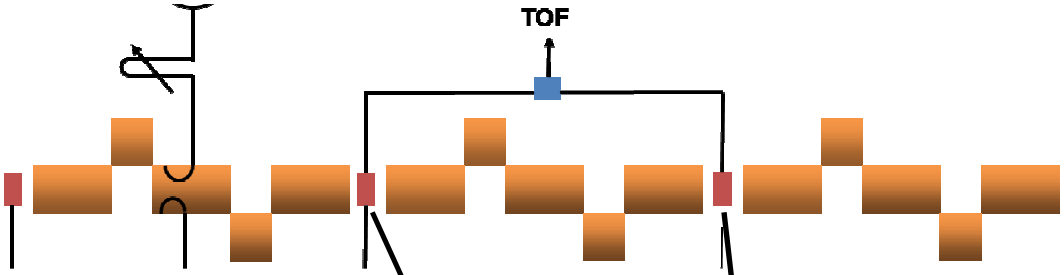


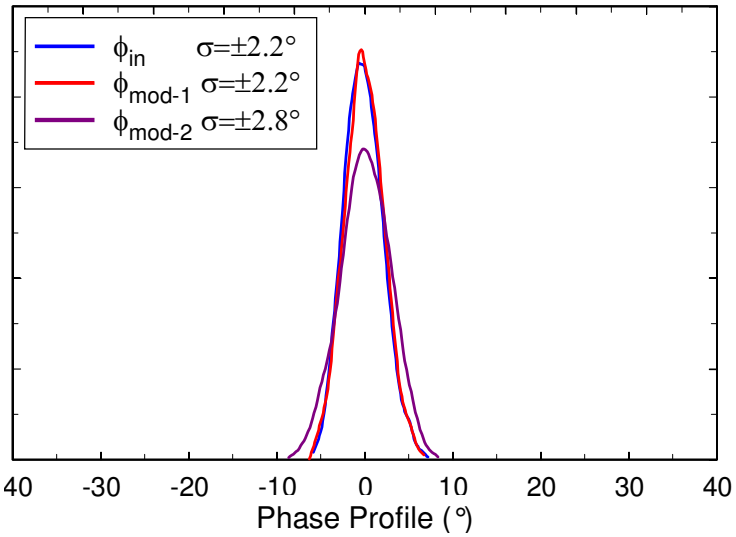
Single-particle phase scans simulate pencil-beam centroids

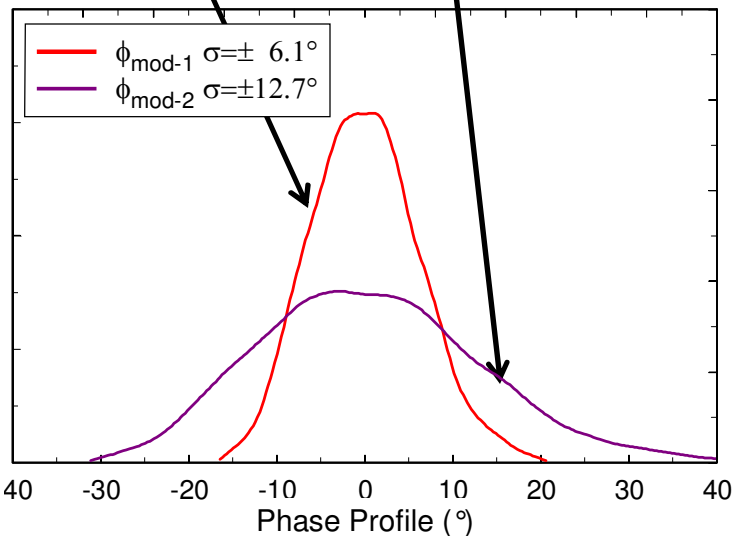


Pencil beam injected at $+\phi_s$ is only slightly debunched at 2nd pickup

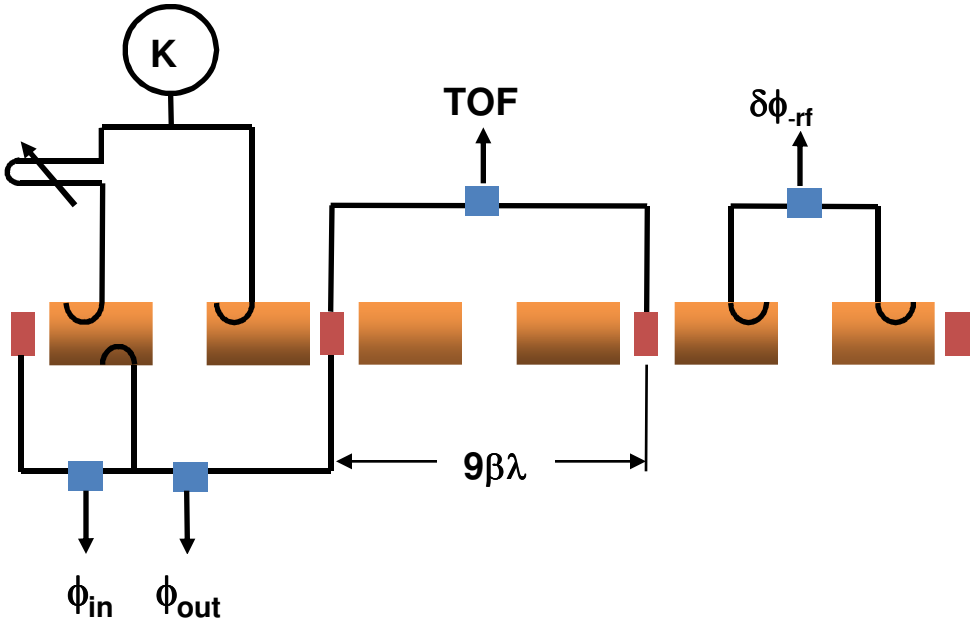








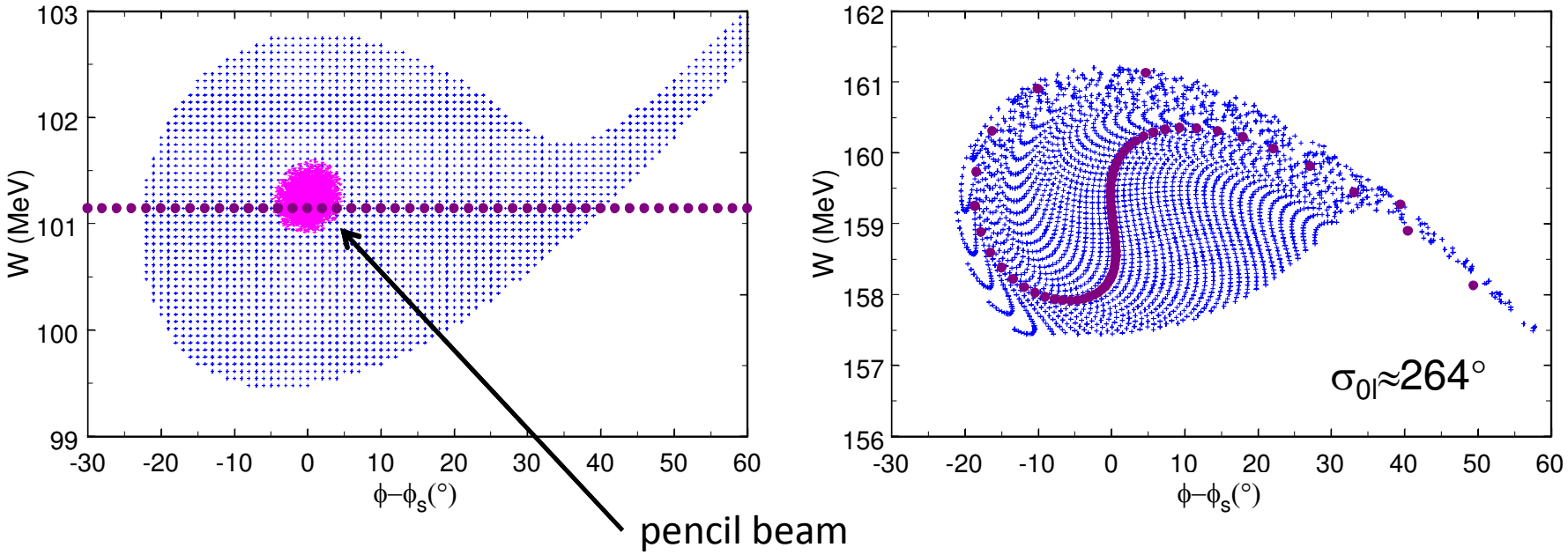
PIMS Longitudinal Diagnostics



$$\frac{\Delta W}{W} \approx 1‰ \approx 100keV$$

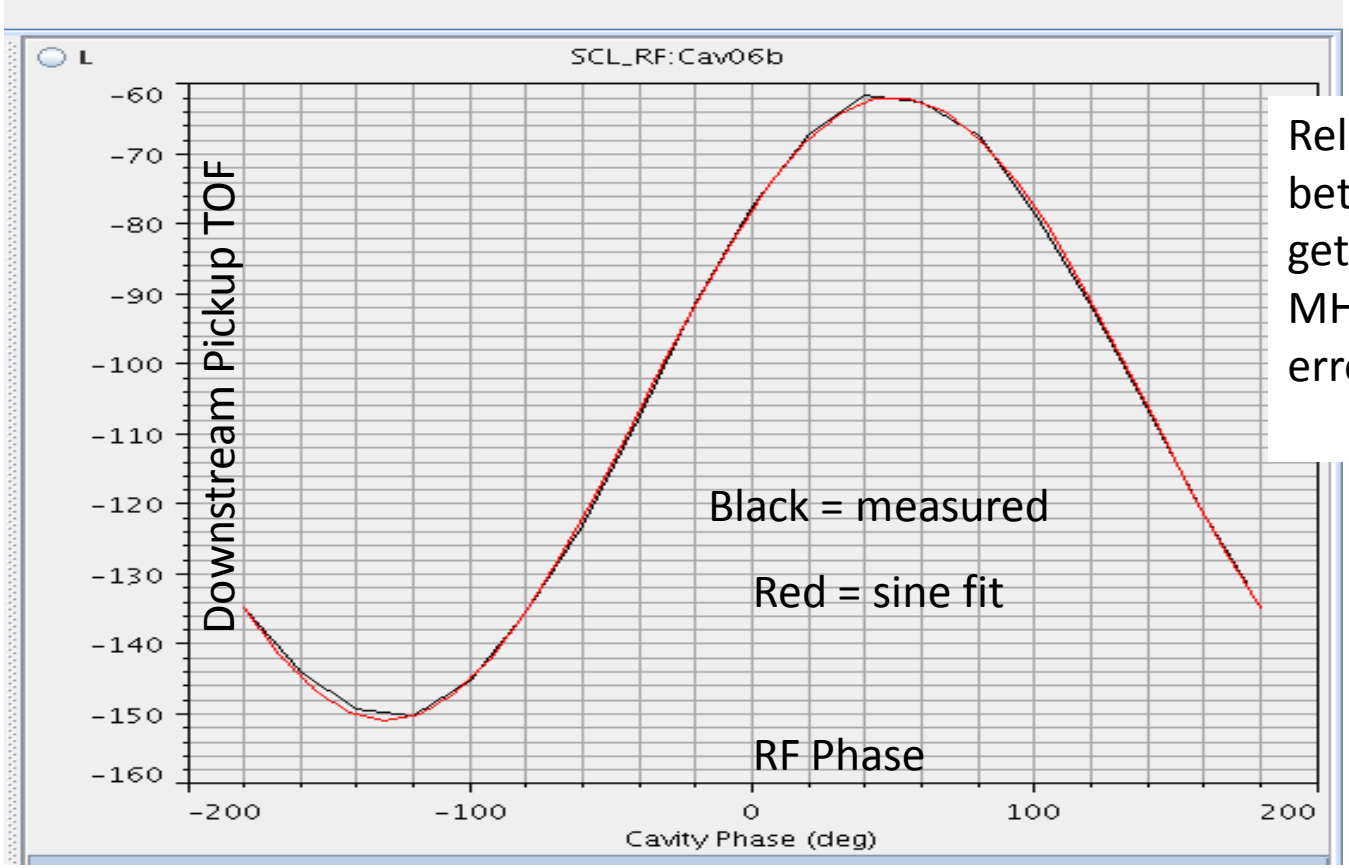
- Can modules be powered and phased independently?
- Drive modules in pairs
  - monitor/control relative phases
  - beam loading effects?

PIMS longitudinal acceptance



- $\sigma_{0l} \approx 22°$/module, 44°/pair

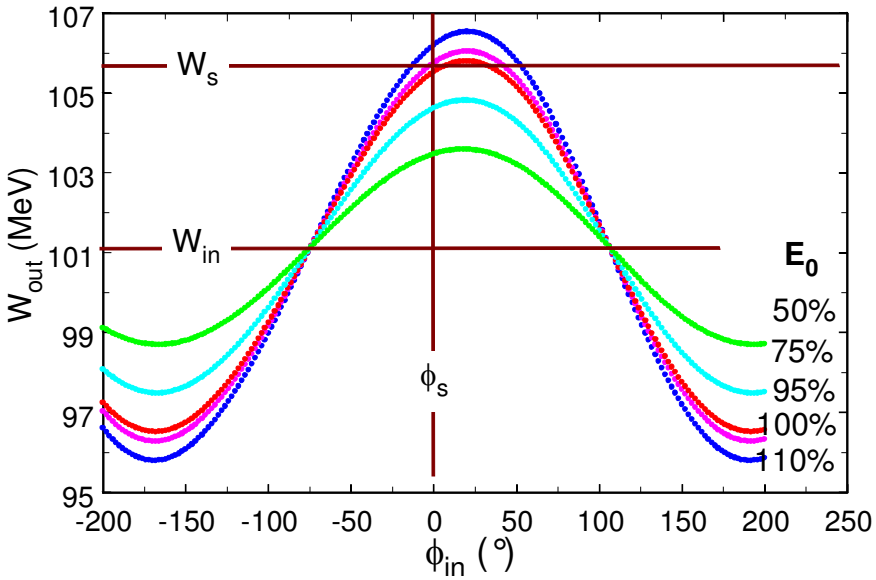
SNS uses TOF phase scans to set ϕ_s in SCL tanks, amplitude is set for maximum acceleration



Relative phase measured between 2 BPMs – Can get ~ 1 degree (805 MHz) relative phase error if you are careful

Measure the "center-of-mass" of the beam
Horizontal, vertical, and arrival time

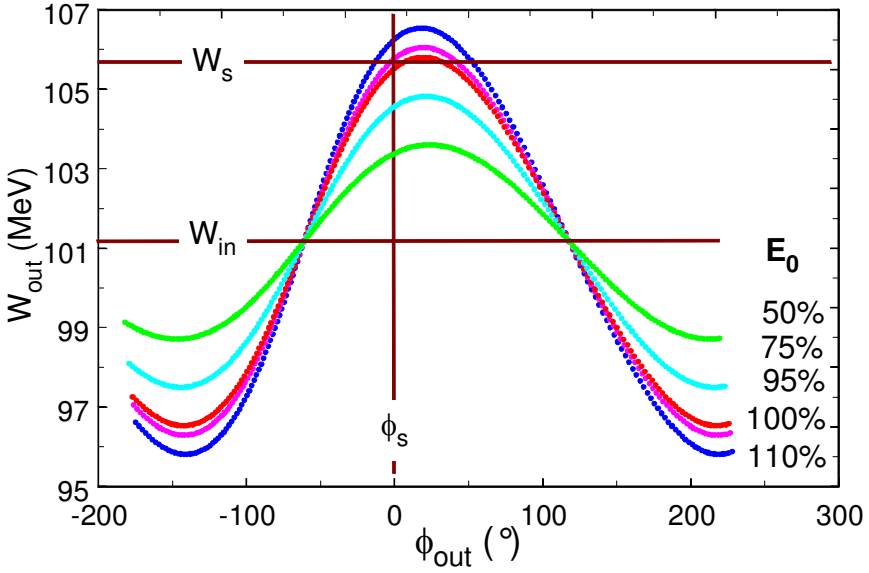
PIMS single-module amplitude scans are essentially sinusoidal



Module 1

ϕ_{in}-W_{out}

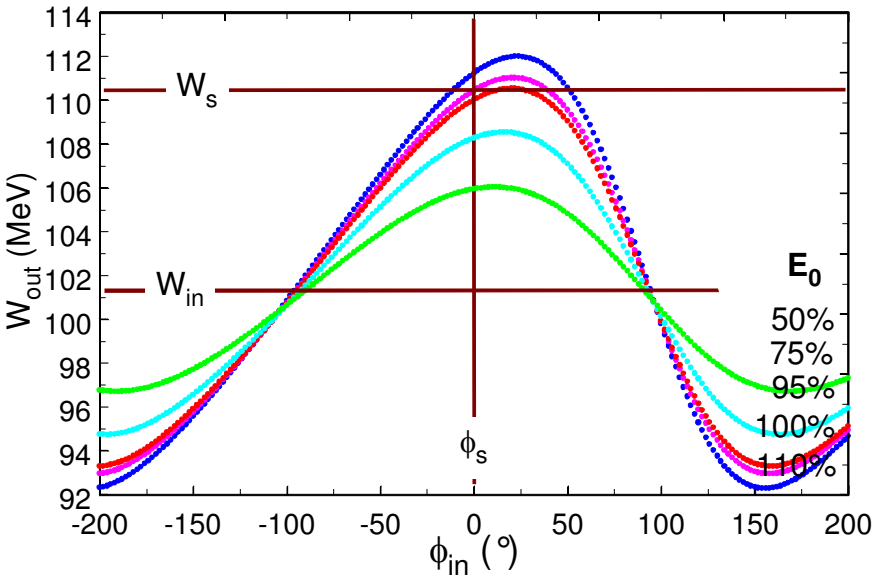
$\sigma_{0l} \approx 25°$



Module 1

ϕ_{out}-W_{out}

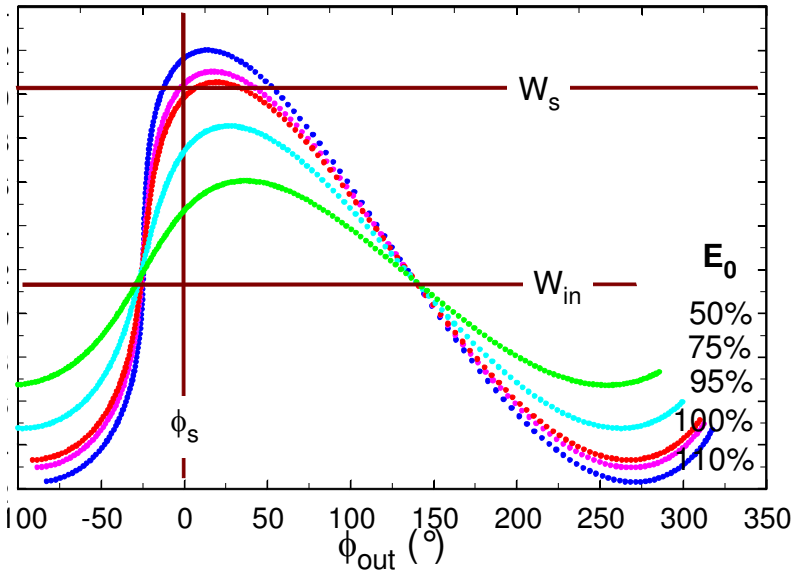
PIMS 2-module scans have distinctive peaks & phase widths



Module 1 & 2

ϕ_{in}-W_{out}

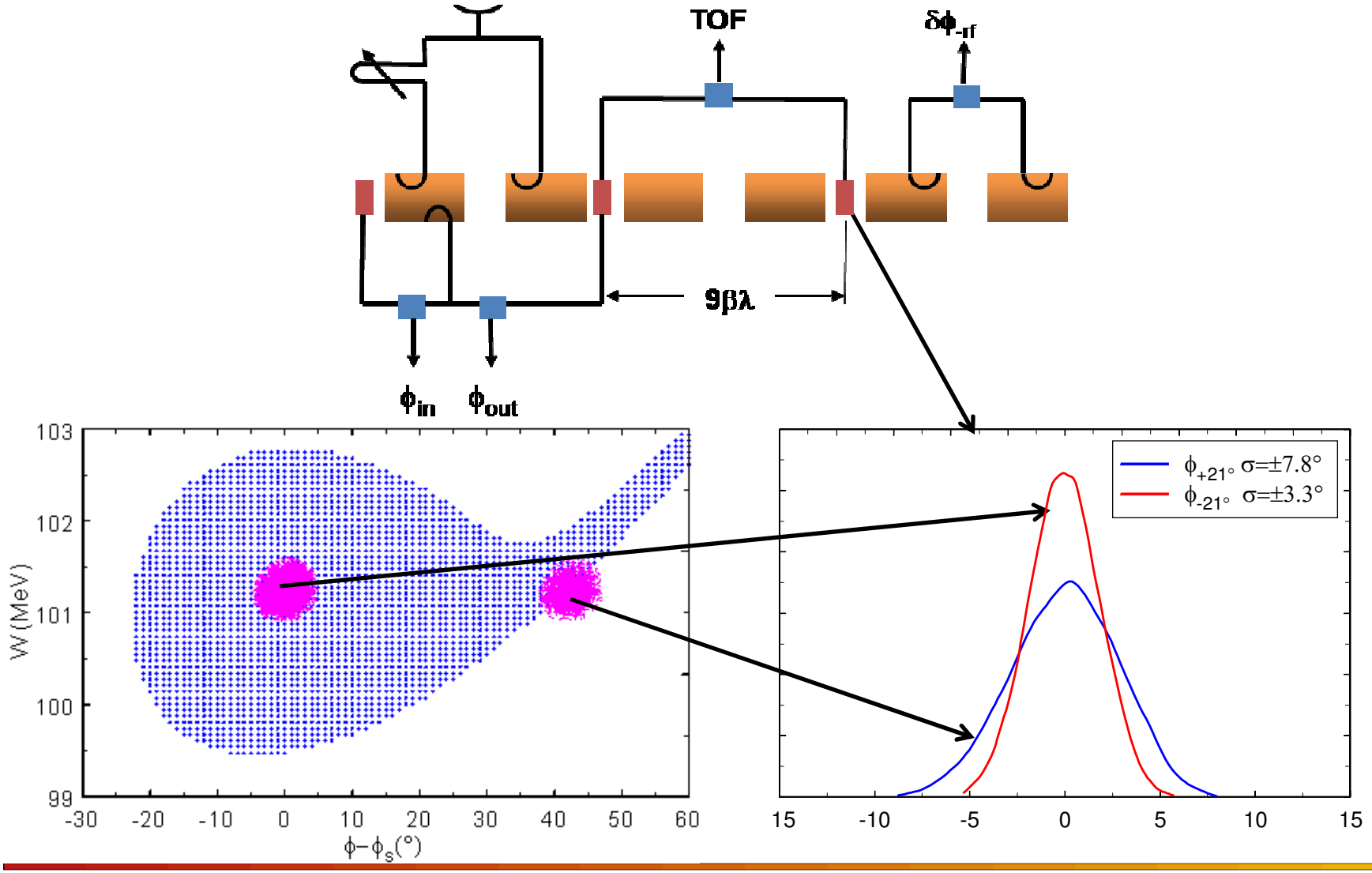
$\sigma_{0l} \approx 50°$



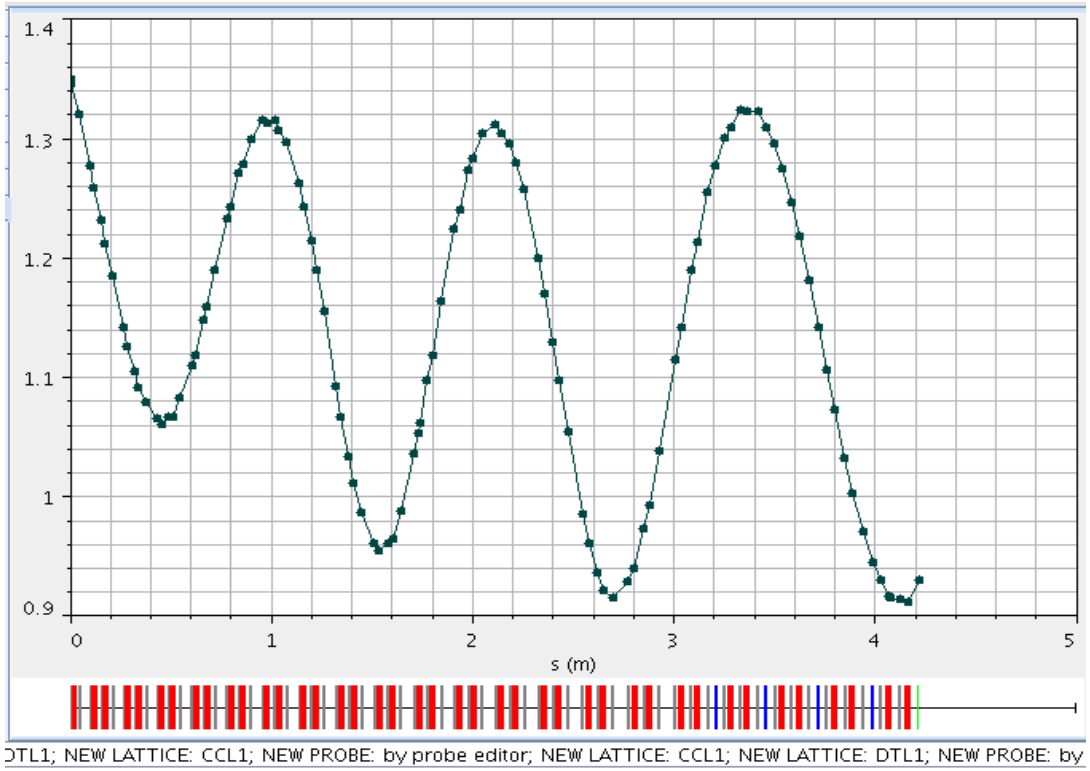
Module 1 & 2

ϕ_{out}-W_{out}

PIMS beam remains well bunched at 2nd pickup

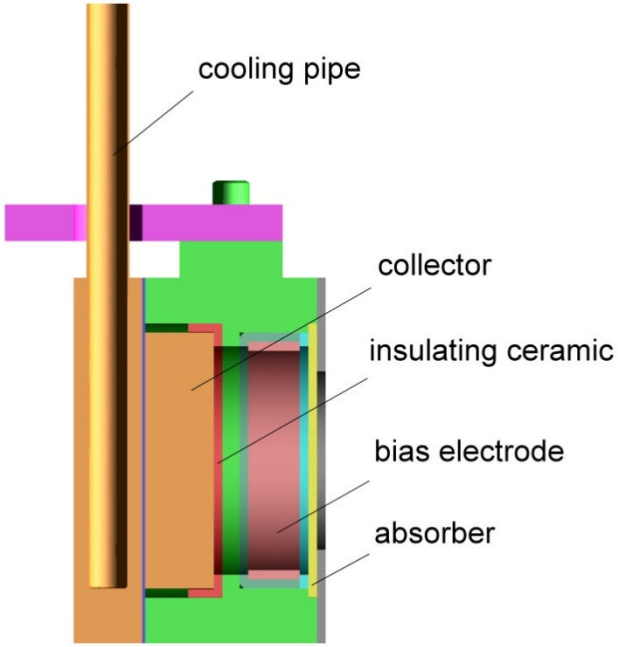


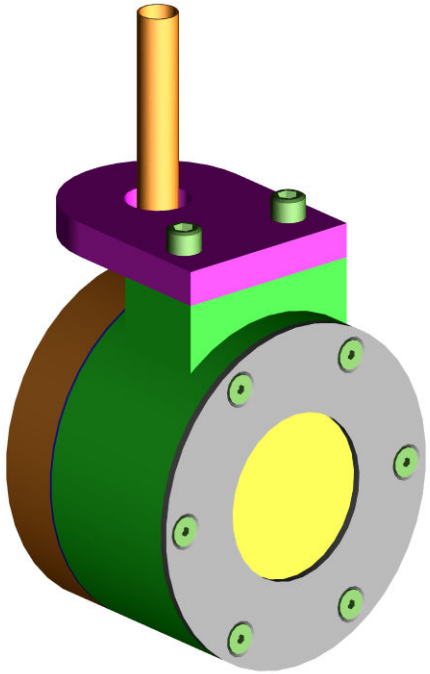
SNS DTL Phase Advance ≈ 11.2 π



- W_{final}W=87 MeV, 216 cells, σ_{0l} ≈2020°
- Large phase advance (longitudinal) and energy gain per accelerating structure
- Single correct RF phase and amplitude setting

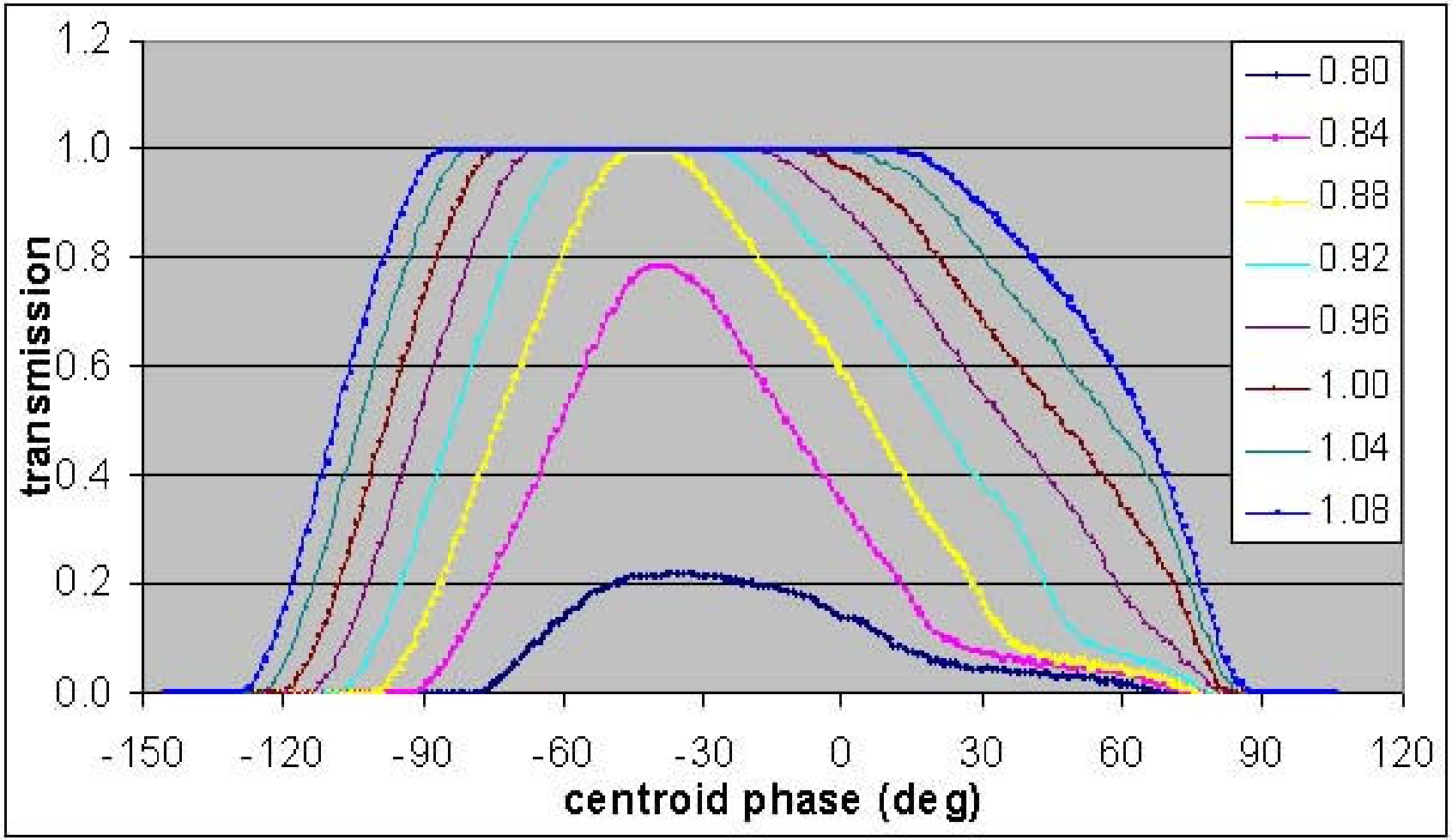
SNS DTL “absorber-collector”



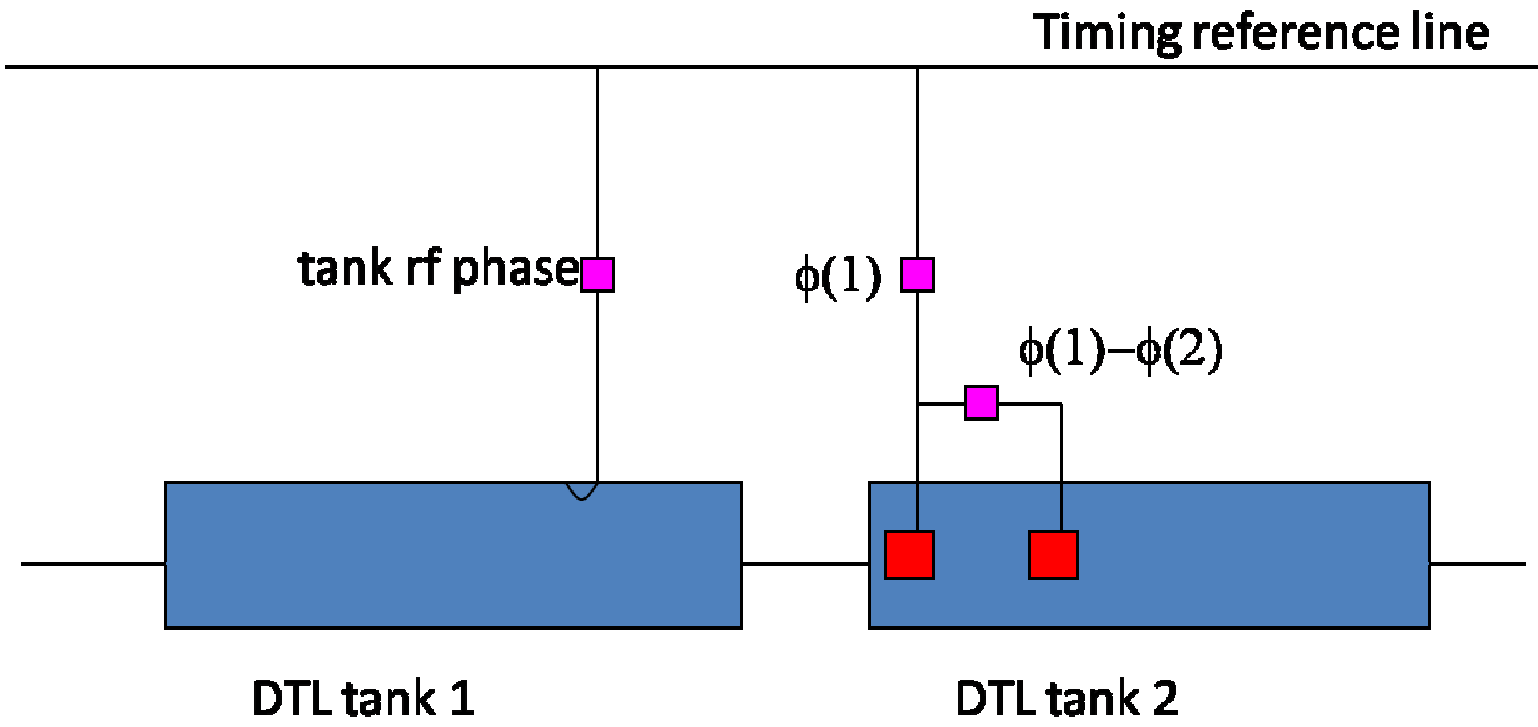


- in-line device mounted on actuators
- collector can take 50μs full current beam pulse at 1 Hz and 185 MeV (300W max)
- absorber : removing low energy tail of beam
- collector (Faraday cup) : collecting the surviving beam particles

SNS DTL phase scan



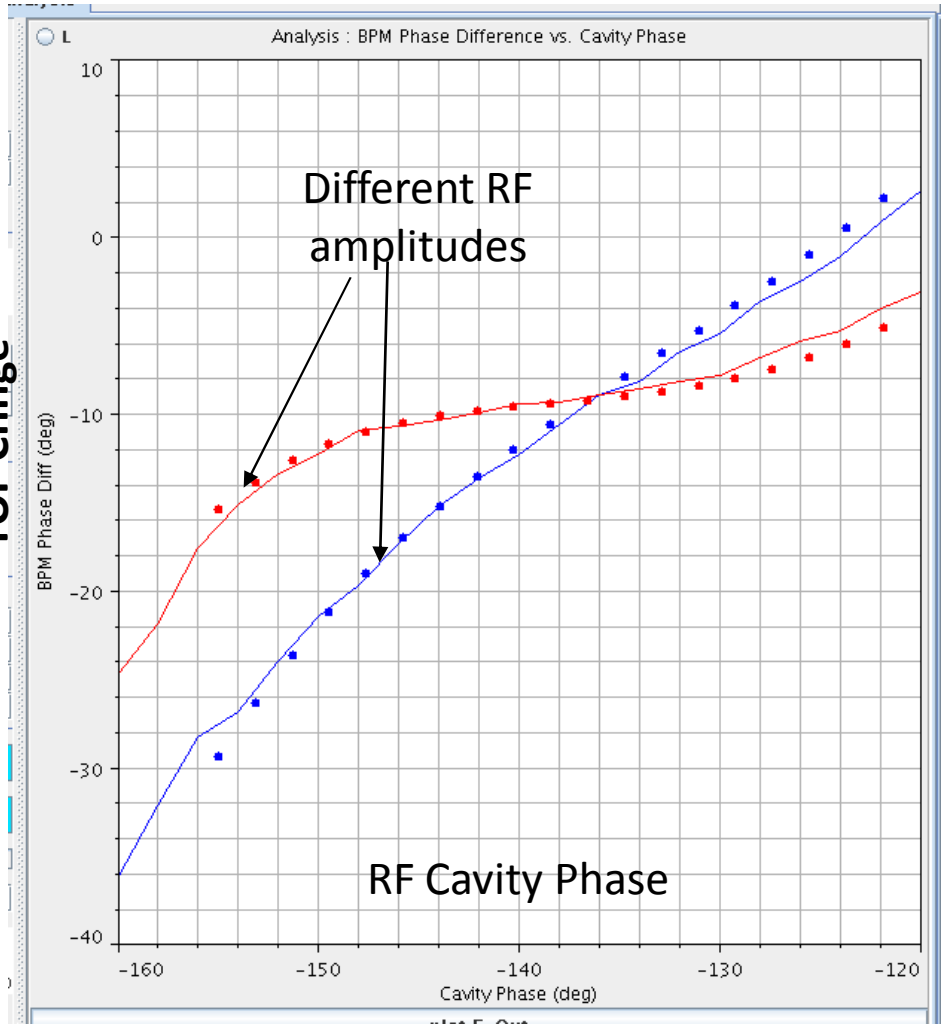
SNS DTL phase scan with two BPMs



BPM (Beam Position Monitor)
BPMs are apart by $6\beta\lambda$ (one period)

$\phi(1)$ and $\phi(2)$ are beam phases at BPM 1 and 2.

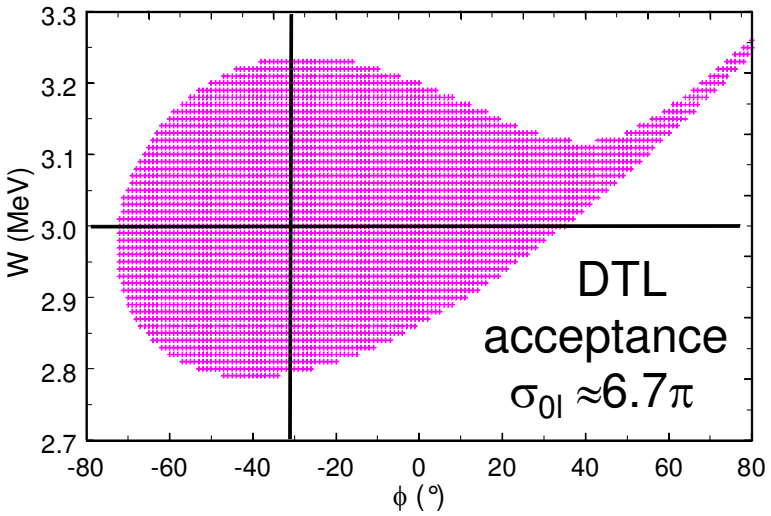
SNS DTL Phase Scans

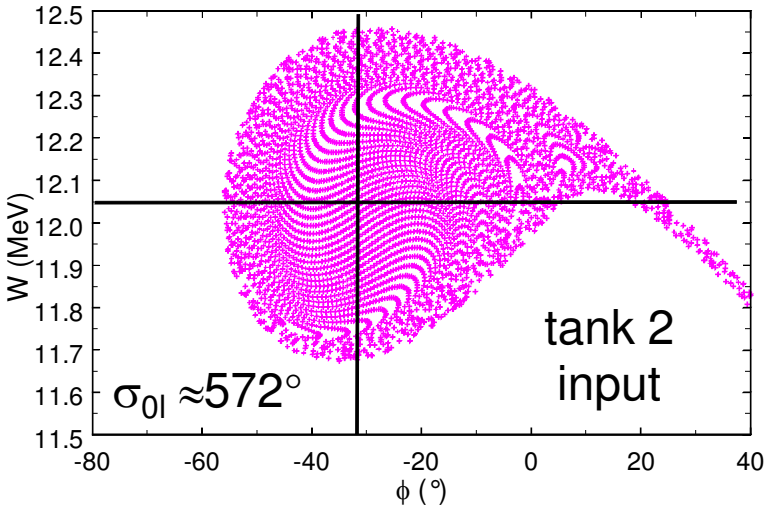


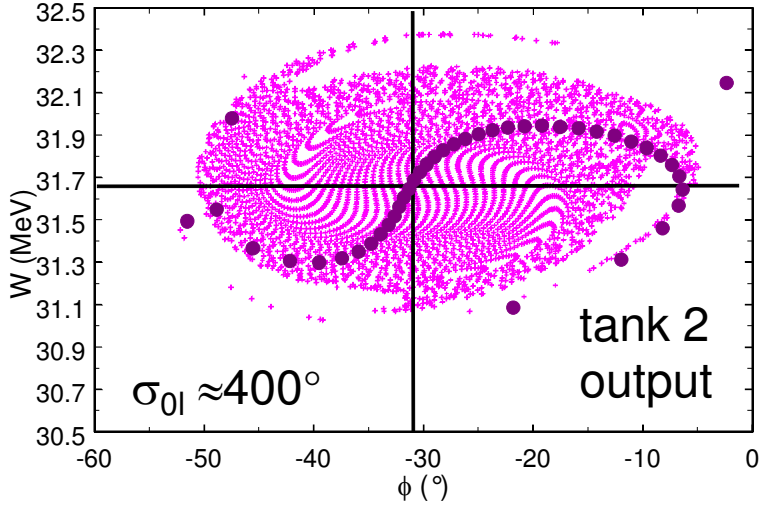
TOF Chnge

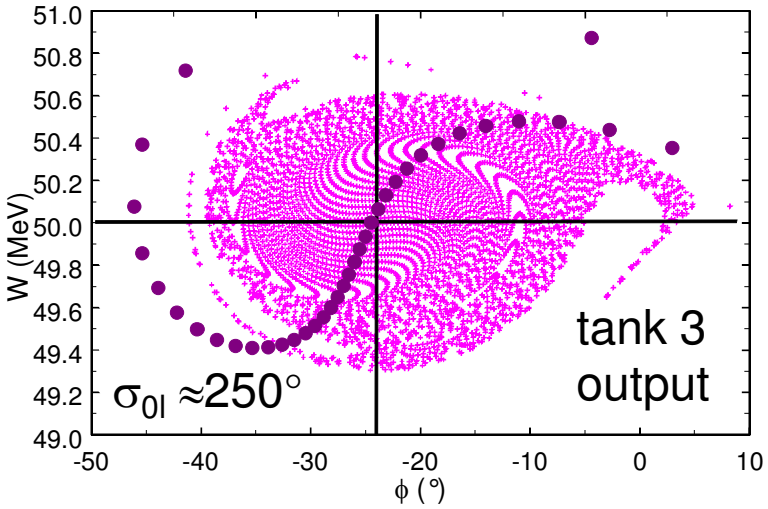
- Each cavity has a unique response (signature) to phase and amplitude scans
- Phase scan signature matching method uses model to match measurements and determine RF amplitude and phase setpoints

Linac4 DTL Phase Advance ≈ 6.7 π

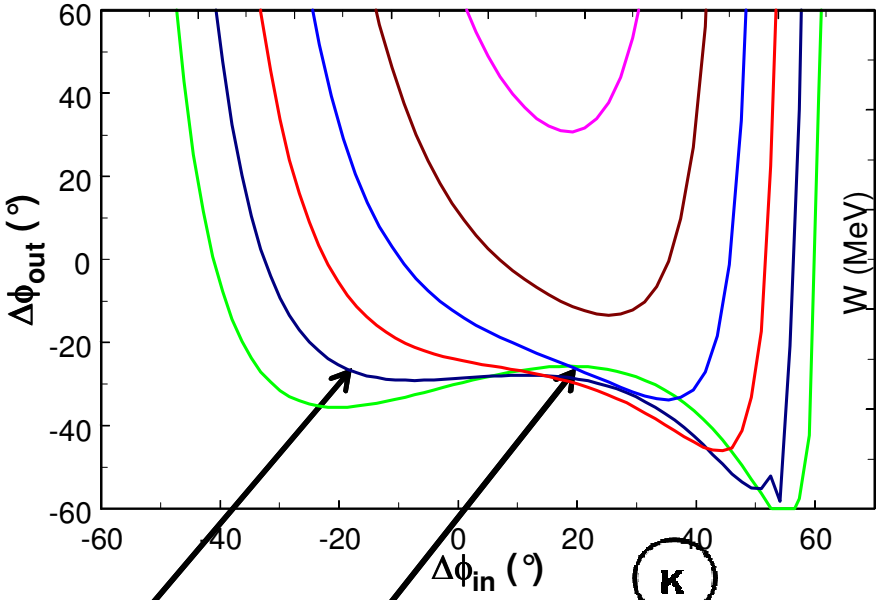


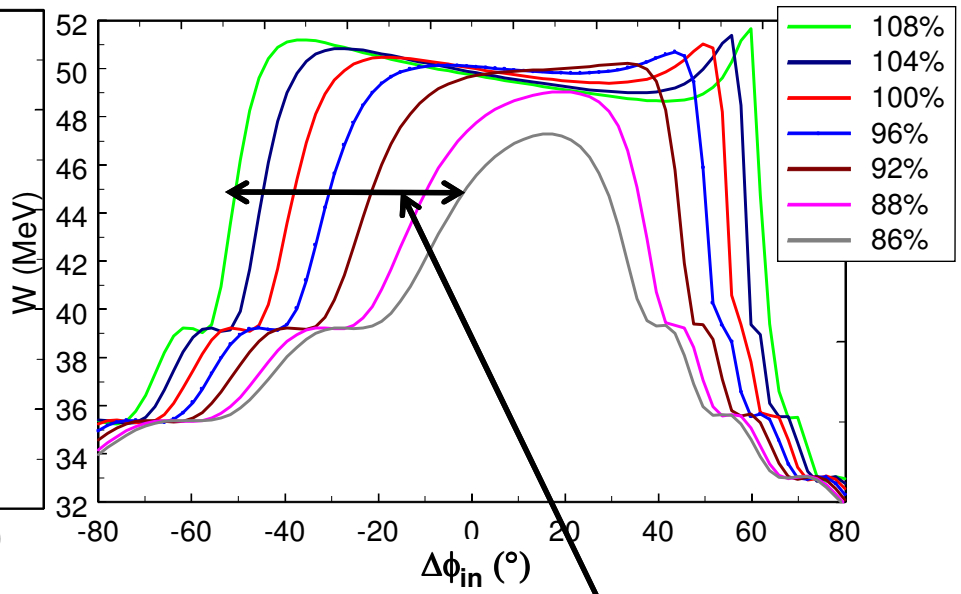




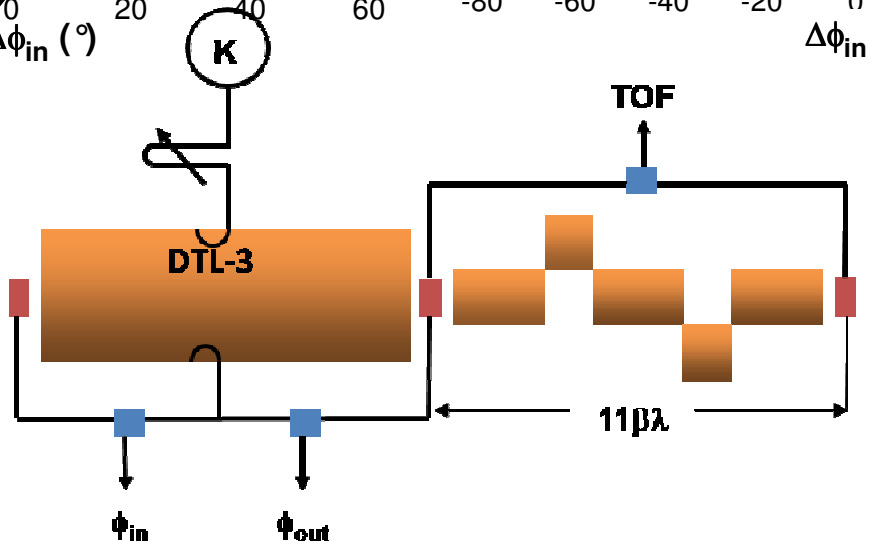


DTL Tank 3 amplitude scans have distinctive measurable features



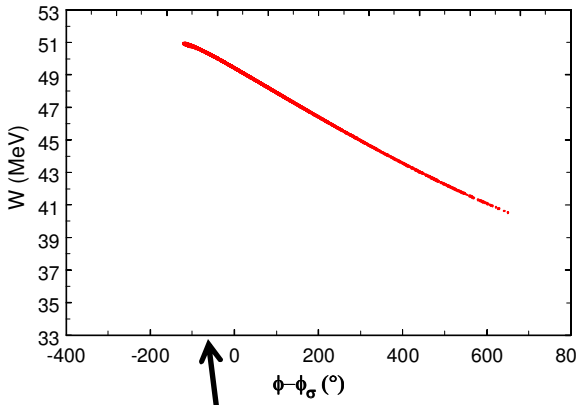


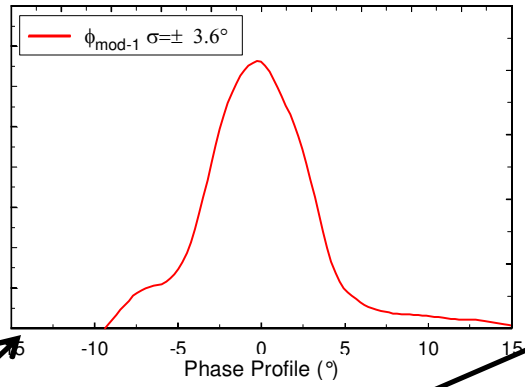
flat intersection

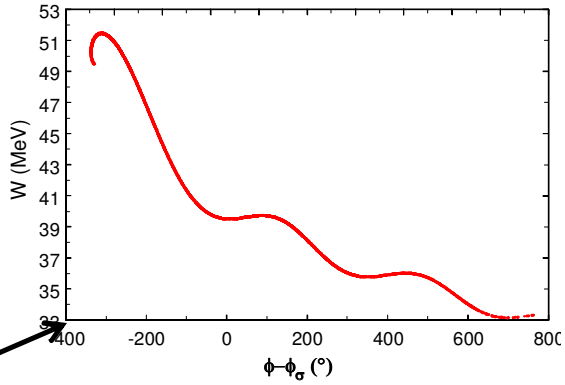


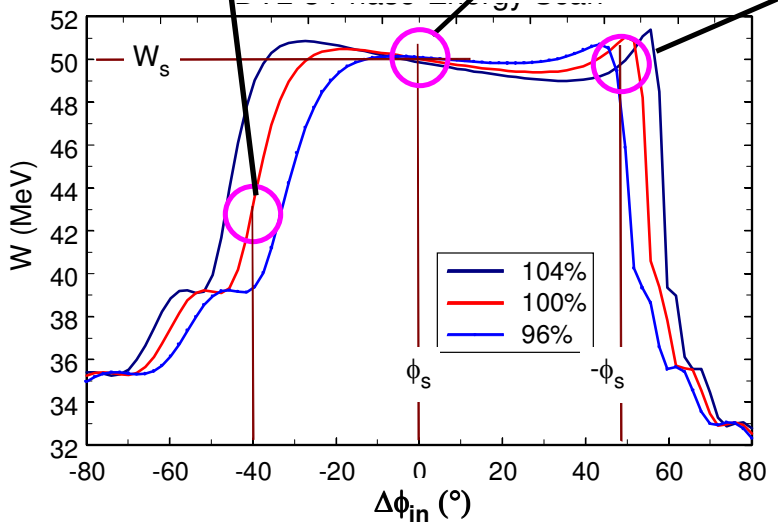
$\Delta\phi_{left}$ vs. E_0 but….

DTL Tank 3 amplitude scans are distinctive but unaccelerated beam debunches too rapidly

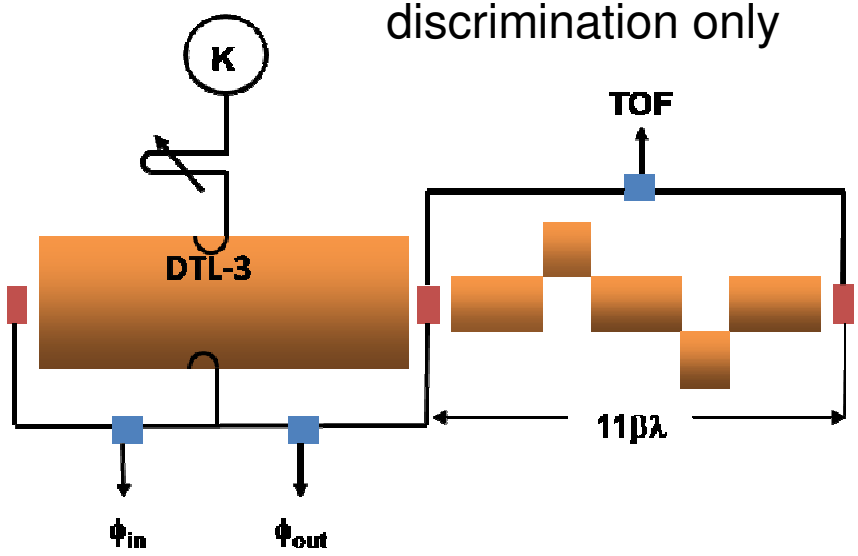




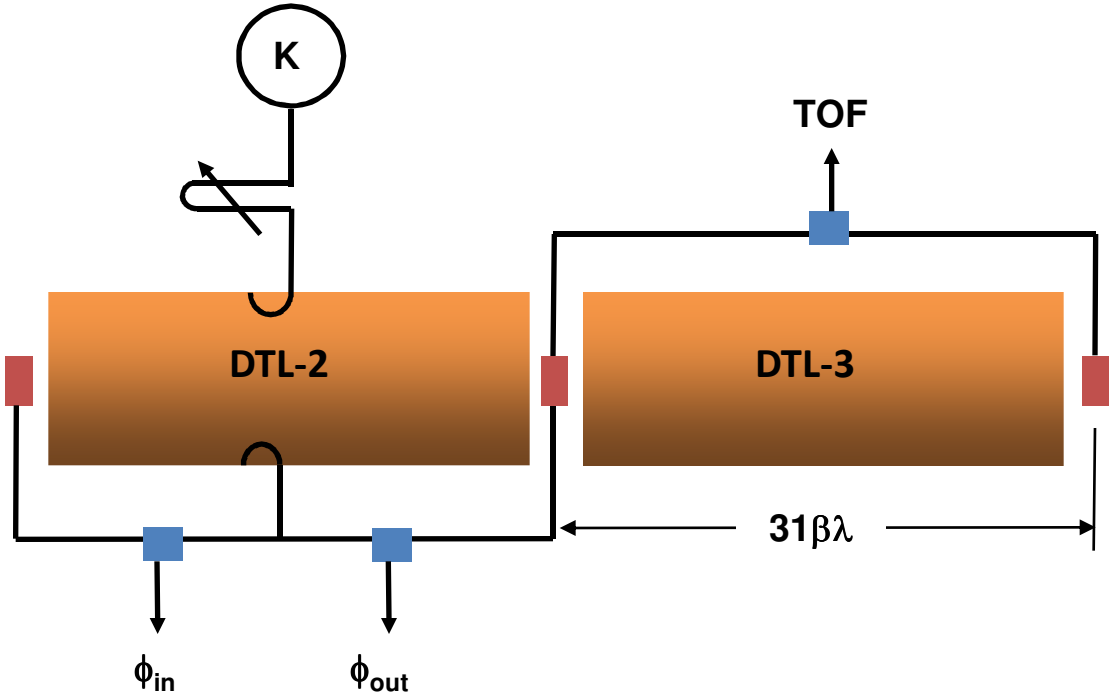




TOF used for energy discrimination only

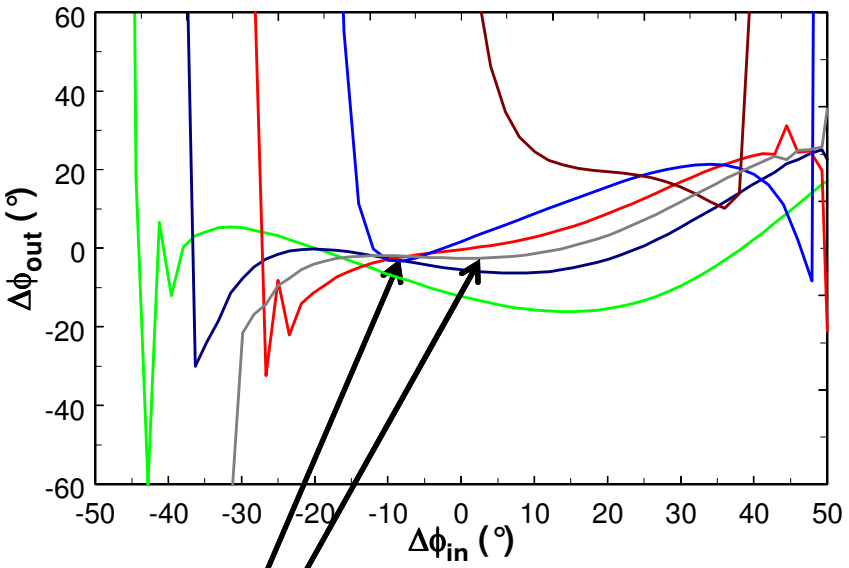


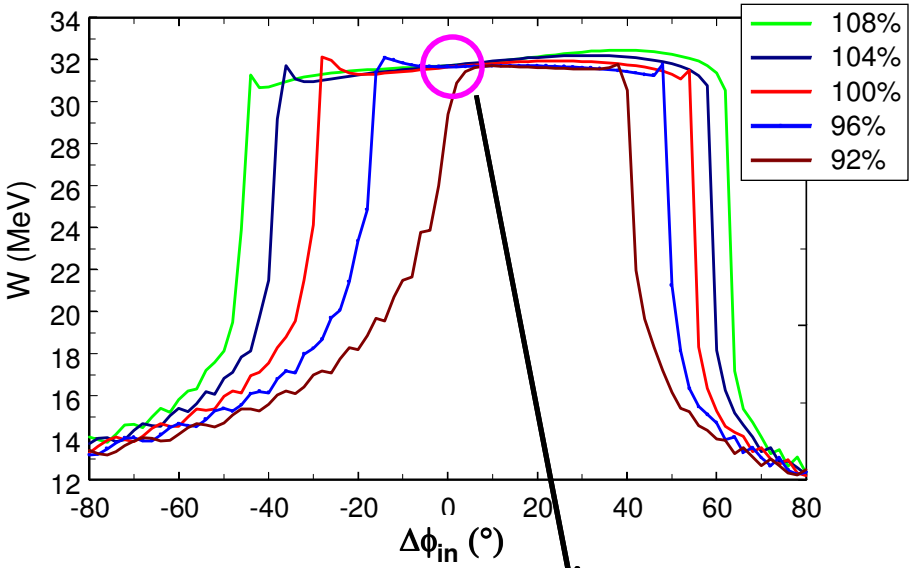
DTL-2 Longitudinal Diagnostics



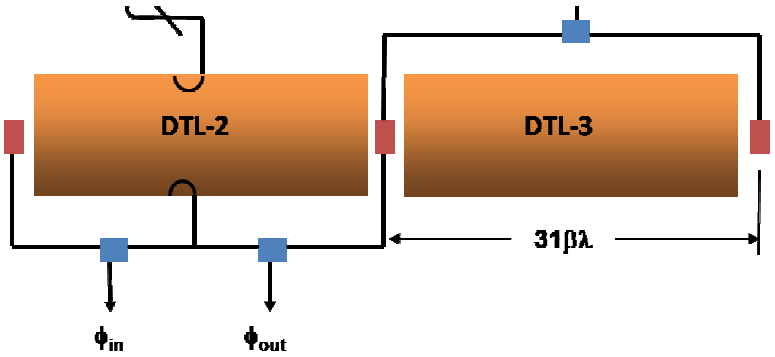
$$\frac{\Delta W}{W} \approx 1‰ \approx 30keV$$

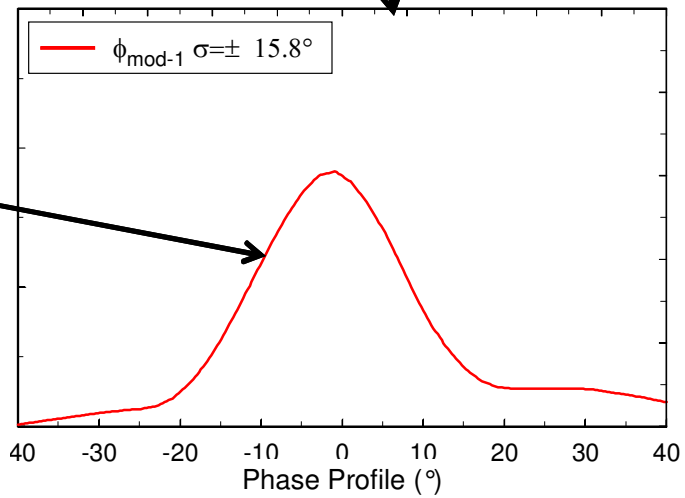
DTL Tank 2 amplitude scans have few distinctive features



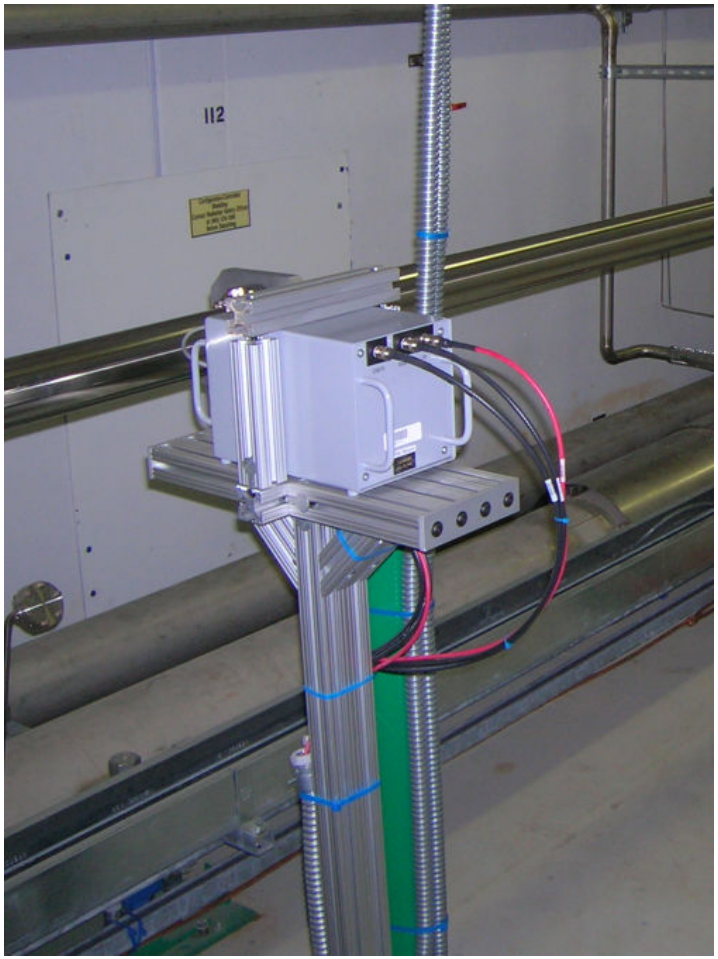


Intersection lat at 102%



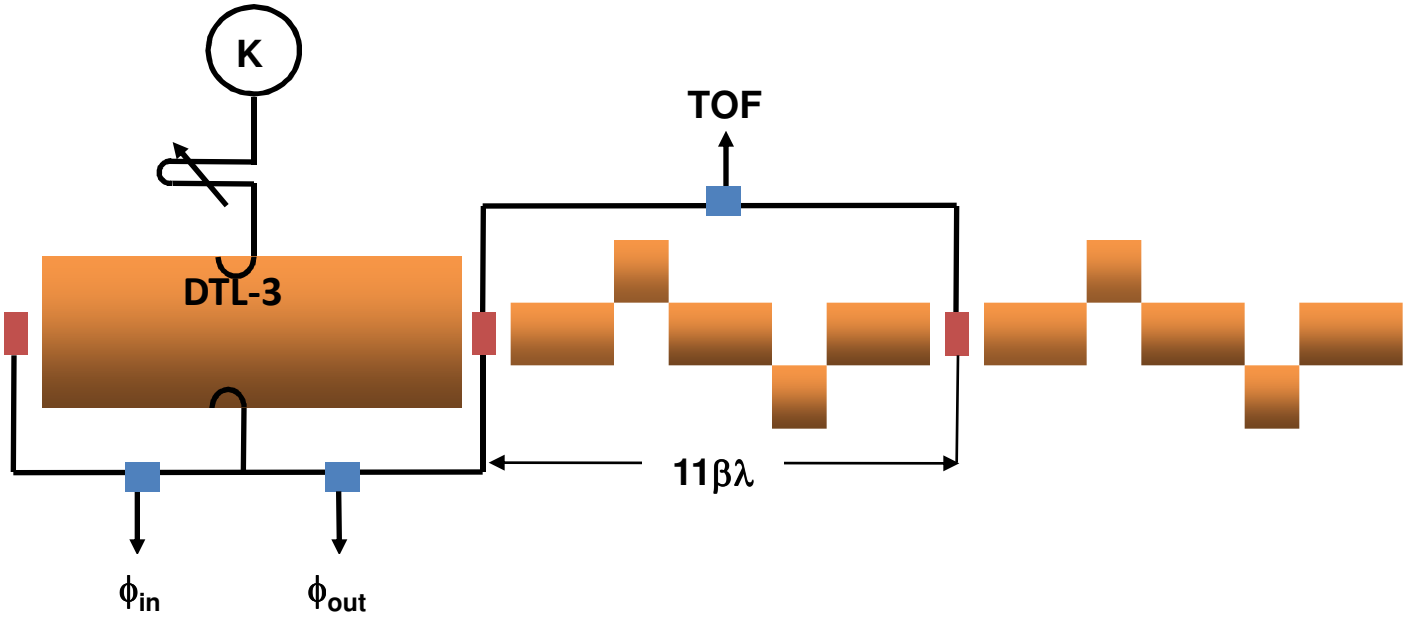


SNS Neutron Detector



- 35 mm poly moderator
- Li (n,alpha)
- Scintillator
- PMT
- 10^4 – 10^8n/cm^2/s
- 0.03eV - 3MeV
- Advantages:
  - No RF contamination
  - Detects beam loss generated in well shielded structures (e.g. DTL tanks)
- Disadvantage
  - Hard to localize the loss source
  - Slow (10 μsec)

DTL-3 Longitudinal Diagnostics



$$\frac{\Delta W}{W} \approx 1‰ \approx 50keV$$